ROAD NETWORK SAFETY MANAGEMENT USING THE TARVA TOOL

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Abstract. The TARVA safety evaluation tool has been created for reliable evaluation of the current safety situation and the safety effects of improvements. Separate versions of TARVA have been created for the Lithuanian and Finnish roads and Finnish level crossings. Using TARVA, one can also reliably rank the existing network by its safety. Safety ranking is based on expected accident numbers achieved by combining accident history data with accident prediction model data. In addition to comparing the safety of individual roads, an example is presented on comparing the road safety of different areas using the simple accident prediction models prepared for TARVA. Initial results from the comparisons suggest that quite a lot can be learned about safety potential by comparing the safety of different areas and of individual roads using available science-based analysis tools.

Keywords. Road safety, Estimation, Comparison, Accident prediction model.

INTRODUCTION

Road safety ranking and impact assessment of all road infrastructure projects have been requested for the trans-European road network (European Parliament, 2008). However, science-based safety evaluation tools are not widely available or used. If the allocation of road safety improvements is not based on scientifically justified tools, one cannot expect safety work to be as effective as it should be.

The expected number of accidents after implementing a measure can be calculated as a product of the predicted number of accidents in the future without the measure (target accidents) and a crash modification factor (CMF, also called impact coefficient or accident modification factor) describing the effect of the planned measure. For example, a 0,9 CMF corresponds to a 10% reduction in the number of accidents. CMFs are a proper way of transferring information on traffic safety effects if the quality of the safety studies and transferability of effects are properly taken into account (OECD/ITF, 2012). Information about CMFs can be found e.g. from publications such as the book by Elvik et al. (2009).

As mentioned above, the expected safety effect depends not only on the CMF estimate but also on the expected future number of target accidents, a quantity that is also insufficiently known. In some cases errors in target accidents can be substantial, even more so than errors in CMF. It is not infrequent for the estimation of future expected number of target accidents to be based on accident records with no modelling.

Consequently, in order to maximise efficient use of existing reliable safety knowledge, scientifically well-founded safety evaluation tools for road improvements are needed. The aim of this paper is to present a tool called TARVA that fits those needs. Specifically, the use of TARVA as a network safety management tool is demonstrated.

We start by describing the principles and use of the TARVA tool and explaining why such a tool is needed. Next, we present a comparison of the traffic safety of Lithuanian road regions and demonstrate how TARVA can be used for safety ranking of the road network. Finally, we outline the latest development of an accident analysis tool called Onha.

1 TOOL FOR SAFETY EVALUATIONS

1.1 Purpose and principles of TARVA

The purpose of TARVA is to provide a common method, database and user interface for (1) predicting the expected number of road accidents for selecting locations for safety treatments, and (2) estimating the safety effects of road safety improvements in order to evaluate the cost-effectiveness of combinations of safety measures.

The underlying logic of TARVA is combining general safety (accident model) with information from local safety factors (accident record) using the Empirical Bayesian (EB) method. For creating accident prediction models, the road network is divided into homogeneous road sections and crossings.

The estimation of safety effects of road improvements is a four-phase process, shown in Fig. 1, to which the following numbers refer:

(1) For each entity (homogeneous road section or crossing) the most reliable estimate of the expected accident number is calculated. Information about accident record and accident model is combined into a formula that takes into account the model's goodness of fit and random variation in the number of accidents.

(2) To predict the number of accidents without road improvements, the most reliable estimate of the number of accidents can be corrected by the growth coefficient of the traffic.

(3) The effects of the measures on casualty accidents are estimated based on the predicted number of accidents and planned measures for which the average impacts on casualty accidents have been estimated.

(4) Measures can also affect the severity of accidents still occurring on the road after treatment. TARVA takes these effects into account with severity reduction coefficients. Using the available knowledge on the average severity (fatalities per 100 casualty accidents) and its change due to measures, TARVA produces an estimate of yearly-avoided fatalities.

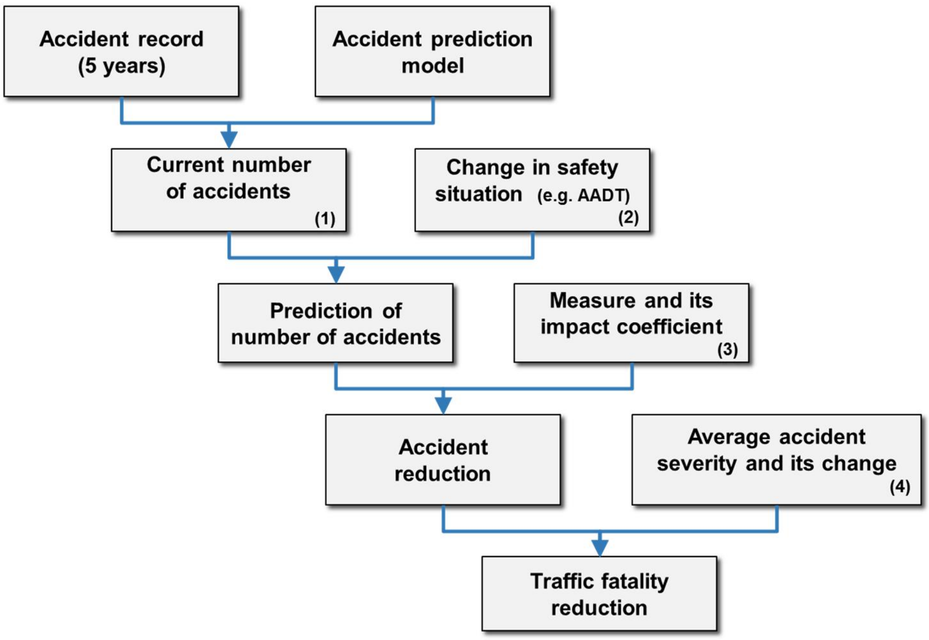


Fig. 1. Evaluation of traffic safety effects of road improvements, using TARVA (Peltola et al., 2013).

1.2 Practical use of TARVA

The databases for all TARVA versions are updated yearly. Thus up-to-date prediction of expected numbers of accidents for any part of the network is always available and safety effects can be estimated using the latest information. The minimum input needed for estimation of safety effect is (1) what the measures are and (2) where they are implemented. There are almost 100 predetermined measures in the Lithuanian highway safety evaluation version. Additionally the user can define his/her own measures, provided reliable CMF estimates are available.

The results of the calculations include (1) the expected safety situation on the modified network if no measures are implemented and (2) the safety effects of selected improvements (yearly injury accidents and fatalities).

Estimates of yearly-avoided injury accidents and fatalities caused by road improvements are used to calculate the benefit in accident costs. Because TARVA estimates the costs of measures as well, results can be used to calculate what kinds of measures are most effective regarding safety, and where those measures pay off most effectively. Implementation costs can be entered while performing the evaluations, but the average costs for measures (per km or per measure) are used if these values are not entered.

2 WHY USE ACCIDENT PREDICTION TOOLS

To be able to implement cost-effective road safety improvements, reliable safety ranking must be performed in order to allocate the measures optimally. Additionally, proper safety estimates for alternative road improvements are needed – and these must be based on expected number of accidents if no measures are implemented.

Based on a comparison of definitions of hazardous road locations (also called black spots or hotspots) in eight countries, Elvik (2008a) argued that "currently applied operational definitions of hazardous road locations in most of the European countries included in this survey are not close to the state-of-the-art and are in need of considerable development in order to approach the state-of-the-art." Furthermore, Elvik (2008b) and Montella (2010) have concluded that the EB method should be a standard in identification of hazardous location. Identification should be based on best estimate of accidents and it should be achieved by combining information from accident records and accident prediction models (Elvik, 2008b).

Peltola et al. (2013) compared different kinds of accident predictions and found out that in many cases relying on the accident record only is the least accurate option - even the lottery performed better than the accident record. Advanced model-based estimates such as those used by TARVA performed best and should be employed. This change could lead to tremendous consequences for current practices in road safety by substantially improving and strengthening road-safety work and thereby enhancing safety.

3 COMPARING ROAD SAFETY USING TARVA MODELS

In this section, we discuss how the simple accident prediction models used in TARVA LT (Jasiūnienė et al., 2012) can be used even for comparing the safety of roads in different road districts. The idea is to provide equal safety conditions to people around the country, and from comparisons with other road districts find ideas of optimal locations for road improvements.

3.1 Lithuanian road districts – management of the national road network

The Lithuanian Road Administration is in charge of organizing and co-ordinating the reconstruction, maintenance and development of roads of national significance (the national road network). Routine maintenance of these roads is carried out by 11 state enterprises, 10 of which work regionally and one (SE "Automagistralė") maintains the motorways (see Fig 2 and Table 1). County-based state enterprises – here called road districts – have the authority and responsibility to carry out maintenance, repair and inventory of national roads and road facilities within the region. They do this with the help of companies located within the county area.

Fig. 2. Map of Lithuanian counties (http://regionai.stat.gov.lt/)

Table 1. Lithuanian national road network and regional information

Region (County)	Population [1]	Area [2], km²	National road network [3], km							Proportion of the road network of Lithuania, %
			Main	National	Regional			Total		
					Regional roads total, km	Gravel pavement, km	Gravel pavement proportion, %			
Alytus	155203	5425	95	390	987	353	35,8	1471		**6,9**
Kaunas	600363	8089	187	620	1869	889	47,6	2677		**12,6**
Klaipėda	335304	5209	77	449	1344	693	51,6	1870		**8,8**
Marijampolė	159447	4463	121	364	1087	507	46,7	1572		**7,4**
Panevėžys	246591	7881	135	509	1798	1002	55,7	2441		**11,5**
Šiauliai	296305	8540	219	603	1960	1233	62,9	2782		**13,1**
Tauragė	108320	4411	66	376	1002	649	64,8	1445		**6,8**
Telšiai	150111	4350	67	344	900	443	49,2	1311		**6,2**
Utena	149179	7201	158	572	1771	973	54,9	2501		**11,8**
Vilnius	806935	9731	199	711	1873	862	46,0	2782		**13,1**
SE Automagistralė [4]	-	-	415	-	-	-	-	415		**2,0**
Total	**3007758**	**65300**	**1738**	**4939**	**14591**	**7604**	**52,1**	**21268**		**100**

Information source:
[1] The Lithuanian Department of Statistics (Statistics Lithuania) http://www.stat.gov.lt/
[2] The Regional Development Department under the Ministry of the Interior http://www.lietuvosregionai.lt/
[3] The Lithuanian Road Administration under the Ministry of Transport and Communications of the Republic of Lithuania http://www.lra.lt
[4] State Enterprise „Automagistrale“ is responsible for maintenance of two Main roads A1 Vilnius – Kaunas – Klaipėda, A2 Vilnius – Panevėžys

3.2 Comparison of accident rates of national roads between road districts

Road safety comparisons between regions are regularly performed in order to learn from the successes of the best performing regions, but without a proper approach the conclusions may be erroneous. Specifically, comparisons seldom take into account disparities between road categories, making it hard to identify where the differences originate. In the following, we demonstrate a comparison that benefits from the simple prediction models of TARVA LT (Tarva for Lithuanian roads) presented by Jasiūnienė et al. (2012). An example is given in Fig. 3 and Table 2 comparing the rates (risks per vehicle kilometres) and numbers of casualty accidents between ten road districts in Lithuania. Motorways maintained by the Automagistralė are excluded from the comparisons.
The red columns in Fig. 3 show the accident rate variation between Lithuanian road districts by accident record. The accident rate differences between regions are partly caused by different distributions of vehicle kilometrage among road categories between regions. These effects are taken into account in the blue columns in Fig. 3. Differences in actual accident rates and their calculations are further reported in Table 2.

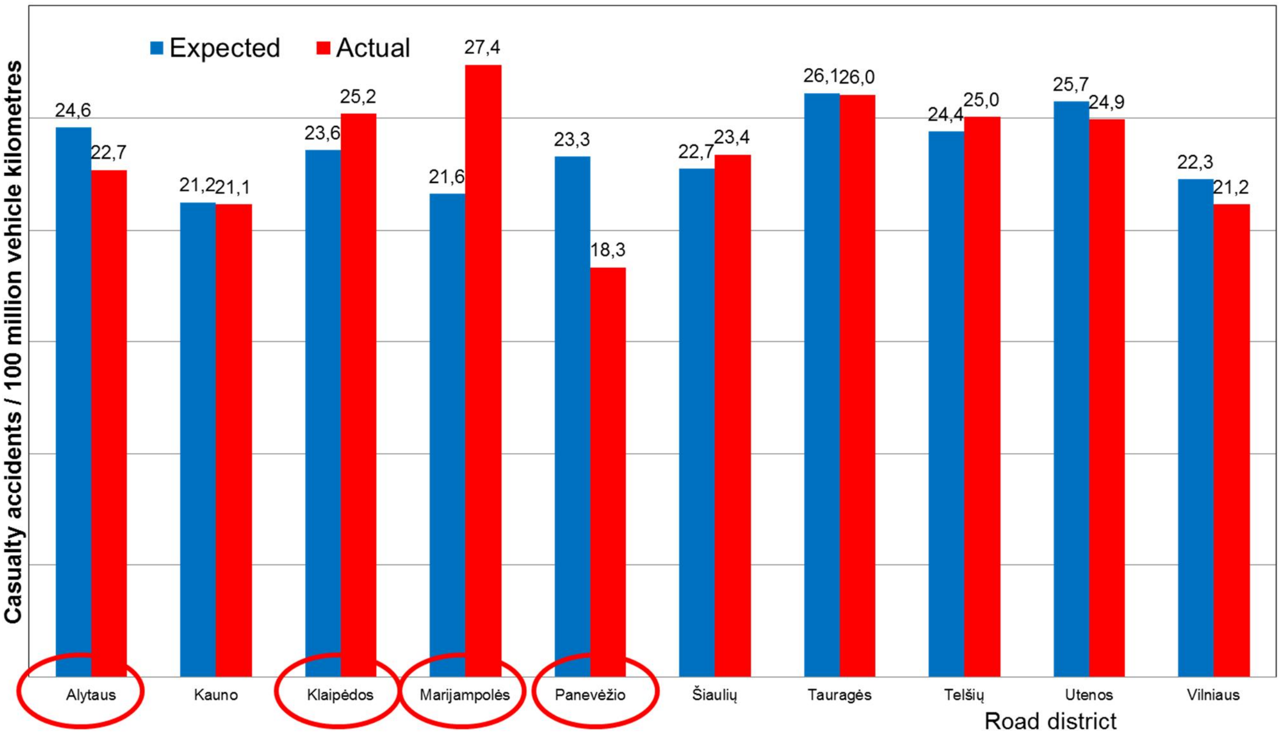


Fig 3. Actual and expected casualty accident rates of nine Lithuanian road districts in 2007–2011. Expected rate is based on the assumption of having the same accident rate in every road district in each road group.

If the accident rates were equal on all roads, injury accidents would be distributed according to column 2 in Table 2. Differences in the distribution of vehicle kilometrage between road groups with different accident rate cause a difference in the number of accidents; the estimate of this effect is shown in column 3 in Table 2. For example, -167 in the Kauno district is caused mainly by the excess proportion of Rural 9 meter main roads (these road groups being safer than average) compared to the rest of the country.
The remaining differences in safety derive from the accident rate disparities – road groups do not have the same rates in all districts. The effects of rate disparities from the average elsewhere in the country are shown in column 4 in Table 2. For example, +207 in the Marijampolės district originates from the 3,6 billion vehicle kilometres having an accident rate of 27,4 accidents per 100 million vehicle kilometres in that district compared to the average rate of 21,6 on respective roads elsewhere in the country. These accident rate differences – seen also as the difference between red and blue columns in Fig. 3 – are essential from the standpoint of locating high-risk roads or regions.

It is acknowledged that these figures include random variation; assuming a Poisson distribution we tested the difference in accident figures producing the blue and red columns in Fig. 3. The tests suggest that the accident rate differences are statistically significant at a 95% significance level in the four road districts circled in red in Fig 3 (Alytaus, Klaipėdos, Marijampolės and Panevėžio).

Table 2. Expected and actual number of casualty accidents per year in 2007–2011 by road district in Lithuania

District	If equal rates [1]	Effects by differences in:		Actual number [4]
		Road categories [2]	Rates [3]	
Alytaus	661	45	-54	651
Kauno	1802	-167	-8	1628
Klaipėdos	1044	39	74	1157
Marijampolės	813	-35	207	986
Panevėžio	975	-10	-206	760
Šiaulių	1128	-10	30	1149
Tauragės	521	75	-2	595
Telšių	580	39	17	635
Utenos	716	91	-25	782
Vilniaus	1451	-64	-70	1317

[1] Casualty accident figures if accident rates (accidents/kilometrage) on all roads equal
[2] Effect on number of accidents caused by different share of kilometrage on safer/less safe road groups
[3] Effect on number of accidents caused by higher/lower than average accident rates in area of relevance, including random variation in actual accident numbers
[4] Recorded accidents during 2007–2011 on national roads

Using the created Excel spreadsheet, it is easy to determine from which road groups the differences are emerging. Differences can be identified by calculating the rate differences and effects of the higher rates as numbers of accidents and fatalities by road category. E.g. the above effect +207 in the Marijampolės district is mainly caused by higher than average rates on 9 meter main roads, 6–8 meter minor roads and urban sign roads. Accident rates on these roads are statistically significantly higher than elsewhere in Lithuania (Table 3).

From the spreadsheet the user selects the study and comparison road districts. He/she can restrict the comparisons to similar areas, such as those with the same kind of climate or traffic conditions. The spreadsheet also provides a summary of the comparison (Table 4). This helps in obtaining an overview of the study area. In this example (Marijampolės vs. rest of the Lithuania), what is striking is the large number of bicycle accidents in Marijampolės compared to what would be expected based on the safety nationwide.

Table 3. Comparison of Lithuanian road districts (2007–2011), Marijampolės vs. rest of Lithuania

Comparison: Kauno , Klaipėdos , Marijampolės , Šiaulių , Tauragės , Telšių , Utenos , Vilniaus ,

Study: Marijampolės ,

Road group[1]		AADT, veh/day	Kilometrage, share, (%)[2]		Risks / 100M veh km[3]				Killed/5years			Casualty acc./5years		
					Comparison		Study		Equal risks[4]	Risk diff.[5]	Police record[6]	Equal risks[4]	Risk diff.[5]	Police record[6]
			Comp.	Study	Fatality	Accident	Fatality	Accident						
Separated driving directions	12. Four lanes, median, ≤ 90 km/h	< 9000	1,2	0,4	1,9	11	0,0	14	0	0	0	2	0	2
		9000–12000	3,0	0,0	2,9	15	0,0	0	0	0	0	0	0	0
		≥ 12000	3,5	1,0	2,7	10	0,0	20	1	-1	0	4	3	7
Main roads, rural	21. Main road, 9 m	< 3000	1,2	0,0	4,8	21	0,0	0	0	0	0	0	0	0
		3000–6000	7,8	6,6	3,8	14	10,4	24	9	16	25	34	24	58
		≥ 6000	6,6	26,7	4,2	13	3,9	16	40	-3	37	128	25	153
	22. Main road, 8 m	< 4500	3,4	2,4	4,8	17	3,5	25	4	-1	3	15	7	22
		≥ 4500	1,1	0,7	4,8	15	0,0	32	1	-1	0	4	4	8
	23. Main road, ≤ 7 m	< 4500	0,8	0,0	5,7	16	0,0	0	0	0	0	0	0	0
		≥ 4500	1,1	0,4	3,1	20	0,0	7	0	0	0	3	-2	1
Minor roads, rural	31. Minor road, 9 m	< 4500	2,0	0,4	4,6	20	7,1	28	1	0	1	3	1	4
		≥ 4500	2,6	0,4	2,9	14	0,0	14	0	0	0	2	0	2
	32. Minor road, 8 m	< 1500	1,1	0,1	5,8	24	53,2	213	0	1	1	0	4	4
		1500–4500	7,0	7,8	3,8	20	4,7	30	11	2	13	56	29	85
		≥ 4500	2,4	4,4	6,2	24	3,1	27	10	-5	5	39	4	43
	33. Minor road, 7 m	< 1500	7,1	6,8	6,6	29	7,4	33	16	2	18	71	10	81
		1500–4500	8,2	8,1	5,5	21	6,5	26	16	3	19	62	14	76
		≥ 4500	3,3	0,0	4,0	18	0,0	0	0	0	0	0	0	0
	34. Minor road, ≤ 6 m	< 1500	10,6	10,7	6,6	32	9,3	40	26	10	36	123	31	154
		1500–4500	6,2	7,5	4,9	21	8,1	31	13	9	22	58	27	85
		≥ 4500	0,5	0,0	4,5	24	0,0	0	0	0	0	0	0	0
	35. Gravel roads	< 150	1,5	0,9	12,3	57	3,1	59	4	-3	1	18	1	19
		150–300	1,8	2,3	5,5	36	3,6	30	5	-2	3	30	-5	25
		≥ 300	1,2	2,3	2,6	21	2,4	20	2	0	2	18	-1	17
Urban roads	41. Urban sign	< 3000	7,7	7,2	5,5	32	3,5	38	14	-5	9	83	15	98
		3000–6000	3,4	2,0	2,0	25	4,1	33	1	2	3	18	6	24
		≥ 6000	3,6	1,0	2,4	26	2,9	52	1	0	1	9	9	18
	All together		100	100	4,8	23	5,5	27	177	22	199	779	207	986

(1) Group as in TARVA LT
(2) Share of kilometrage (%) in the study and comparison area. Values under half or over twice that of the comparison area are highlighted.
(3) Risk of casualty accidents and fatalities by vehicle kilometrage in study and comparison areas in 2007–2011
(4) "Equal risks" means the number of accidents/fatalities calculated using kilometrage in the study area and rates in the comparison area.
(5) Effect of the difference in rate between study and comparison areas. In other words: how many accidents/fatalities more or less happened in the study area if the rate was the same as in the comparison area. Hence, negative values means that the rate in the study area is smaller than in the comparison area. Values statistically different from zero are highlighted.
(6) Police record means the actual number of accident/fatalities in five years and equals the sum of the two previous columns (e.g. 779 + 207 = 986)

4 RANKING OF ROADS BY ROAD SAFETY AND SAFETY POTENTIAL

The idea of the TARVA LT evaluation tool is to create a reliable estimate of the expected number for every road section and crossing in Lithuania. One of the TARVA reports, the Network Safety Report (NSR), produces up-to-date information on the entire road network: road, traffic and accident data and most importantly estimates on expected numbers of accidents and fatalities. Hence it is possible to produce maps like that in Fig 4 from Finland and tables showing the most promising locations for road improvements. Calculations like that presented in Section 3 can be used to help focus on the outstanding safety problems in each area.

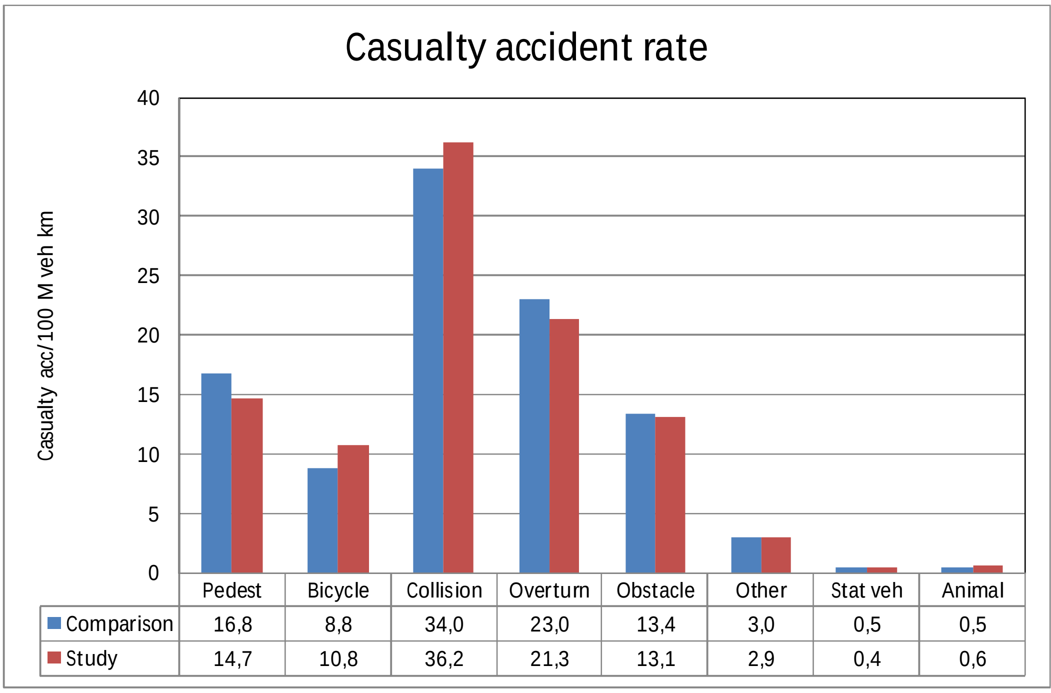
Table 4. Summary of the comparison of Lithuanian road districts (2007–2011), Marijampolės vs. rest of Lithuania

Basic safety figures:

	Roads, km	AADT, veh/day	Mileage, Mkm/y	Casualty accidents /year	Casualty accidents rate[2)]	Casualty accidents density[2)]	Fatalities /year	Fatalities rate[2)]	Fatalities density[2)]	Severity Killed/100 acc.
Comparison[1)]	19301	**1091**	7683	155,7	21,6	10,1	35,3	4,90	2,29	22,7
Study	**1544**	**1278**	**720**	**197,2**	**27,4**	**12,8**	**39,8**	**5,52**	**2,58**	**20,2**

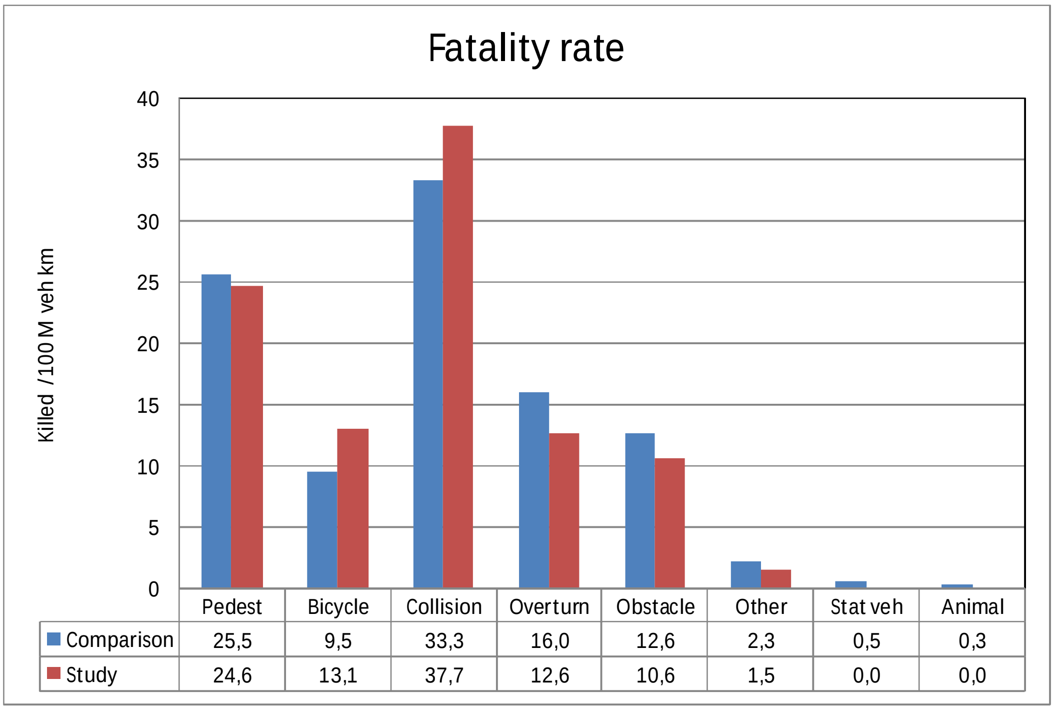
Distributon of accidnts among accident type

	Casualty accidents (number/5 years)						Fatalities (number/5 years)					
	Ped	Bic	Coll	Over	Other	All	Ped	Bic	Coll	Over	Other	All
Comparison[1)]	131	68	265	179	135	779	45	17	59	28	28	177
Study	**145**	**106**	**357**	**210**	**168**	**986**	**49**	**26**	**75**	**25**	**24**	**199**
Difference, %	11 %	55 %	35 %	17 %	24 %	27 %	9 %	54 %	27 %	-11 %	-13 %	13 %



The list below shows which areas are included in the study and which ones are in the comparison group.

HINT: To change study and comparison areas, add/remove checks on the Data_Study and Data_comparison -sheets for the filter of cell B2.



Study	
Alytaus	-
Kauno	-
Klaipėdos	-
Marijampolės	Yes
Panevėžio	-
Šiaulių	-
Tauragės	-
Telšių	-
Utenos	-
Vilniaus	-
Comparison	
Alytaus	Yes
Kauno	Yes
Klaipėdos	Yes
Marijampolės	-
Panevėžio	Yes
Šiaulių	Yes
Tauragės	Yes
Telšių	Yes
Utenos	Yes
Vilniaus	Yes

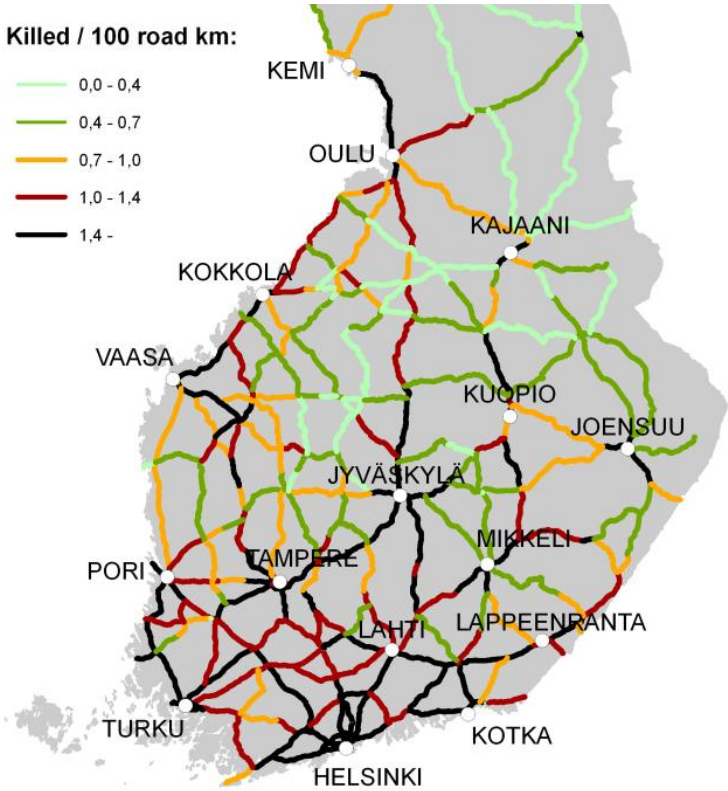


Fig 4. Road fatality density (fatalities/100 km per year) map produced from the TARVA accident number estimates, based on data from 2006-2010 in Finland (Peltola et al., 2013).

Using the NSR report of TARVA LT, we found that the safety of road A7 is not as good as one would expect based on the safety of similar roads elsewhere in Lithuania.

The analysis presented in Tables 2–4 is a preliminary one – a more thorough analysis with maps and results from the analysis done using Tarva LT and Onha will be demonstrated in the presentation. Onha is an accident analysis tool that is now under reconstruction. However, it seems that during the autumn of 2013 we will be able to further analyse the network safety of Lithuanian roads with a set of new science-based tools.

CONCLUSIONS

We demonstrated a safety evaluation tool called TARVA. This provides EB safety predictions as the basis for selecting locations for implementing road-safety improvements. In addition, TARVA provides estimates of the safety benefits of selected improvements. The EB estimation method used by TARVA is superior to the simple methods using the accident record only (e.g. accident black spots), which is currently quite a common estimation method. Relying on the accident record only is the least accurate option for estimating future accidents – at least on low accident frequency segments, where even the lottery performed better than the accident record. This finding suggests that advanced model-based estimates such as those used by TARVA should be employed. This would lead to tremendous consequences for current practices in road safety by substantially improving and strengthening road-safety work and thereby enhancing safety.

We demonstrated how comparisons of road safety between regions benefit from taking into account the differences in road categories. Comparisons between road districts revealed statistically significant differences that can be used in selecting roads to be improved.

Reliably predicting the number of accidents if no measures are implemented is highly crucial for selecting the locations to be treated in an optimal way. Additionally it is essential for estimating the safety effects of road improvements. Estimates on Crash Modification Factors might be transferred from other countries but their benefit is greatly limited if the number of target accidents is not properly predicted. Without proper knowledge and tools one can end up making huge errors in cost-effectiveness estimates, and traffic safety work is ineffective.

The TARVA tool has been used to evaluate all the safety effects of road improvements on public roads in Finland for over 15 years, and enhanced versions have recently been released for Lithuanian roads and Finnish level crossings. Our experience suggests that making predictions and evaluations using the same principle and tools will remarkably improve the quality and comparability of safety estimations.

Road safety impact assessments and network safety ranking are requested in general, and the EU directive on road infrastructure safety management makes them compulsory for Member States. However, science-based safety evaluation tools have neither been widely used nor available. Without proper tools for safety evaluation of road improvements, safety work is not sufficiently effective. Furthermore, the use of proper tools does not necessarily result in higher cost – conversely, road safety could frequently be improved at no extra cost if the safety measures were properly selected and allocated. In addition, commonly used safety evaluation tools could provide benefits in terms of transfer of safety knowledge. For example, it would be much more effective if the development and use of Crash Modification Factors were more common.

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REFERENCES

Elvik, R. 2008a. A survey of operational definitions of hazardous road locations in some European countries. Accident Analysis and Prevention 40, 1830–1835.

Elvik, R. 2008b. The predictive validity of empirical Bayes estimates of road safety. Accident Analysis and Prevention 40, 1964–1969.

Elvik, R., Høye, A., Vaa, T., Sørensen, M. 2009. The Handbook of Road Safety Measures, Second ed. Emerald publishing, Bingley.

European Parliament. 2008. Directive 2008/96/EC of the European parliament and of the council of 19 November 2008 on road infrastructure safety management.

Jasiūnienė, V., Čygas, D., Ratkeviciūtė, K., Peltola, H. 2012. Safety ranking of the Lithuanian road network of national significance. Baltic Journal of Road and Bridge Engineering, vol. 7, 2, 129–136. Retrieved from http://dx.doi.org/10.3846/bjrbe.2012.18 (28.4.2013).

Montella, A. 2010. A comparative analysis of hotspot identification methods. Accident Analysis and Prevention 42, 571–581.

OECD/ITF. 2012. Sharing Road Safety - Developing an International Framework for Crash Modification Functions. Retrieved from http://dx.doi.org/10.1787/9789282103760-en (24.4.2013).

Peltola, H., Rajamäki, R., Luoma, J. 2012. Tools needed for enhancing transferability of cost-effective road safety measures. Transport Research Arena 2012, Procedia - Social and Behavioral Sciences . Vol. 48 (2012), 1234 – 1243. Retrieved from http://dx.doi.org/10.1016/j.sbspro.2012.06.1099 (24.4.2013)

Peltola, H., Rajamäki, R., Luoma, J. 2013. A tool for safety evaluations of road improvements. Accident analysis and prevention. Retrieved from http://dx.doi.org/10.1016/j.aap.2013.04.008 (25.4.2013)