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THE APPLICATION OF RELIABILITY REALLOCATION MODEL IN TRAFFIC SAFETY ANALYSIS ON RURAL ROADS

Summary. The number of accidents on rural roads still represents a higher percentage of accidents than those occurring on built-up areas and motorways. Many countries are working on the definition and implementation of strategies that relate to the improvement of traffic safety on rural roads. This paper presents an approach to the analysis of traffic safety and the frequency of traffic accidents. The developed model is based on reliability theory and the application of the reliability reallocation model on data concerning traffic accidents that have occurred on rural roads. To test the model, a state road made up of 20 sections of a total length of 255 km was selected. The analysis of traffic safety on the observed road covers the period between the years 2005 and 2013 (this period is divided into two intervals 2005–2009 and 2010–2013). Following the basic analyses of traffic safety that are positioned in a space-time coordinate system, the next step is the reliability analysis and the ranking of the section. In this paper, the reallocation method was observed from the aspect of the reduction in accident frequency by 10% and the application of the ARINC apportionment technique.

1. INTRODUCTION

Injuries in road traffic represent a significant global public issue. Road traffic is the most complex and most dangerous system. According to estimates by the World Health Organization, each year 1.24 million people around the world are killed in road traffic accidents, whereas the number of injured ranges between 20 and 50 million [1]. Research in Europe indicates that in 2016, 25500 people lost their lives on EU roads, and further 135000 people were seriously injured on the road. The research in Europe showed that the EU28 collectively reduced the number of road deaths by 19% over the period 2010–2016 [2]. The analysis of road safety by road type in 2015 in most European countries shows that more than 50% of accidents occurred on rural roads. For example, more than 50% of fatalities occurred on rural roads in Hungary (54%), Slovenia (55%), Denmark (56%), United Kingdom (59%), whereas more than 70% occurred in Finland, Ireland, New Zealand, Sweden, and Lithuania. Less than 50% of fatalities occurred in a small number of countries, including Greece, Switzerland, and Serbia. In Serbia, in 2015, 62.6% of fatalities occurred inside urban areas, 27.5% on rural roads and 9.8% on motorways [3].

Interventions in places of high frequencies of traffic accidents are considered one of the most effective approaches to the prevention of road traffic accidents [4]. The development of methods of road accident analysis on rural roads plays an important role in the modern approach to road safety management. It is necessary to constantly monitor, analyze, and compare the states of traffic safety for the purpose of developing and improving measures for increasing the level of traffic safety. The road accident frequency has traditionally been the subject of a large number of research works, with a number of different methodological approaches to the prevention of the road accident occurrence in the previous period [5]. There are a few aspects of the analysis of the road accident frequency. The basic one is temporal and spatial analysis, although research and development of spatial–temporal analysis of traffic accidents have become actual in recent years [6-10].

For the road authority, it is very important to know which model to apply in order to increase traffic safety. Models that observe the time between two traffic accidents, unlike other models that are used to analyze the accident frequency, require only data about the time of occurrence of a road accident and location. These models have a number of advantages for the road authority. Jovanović et al. and Bačkalić et al. [11-12] showed the practical application of these models in analyzing the road accident frequency on rural roads.

This paper presents the results of applying the reliability theory model according to the methodology developed in [11-12] and compares traffic safety on rural roads for two periods of analysis, five years before the adaptation of the new law on road traffic safety and four after it.

2. DEFINING THE MODEL

Before showing results of ARINC reallocation model and comparing traffic safety in these periods, it is necessary to first calculate the parameters of road reliability.

2.1. The parameters of road reliability

Temporal and spatial data about the road accident occurrence are input parameters for the testing reliability models of the road and the road sections, which takes into account the time between the occurrences of two consecutive accidents on the observed road.

The parameters of road reliability are then calculated from a temporal aspect according to the forms of the technical systems reliability theory [13-17]. When analyzing the probability and the occurrence of accidents on the sections, and on the road as a whole, we observed the period of t = 365 (days) = 8,760 (h). All the traffic accidents have been allocated based on the time of occurrence (year/month/hour) and location on the road (kilometer/meter), which provides us with the temporal–spatial distribution of traffic accidents per section. Testing whether the empirical time distributions between successive accidents on the sections match the theoretical distributions was performed using the χ^2 test.

According to formulas explained in the paper [11], we calculated the main parameters of sections (i=1,2,3,…,20) and road as follows:

- Accident rate function (λ)

$$\lambda = \frac{1}{T_0} \quad . \tag{1}$$

- Distribution function (F)

$$F(t) = \int_0^\infty f(t)dt = \int_0^\infty \lambda e^{-\lambda t} dt = 1 - e^{-\lambda t} \quad . \tag{2}$$

- Reliability function (R)

$$R(t) = 1 - F(t) = e^{-\lambda t} \quad . \tag{3}$$

- Meantime between two accidents (T_0)

$$T_0 = \int_0^\infty R(t)dt = \frac{1}{\lambda} \quad . \tag{4}$$

- The probability that there will not be an accident (P_0)

$$P_0 = e^{-\lambda t} \quad . \tag{5}$$

- The probability of n recoveries (P_n)

$$P_n = \frac{(\lambda t)^n}{n!} e^{-\lambda t}. \quad (6)$$

2.2. Reallocation of reliability/safety of a road

Reliability allocation represents the process of defining goals or reliability requirements for the components of a system in such a way so as to ensure the achievement of the goals or required reliability of the system. Several methods have been developed for reliability allocation. These methods include equal apportionment technique, AGREE apportionment technique, ARINC apportionment technique, EFTES apportionment technique, minimum effort algorithm, etc. [12-13]. All of these methods have some advantage or disadvantage. In the field of traffic safety, it is also important to set precise requirements that need to be achieved in order to increase the safety of a particular road. Before applying some of the reallocation methods, it is necessary to first study the system and all the relevant factors. In this paper, we applied the ARINC apportionment technique.

2.3. Reliability reallocation through the application of the ARINC apportionment technique

The ARINC allocation method requires the possession of approximate values of the failure rate of all elements of the system. The prerequisites for the application of this method are as follows: (i) the system consists of n serially connected elements so that the failure of any one element represents the failure of the entire system, (ii) the failure rates are constant, and (iii) the operating time of the system's elements is equal to the operating time of the entire system. The ARINC allocation method demands that the reliability requirements are expressed through failure rates.

The application of the ARINC method requires that the reliability requirements are expressed through failure rates [12-13]. It is necessary to select λ_i^* so that

$$\lambda = \sum_{i=1}^{n} \lambda_i^* \leq \lambda^*, i = 1, 2, ..., n \quad (7)$$

where λ_i^* is the failure rate reallocated to the ith element of the system, and λ^* is the maximum allowable failure rate.

On the basis of determined values of the elements' failure rates (λ_i), we determine the weighting factor (u_i) for each element of the system, using the following expression:

$$u_i = \frac{\lambda_i}{\sum_{i=1}^{n} \lambda_i}, i = 1, 2, ..., n. \quad (8)$$

As u_i represents the relative sensitivity to the failure of the *i*th element of the system, it follows that: $\sum_{i=1}^{n} u_i = 1$

The required failure rate of the *i*-th element of the system (λ_i^*) is calculated by applying the following equation:

$$\lambda_i^* = u_i \lambda^* \quad , \quad (9)$$

where as the corresponding values of reliability that are allocated to subsystems are calculated as follows:

$$R_i(t) = e^{-\lambda_i^* t} \quad , \quad (10)$$

where t is the operating time of the system.

This equation gives us the reliability values that need to be reallocated to the elements of the system, in order to achieve the required failure rate of the system (λ^*), as well as the required reliability of the system (R^*).

3. RESULTS

To test the model, we selected a state road made up of 20 sections of a total length of 255 km. The analysis of traffic safety on the observed road covers the period between the years 2005 and 2013. Within the framework of the work, the parameters of road reliability were observed in three time periods, the first period of observation ranged between 2005 and 2009, the second one between 2010 and 2013, and the last third covered the period of nine years between and 2005 and 2013. It is important to note that the new law on road traffic safety was adapted at the end of 2009. This change may have had an impact on the state of traffic safety. The law was effective from early 2010. In that period of time, media campaign was actively running and the new law brought a change in penal policy. It is assumed that this action affected the behavior of participants that also resulted in a reduction in the number of people who were killed on road. This was one of the reasons why it was taken as a groundbreaking year in 2010 in order to see is there any the change in road safety between these periods. As the subject of the analysis was not the influence of other circumstances on the change in the number of traffic accidents, the analysis did not take into account whether during the observation period some reconstructions or changes were made on the observed roads that would have an impact on the change in the number of traffic accidents.

This road is within the model observed as a system of 20 serially connected elements (sections) (Table 1). The sections represent parts of the road network between two consecutive traffic nodes and are used to provide for continuous and unobstructed traffic flows [18]. Each section is specified by the structure and volume of the traffic, road environment, units, and road equipment. The reliability parameters that were used in the reallocation model are follows: the failure rates of the sections and the road (λ), the reliability function ($R_i(t)$), and the mean time between the occurrences of two consecutive accidents (T_0) (Table 1). The reliability parameters of the observed sections and the road as a whole can be calculated for different periods (t = 7 (days) = 168 (h); t = 30 (days) = 720 (h); and t = 365 (days) = 8760 (h)). When analyzing the probability and the occurrence of the accidents on the section, as well as the road as a whole, we observed the period of t = 365 (days).

Comparison of accident frequency rates among road sections (the number of accidents during one week - λ_i), in each period of observation, highlights the section 15 as the most unfavorable, i.e. on this section accidents happen most often than on other road sections. On the observed road, on average, 172.44 accidents happen per year in period 2005–2009, whereas this number is smaller in period 2010–2013 (λ=102.88 (year^{-1})). For period 2005–2013 on the observed road as a system, on average, 139.23 accidents happen per year. The better parameter for comparison is the mean time between two accidents. Comparing these three periods according to this parameter of reliability, it could be concluded that in period 2005–2009 traffic accident happens every 50.80 hours, whereas in period 2010–2013 mean time between two accidents is longer, accident occurring every 85.143 hours (Table 1).

By comparing the reliability or the mean time between two consecutive accidents on the sections and the periods of observations, we may conclude that section 15 is the least reliable or it has the shortest T_0. Other sections are not on the same position in these three periods. For period 2005–2009, the section 15 is followed by section 19, 14, 9, and for period 2010–2013 after section 15, sections 14, 10, and 7 follow. The most reliable sections are 5, 16, 17, 18, and 12 for all three periods (Table 1). On section 5, there is no traffic accident for all period of observation, so the reliability of this section is 1 (Table 2).

Following the basic analyses of traffic safety on the basis of traffic accidents that are positioned in a space-time coordinate system, the next step is the reliability analysis and the ranking of the section. After the reliability analysis and ranking, the road authority defines the desired level of reliability. The required level of reliability can be defined as an exact value or as the result of a precise percentage of increase.

Request in rural road traffic safety analysis could be for example increased reliability of the road by 20% or request for reducing the frequency of accidents by 20% [11]. In this paper, the reallocation method was observed from the aspect of a reduction in accident frequency by 10%. Hereafter, the values of the required reliability of the system (R_S^*), the required traffic accident frequency (λ_S^*) during one year, and the mean time between two accidents (T_{0S}^*) have been calculated and provided in Table 3.

Table 1

Basic characteristics of observed road for three periods of observations

Road section (i)	Length (km)	2005–2009		2010–2013		2005–2013	
		Mean time between two accidents T_{0i} (h)	Accident rate function λ_i (year^{-1})	Mean time between two accidents T_{0i} (h)	Accident rate function λ_i (year^{-1})	Mean time between two accidents T_{0i} (h)	Accident rate function λ_i (year^{-1})
1	0.333	15132.33	0.578892878	14304.75	0.612383998	13195.80	0.663847588
2	0.931	4133.38	2.119333474	2158.07	4.059188780	3312.83	2.644267997
3	33.000	1684.65	5.199881281	932.54	9.393693485	1243.30	7.045756307
4	6.639	2236.53	3.916788252	6253.20	1.400882748	3128.75	2.799840192
5	4.668	Infinite	0.000000000	Infinite	0.000000000	Infinite	0.000000000
6	5.491	952.73	9.194597999	1989.06	4.404092979	1252.23	6.995543419
7	36.265	700.47	12.505929218	835.41	10.485865996	756.49	11.579870427
8	1.752	2263.00	3.870967742	6221.40	1.408043206	4995.40	1.753613324
9	19.574	524.68	16.695797694	915.31	9.570483206	648.38	13.510677564
10	15.996	689.75	12.700326782	832.60	10.521318882	750.41	11.673625830
11	15.701	761.95	11.496857084	1325.31	6.609785826	943.16	9.287958918
12	1.661	6496.83	1.348349196	25208.00	0.347508727	9861.71	0.888283695
13	8.622	594.92	14.724653148	1282.85	6.828566289	867.17	10.101842494
14	34.030	502.51	17.432631751	702.65	12.467034563	583.99	15.000383367
15	25.520	237.97	36.810995287	697.24	12.563823074	340.63	25.716900084
16	5.296	21457.50	0.408248864	22747.00	0.385105728	27127.00	0.322925499
17	2.033	6796.67	1.288867092	Infinite	0.000000000	5256.00	1.666666667
18	1.251	6682.00	1.310984735	17802.00	0.492079542	8872.80	0.987286989
19	28.672	482.73	18.146664825	869.63	10.073231253	600.55	14.586704826
20	7.678	3246.77	2.698066717	6938.60	1.262502522	4362.06	2.008227518
Road	**255.113**	**50.80**	**172.44883402**	**85.143**	**102.88559080**	**62.92**	**139.23422270**

Required reliability according to lambda reduction (R_i^*) equals R^*

$$R_i^* = e^{-u_i \cdot \lambda_S \cdot t} = R_S^{u_i} \quad . \tag{11}$$

The required frequency of traffic accidents (λ_S^*) equals

$$\lambda_S^* = \frac{\ln R_S^*(t = 365 \cdot 24)}{t}. \tag{12}$$

The mean time between two accidents (T_{0S}^*) is calculated according to the expression:

$$T_{OS}^* = \frac{1}{\lambda_S^*}. \tag{13}$$

On the basis of defined goals (determined increase in reliability), we calculated the values of the new parameters of the sections (reliability, frequency of accidents, and the mean time between two accidents), applying the ARINC apportionment technique. Tables 3, 4, and 5, in addition to the values of the reliability parameters, also provide the changes in these values. With the ARINC method, the percentages of changes in the frequency ($\Delta\lambda$) are the same for all of the sections, and they equal.

Table 2

The reliability function of the section and road for three periods of observations

Road section (i)	Length (km)	2005–2009	2010–2013	2005–2013
		R_i	R_i	R_i
1	0.333	0.508379919159075	0.542057064341170	0.514866524381335
2	0.931	0.120111659325682	0.017263017540370	0.071057348928872
3	33.000	0.005517219379274	0.000083247414652	0.000871097796405
4	6.639	0.019904921774911	0.246379377008090	0.060819781350245
5	4.668	1.000000000000000	1.000000000000000	1.000000000000000
6	5.491	0.000101586693718	0.012227191703509	0.000915954909939
7	36.265	0.000003704622411	0.000027928413132	0.000009352466737
8	1.752	0.020838193670453	0.244621489058721	0.173147174886071
9	19.574	0.000000056118647	0.000069757668100	0.000001356398457
10	15.996	0.000003050128667	0.000026955616377	0.000008515471865
11	15.701	0.000010161981720	0.001347120636432	0.000092531732543
12	1.661	0.259668568996169	0.706445848475546	0.411361168653237
13	8.622	0.000000402869500	0.001082408867281	0.000041003936078
14	34.030	0.000000026859890	0.000003851551273	0.000000305785070
15	25.520	0.000000000000000	0.000003496237828	0.000000000006781
16	5.296	0.493813152645042	0.680378697167710	0.724027793456810
17	2.033	0.188875602837562	1.000000000000000	0.188875602837562
18	1.251	0.077630205057962	0.611353735829065	0.372586151223502
19	28.672	0.000000013152357	0.000042194053743	0.000000462460437
20	7.678	0.067335565674966	0.282945063491088	0.134226377835536
Road	**255.113**	**1.277682580723E-75**	**2.0766133706254E-45**	**4.657395641E-66**

Table 3

The values of the required reliability parameters of the road for the reduction in accident frequency by 10%

	2005–2009	2010–2013	2005–2013
R_S^*	3.942581470772E-68	6.104078095892E-41	3.786263623656E-55
λ_S^* (accident/year)	155.2039	92.5970	125.3108
T_{0S}^* (h)	56.44	94.60	69.91

The provided results indicate the basic characteristics of the proposed methods. The ARINC method assigns each section with a particular “effort” that is necessary to achieve a defined level of reliability. Table 4 shows the results of the ARINC method, i.e., how much the reliability of each road section needs to be increased in order to achieve the required reliability of the system when the request is the reduction in accident frequency by 10% (Tables 4–6).

4. CONCLUSIONS

For many years, experts in the field of traffic safety tend to reduce the number, as well as to mitigate the consequences, of traffic accidents. The basis of any research is a detailed analysis as well as continuous monitoring of the temporal and spatial distribution of traffic accidents, or casualties respectively. Besides these basic tasks, experts from the field of traffic safety need to identify, rank, select and treat dangerous road section, and define the goals of traffic safety. For these actions, road authority needs tools and procedures that would serve as support in the decision-making process. In spite of huge efforts and many developed methods and models, the number of accidents on rural roads still has a higher percentage in the total number of accidents than the accidents occurring on built-up areas and motorways. Researchers and road authorities in many countries constantly work on the definition and implementation of strategies that relate to the improvement of traffic safety on rural roads.

Table 4

Results of reliability reallocation by the application of ARINC method for reduction in accident frequency by 10%, period 2005–2009

Road section	u	λ^*	R_i^*	R_i^*/R_i (%)	T_{0i}^*
15	0.213460389547	0.003781951571	0.00000000000000409	3869.00	264.41
19	0.105229269472	0.001864383372	0.00000008074269505	513.90	536.37
14	0.101088719158	0.001791023810	0.00000015353019544	471.60	558.34
9	0.096815950012	0.001715321681	0.00000029798641913	430.99	582.98
13	0.085385634713	0.001512806830	0.00000175649917748	336.00	661.02
10	0.073646927533	0.001304828094	0.00001086141340529	256.10	766.38
7	0.072519650764	0.001284855742	0.00001293807173260	249.24	778.30
11	0.066668221614	0.001181183947	0.00003208341348336	215.72	846.61
6	0.053317832219	0.000944650479	0.00025477284878659	150.79	1058.59
3	0.030153183179	0.000534234378	0.00928000537367530	68.20	1871.84
4	0.022712755785	0.000402409752	0.02944858471622780	47.95	2485.03
8	0.022447050825	0.000397702165	0.03068838705604300	47.27	2514.44
20	0.015645607188	0.000277198635	0.08819014600687120	30.97	3607.52
2	0.012289636439	0.000217739741	0.14846587768900400	23.61	4592.64
12	0.007818836256	0.000138529027	0.29715117106559400	14.43	7218.70
18	0.007602166420	0.000134690213	0.30731368998134800	14.01	7424.44
17	0.007473910154	0.000132417852	0.31349233074539700	13.76	7551.85
1	0.003356896448	0.000059475296	0.59392419206769500	5.96	16813.70
16	0.002367362275	0.000041943376	0.69251597151281000	4.17	23841.67
5	0.000000000000	0.000000000000	1.00000000000000000	0.00	Infinite

The application of the reliability theory in analysis of the traffic accident frequency allows setting of precisely defined levels for practical analysis and actions in real time in cases when the modest data base is available (the time between two events is observed, which is at the same time the main advantage of these models). The main theoretical goal of this paper is the presentation of the developed approach to the analysis of traffic safety and the traffic accidents frequency on rural roads based on the theory of the reliability reallocation. The model has been tested using the ARINC method for the reliability reallocation. The advantage of the ARINC method is reflected in its simple mathematical approach and application, the only input values are location and time of a traffic accident's occurrence, it have possibility to set a precisely express goal (the reliability level) and output is a user friendly report. One of the shortcomings of this method is the allocation of a new, required reliability to all elements of the system, which in a practical sense creates certain problems. The secondary goal is the presentation of the main advantages of the proposed model - flexibility and decision support in real time. In the classic approach (spatial–temporal analysis), analysis requires data collected in longer previous periods with no interruptions and do not offer decision support in real time. As well, when the subject of analysis is the comparison of the number of accidents between two roads or the same road in the different periods, researchers or road authorities require data for periods with the same duration. The presented method offers solution when we have modest database and different duration of the observation period.

Table 5

Results of reliability reallocation by the application of ARINC method for reduction in accident frequency by 10%, period 2010–2013

Road section	u	λ^*	R_i^*	R_i^*/R_i (%)	T_{0i}^*
15	0.122114505788	0.001290803740	0.000012281202	251.27	774.71
14	0.121173766563	0.001280859715	0.000013398992	247.89	780.73
10	0.102262316813	0.001080957419	0.000077194141	186.37	925.11
7	0.101917731273	0.001077315000	0.000079696938	185.36	928.23
19	0.097907113859	0.001034921019	0.000115538341	173.83	966.26
9	0.093020637113	0.000983268823	0.000181648894	160.40	1017.02
3	0.091302323399	0.000965105495	0.000212977478	155.84	1036.16
13	0.066370482353	0.000701565030	0.002142654796	97.95	1425.38
11	0.064244038203	0.000679087585	0.002608950506	93.67	1472.56
6	0.042805731539	0.000452475306	0.018993021034	55.33	2210.07
2	0.039453423442	0.000417039943	0.025906279134	50.07	2397.85
8	0.013685523840	0.000144661973	0.281608101625	15.12	6912.67
4	0.013615927528	0.000143926310	0.283428760465	15.04	6948.00
20	0.012270936214	0.000129709163	0.321019866002	13.46	7709.56
1	0.005952087105	0.000062916164	0.576289235998	6.32	15894.17
18	0.004782783845	0.000050556117	0.642189666998	5.04	19780.00
16	0.003743048227	0.000039565657	0.707091532505	3.93	25274.44
12	0.003377622898	0.000035702951	0.731427002775	3.54	28008.89
17	0.000000000000	0.000000000000	1.000000000000	0.00	Infinite
5	0.000000000000	0.000000000000	1.000000000000	0.00	Infinite

The presented case study was implemented on the same rural roads in two periods. The required level of reliability was defined as a reduction in observed accident frequency by 10%. The results of the analysis (reallocated reliability and new mean time between two accidents) and sections rankings are shown in Table 7.

The differences in the sections ranking, which are ranked by the value of the mean time between two accidents after the reallocation of new required reliability, confirm the assumption that the reliability of the road as a system and its sections as elements is variable over time. The differences in the ranges of sections between the two periods observed (2005–2009 and 2010–2013), and its comparison with the values for the entire period (2005-2013), indicate that it is necessary to analyze shorter periods. With a classic approach, the length of the observation period allows working with a larger sample, i.e., number of traffic accidents. However, the longer period prevents the monitoring and analysis of changes over time. Comparison of the results given in Table 7 indicates that it is not the same rank of the individual sections, that is, the task of reducing the frequency of traffic accidents needs to completely differently be reallocated on sections over different periods.

The approach described in this paper represents a form of proactive action that allows the decision maker to monitor the condition of traffic safety on certain roads by observing only the time between the occurrences of two accidents. The differences in the ranking of the section, which are ranked by the value of the reallocated mean time between two accidents, confirm the assumption that the reliability of the road as a system and its sections as elements is variable over time. The proposed model has great potential for expansion and development.

Table 6

Results of reliability reallocation by the application of ARINC method for reduction in accident frequency by 10%, period 2005–2013

Road section	u	λ^*	R_i^*	R_i^*/R_i (%)	T_{0i}^*
15	0.184702435827	0.002642147269	0.000000000089	1208.78	378.48
14	0.107734887844	0.001541135277	0.000001370486	348.19	648.87
19	0.104763789700	0.001498634057	0.000001988690	330.02	667.27
9	0.097035608786	0.001388083311	0.000005237796	286.15	720.42
10	0.083841641825	0.001199345119	0.000027364521	221.35	833.79
7	0.083168277184	0.001189712715	0.000029773751	218.35	840.54
13	0.072552870249	0.001037860530	0.000112601193	174.61	963.52
11	0.066707442591	0.000954242355	0.000234240305	153.15	1047.95
3	0.050603624382	0.000723879073	0.001762220397	102.30	1381.45
6	0.050242988280	0.000718720214	0.001843684844	101.29	1391.36
4	0.020108850665	0.000287654814	0.080471179878	32.31	3476.39
2	0.018991509022	0.000271671370	0.092565275993	30.27	3680.92
20	0.014423375795	0.000206324745	0.164079409210	22.24	4846.73
8	0.012594700428	0.000180165752	0.206335459224	19.17	5550.44
17	0.011970237161	0.000171232877	0.223130160148	18.14	5840.00
18	0.007090835646	0.000101433595	0.411248226034	10.38	9858.67
12	0.006379779894	0.000091262023	0.449573769004	9.29	10957.46
1	0.004767847839	0.000068203519	0.550205832927	6.86	14662.00
16	0.002319296882	0.000033177277	0.747790104964	3.28	30141.11
5	0.000000000000	0.000000000000	1.000000000000	0.00	Infinite

Table 7

Comparison of the results of reallocation for three periods of observations

2005–2009		2010–2013		2005–2013	
Road section	T_{0i}^*	Road section	T_{0i}^*	Road section	T_{0i}^*
15	264.41	15	774.71	15	378.48
19	536.37	14	780.73	14	648.87
14	558.34	10	925.11	19	667.27
9	582.98	7	928.23	9	720.42
13	661.02	19	966.26	10	833.79
10	766.38	9	1017.02	7	840.54
7	778.30	3	1036.16	13	963.52
11	846.61	13	1425.38	11	1047.95
6	1058.59	11	1472.56	3	1381.45
3	1871.84	6	2210.07	6	1391.36
4	2485.03	2	2397.85	4	3476.39

8	2514.44	8	6912.67	2	3680.92
20	3607.52	4	6948.00	20	4846.73
2	4592.64	20	7709.56	8	5550.44
12	7218.70	1	15894.17	17	5840.00
18	7424.44	18	19780.00	18	9858.67
17	7551.85	16	25274.44	12	10957.46
1	16813.70	12	28008.89	1	14662.00
16	23841.67	17	Infinite	16	30141.11
5	Infinite	5	Infinite	5	Infinite
Road	**56.44**	**Road**	**94.60**	**Road**	**69.91**

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