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ESTONIAN TRAFFIC BEHAVIOUR MONITORING STUDIES 2001–2016: OVERVIEW AND RESULTS

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Abstract. One of the most significant factors affecting road safety is human. Estonia has improved road safety dramatically since its re-independence in 1991, and among the other reasons, this has happened due to changes in behaviour of road users. Likely, at the same time, there have been annual studies conducted, aimed at measuring specific indicators connected to compliance with road traffic law. As a result, one gets long-term trends in such indicators as compliance with traffic signals, usage of seat belts, yielding to pedestrians at uncontrolled crossings. This paper aims to describe Estonian traffic behaviour studies, analysing their results and pointing out actual problems in traffic behaviour. According to the results of studies, all aspects of traffic behaviour showed positive trends, but these trends are different. Certain indicators such as usage of seat belts have changed dramatically, while others like compliance with traffic signals showed only moderate changes. The foremost problem in traffic behaviour is found out to be ignorance to yield at uncontrolled pedestrian crossings. It is certainly one of the issues to deal with in the context of achieving Estonian strategic goals in road safety.

Keywords: Estonia, behaviour of road users, road safety, safety performance indicators, traffic behaviour, traffic behaviour monitoring, traffic study.

1. Introduction

The road-transport system serves a vital role in the well-being and prosperity of modern societies, yet according to statistics from World Health Organization by 2016, this system is a major source of trauma with more than 1.25 million people killed worldwide. The latter number is comparable to the population of Estonia, which is 1.3 million inhabitants.

Road safety has been amongst the most important topics in Estonia since the 1990s. The first road safety social campaign was held in 1995, and since then similar campaigns have become standard practice. In 2003, the Estonian National Road Safety Program (hereafter ENRSP) was launched, which aimed at reducing the number of fatal accidents from 264 in 2002 to 100 in 2015. This goal was achieved much earlier – already in 2009 – and by 2015 the number of fatal accidents reduced to 67. At the same time, the Annual Average Daily Traffic on Estonian highways increased 1.5 times, and motorization level increased 1.6 times. It indicates that the number of fatal accidents decreased in spite of the rapid development of the Estonian transport sector.

Compared to European statistics, the reduction of fatal accidents in Estonia was happening faster. Figure 1 gives numbers of road accident fatalities per million population, provided by Estonian Road Administration. The number of road accident fatalities in Estonia decreased faster than across the the European Union (hereafter EU) in general. In fact, in 1991 the number of road accident fatalities in Estonia was almost twice as high as on average in the EU, then in 2015, it was 2% less than the EU average. Much smaller sample sizes explain why the Estonian graph is more uneven (correlation coefficient R-squared is 0.846) compared to those for the EU.

Amongst the reasons for rapid improvements in road safety, there is a combination of different factors named. Some of them are on a global scale – such as the development of the car industry and safer fleet as well as economic factors (especially the recession in 2007, which favoured the reduction of fatal accidents nearly twice). Other factors refer to ENRSP 2003–2015, which assumed conducting social campaigns, rebuilding major roads and dangerous road sections, enforcement and lots of other activities. While it is impossible to access the effectiveness of each road safety improvement measure separately, one still gets the general results. In Estonia changes in behaviour of road users are accessed using annual state-wide studies conducted since 2001. By analysing respective data,

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understanding trends and comparing them to other information that is available, it is possible to establish the behavioural problems to concentrate on in future work.

This paper aims to make the analysis mentioned above. The literature review helps to understand the connection of behaviour of road users to road safety and provides a general overview of road safety studies. In the main part of this paper, there is a description of Estonian traffic behaviour studies, and the results of these studies are provided and analysed.

2. Literature analysis

The term "road safety" is considered as the absence of unintended harm to living creatures or inanimate objects (Evans 2004). There are different options for measuring road safety using various parameters connected to road accident fatalities, injuries and crashes (Abbas 2004; Madsen *et al.* 2017; Rundmo *et al.* 2004). Regardless of the variety of respective indicators, road safety research and practice focus on accident prevention. Thus the number of accidents is being considered the main criterion (Gehlert *et al.* 2014). At the same time when speaking about road safety, the accent is being done at the personal damage (accidents resulting in injuries and deaths) rather than at material damage. For instance, a popular safety paradigm, Vision Zero, focuses on incidents, which lead to a person being killed or seriously injured (Johansson, 2009).

A key factor in crash risk is road user behaviour (Rowe *et al.* 2015). Some studies estimate human error to account

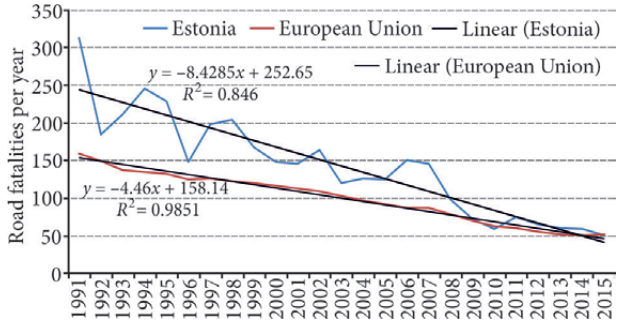

Fig. 1. Road accident fatalities per million population in Estonia and the European Union (1991–2015)

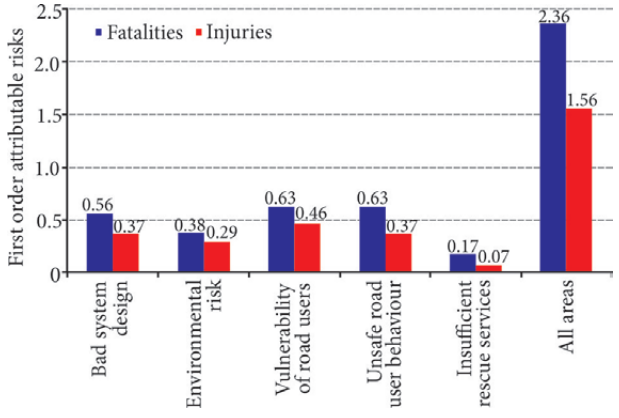

Fig. 2. Importance of risk factors in contributing to traffic accidents and injuries (Elvik *et al.* 2009)

for about 90% of all traffic accidents (Finley *et al.* 2015; Lund *et al.* 2009). If violations of road traffic law did not occur, the number of fatalities could be reduced by 63% (Elvik *et al.* 2009), and in this context, behaviour of road users is one of the most important aspects of road safety (Fig. 2). Drinking and driving, speeding and failing to wear a seat belt are named as major contributing factors to roadway fatalities (Adminaitė *et al.* 2016; Finley *et al.* 2015).

Latest approaches to road safety assume improving road safety climate (Gehlert *et al.* 2014). Road safety climate is understood as the attitudes of road users and perceptions of the traffic in a context (e.g., country) at a given point in time (Özkan, Lajunen 2011). It is assumed that the much positive a road safety climate is perceived, the more behavioural control is be seen, and the fewer traffic violations are indented and committed (Gehlert *et al.* 2014). Unfortunately, empirical research on road safety climate is still in its infancy (Ostroff *et al.* 2013; Zohar 2010). At the same time, there are numerous studies on behaviour of road users.

Studies on pedestrian behaviour mostly focus on safety on zebra crossings. Among the study methods being used, there are field observation, interviews and self-report surveys (Koekemoer *et al.* 2017; Porter *et al.* 2017). Observation often includes pedestrian-vehicle conflict counts on zebra crossings and intersections (Fu *et al.* 2016; Gitelman *et al.* 2017). Ontario Traffic Manual defines a conflict as a traffic event involving the interaction of two or more road users, where an evasive action such as braking or swerving occurs to avoid a collision. Conflicts are used because they are considered as good surrogates for pedestrian collisions (Fu *et al.* 2016).

The literature analysis shows that there are two general approaches to estimating behaviour of drivers, which are self-report survey studies and observation studies. One of the most popular tools for survey studies is the Driver Behaviour Questionnaire (hereafter DBQ), in which respondents indicate how often they commit particular types of aberrations in traffic. Driver Behaviour Questionnaire investigates such components as involuntary errors, involuntary lapses, intentional rule violations and intentional aggressive violations. Intentional rule violations and aggressive violations are considered to be dangerous, errors are judged as "potentially dangerous", and lapses are characterised as "not dangerous" or "silly" (Lawton *et al.* 1997; Mattsson *et al.* 2015). Over the other options, DBQ is used to investigate differences in traffic behaviour between countries (de Winter *et al.* 2016). Among popular observation study methods, there is naturalistic driving, which is considered to reflect more realistic driver behaviour than other alternatives (Bao *et al.* 2015). However, at the same time, this fails to provide information whether aberrations in traffic are intentional or not. In such studies, specialized research vehicles are used to record a significant amount of data continuously from the driver, the car and the surroundings (Valero-Moraa *et al.* 2013). The naturalistic driving method is used for studying different aspects

of risky driving behaviours such as speeding, secondary task engagement (for instance, cell telephone dialling), as well as seat belt usage (Bao *et al.* 2015; Simons-Morton *et al.* 2015). As with every study method, both DBQ and naturalistic driving have some restrictions. Weaknesses of DBQ are connected to the subjectivity of answers and issues with sampling methods (Mattsson *et al.* 2015). Limitations of naturalistic driving studies are linked to behavioural modification as drivers know they are under observation, issues with large amounts of data and high costs (Valero-Moraa *et al.* 2013).

As a rule, studies on behaviour of road users are done within short periods and fail to reveal long-term trends. The only exception known to Authors of this paper is Finnish traffic behaviour monitoring, which has been held annually since 1992. The main objective of this observation study is monitoring the behavioural changes taking place in Finland. The idea of Estonian studies on behaviour of road users was taken over from Finland, so these studies have much in common. However, interviews with Finnish researchers dealing with traffic behaviour monitoring revealed certain differences in the methods being used in field observation. As a result, it is impossible to compare Estonian and Finnish data directly, but trends in traffic behaviour in the two countries are still comparable.

To conclude, traffic behaviour is an important part of the road safety paradigm. There are numerous studies on behaviour of road users, which are done mostly using surveys or observation. Most of the parameters being used for assessing traffic behaviour are connected to violations of road traffic law. Literature analysis showed that the absolute majority of traffic behaviour studies are done on an irregular basis and fail to provide long-term trends in behaviour of road users.

3. Traffic behaviour monitoring in Estonia

In Estonia behaviour of road users is assessed using annual studies aimed at revealing trends. Between 2001 and 2005, both survey and observation methods were used, but later survey studies were separated from observation and concentrated on estimating attitude of road users towards the observance of traffic regulations.

Estonian monitoring on behaviour of road users is done within an annual state-wide observation study. There are over 100 fixed observation places on urban and rural roads where data is collected using standardised observation methods. Traffic behaviour is estimated using definite Safety Performance Indicators (hereafter SPI-s) connected to compliance with road traffic law. Each indicator is an average share of violators among respective observation places. As indicators are measured regularly, they provide a good idea about behavioural trends of road users. Since 2001 there have been different SPI-s, and for five of them, there are 16 year-long data rows available. These indicators are compliance of drivers with traffic signals, compliance of pedestrians with traffic signals, yielding to pedestrians at uncontrolled crossings, using turn indicators and using seat belts. There have been other safety indicators used, such as speeds, compliance with traffic signals at railroad crossings and use of safety reflectors by pedestrians, but for different reasons, observations were terminated. For instance, speed monitoring was made using Global Positioning System, and researchers had to drive in a traffic flow with the speed of the flow. This speed was higher than the speed limit, and at some point, Estonian Road Administration decided that they do not have the right to ask researchers break the speed limit and this research was terminated.

Compliance of drivers and pedestrians with traffic signals is observed on intersections, and zebra crossings controlled by traffic lights. Adequate safety indicators are calculated by dividing the number of violators by the total number of drivers or pedestrians observed. Yielding to pedestrians at uncontrolled, crossings is estimated using episodes. An episode is a situation when a driver has to yield to a pedestrian or pedestrians at an uncontrolled crossing. The share of violators is calculated by dividing the number of violators, by the total number of drivers who participated in episodes. Usage of seat belts is observed both on the front and rear seats of passenger vehicles. Data is collected into four categories – driver, front passenger, rear passenger and child. The share of violators is calculated in each category separately (for instance, the number of drivers, who fail to wear a seat belt, is divided by the total number of drivers observed). Usage of turn indicators has been observed using different methods. Between 2014 and 2016, studies were done at roundabouts where the objects of observation were cars driving out from roundabouts. The share of violators was calculated by dividing the number of drivers, who left the roundabout without indicating a turn, by the total number of drivers who left the roundabout. Before 2014, usage of turn indicators was observed near bus stations, and at regular junctions, so one has to admit that respective data incomparable. Therefore, trends in the usage of turn indicators are excluded from the future analysis.

It is important to mention that according to the European Transport Safety Council, drinking and driving, speeding and failing to wear a seat belt are major contributing factors to fatal accidents. At some point in time, official reports of Estonian traffic behaviour studies contained data for all the above mentioned violations, but researchers never dealt with drinking and driving – the police did it. As data rows for drinking and driving and speeding behaviour are rather short, they are being excluded from the future analysis in the scope of this paper.

4. Analysis of the study results

Hereafter, the results of the analysis are based on data available from studies of road users behaviour conducted in Estonia during the period from 2001 until 2016. Authors of this paper are operating only with the available data and cannot calculate confidence intervals or estimate preciseness of the SPI-s in another way. Therefore, the data is taken "as is" and the accent is done rather at trends in behaviour of road users, than at single values.

There are four SPI-s, which is possible to analyse for the period from 2001 to 2016. This is the compliance of drivers and pedestrians with traffic signals, usage of seat belts and yielding to pedestrians at uncontrolled crossings. Trends for all of the four SPI-s are positive (share of violators was decreasing), but these trends are still different. There are there are two groups of SPI-s – those who have shown dramatic changes and those who showed only minor changes.

Usage of seat belts belongs to the first group of SPI-s – in 2001–2016, this indicator showed the very best improvement trend (Fig. 3). Both road administration and police contributed to this using numerous social campaigns and enforcement procedures. Figure 3 shows that the most rapid changes have taken place in categories of grown-ups on rear seats and children. Due to smaller sample sizes, these graphs are more uneven compared to the others (the biggest issue is with grown-ups on rear seats), despite that they show strong improvement trends. Such a rapid change in behaviour of drivers and passengers is explained among the other factors by a poor initial benchmark. General improvement of seat belt use rates happened before 2011 when these rates nearly reached the maximum, and afterwards, the positive trend stagnated. Seat belt use rate in the category of grown-ups on rear seats achieve lower level than the other categories. Taking into account the general trend and small sample sizes, there is a high probability that the decrease in the share of violators among grown-ups on rear seats in 2011–2013 was occasional and is in 2014, the graph just came back to the right place.

Another SPI, which showed a strong improvement trend is yielding to pedestrians at uncontrolled crossings.

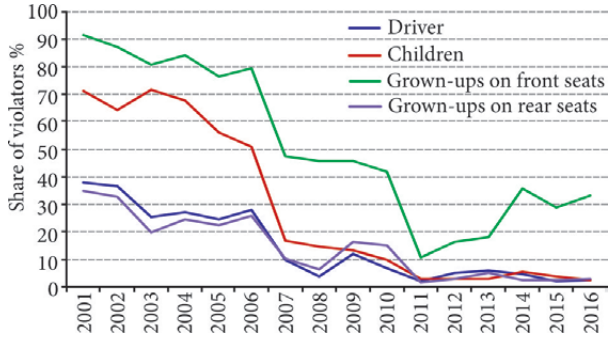

Fig. 3. Seat belt use rate in Estonia (2001–2016)

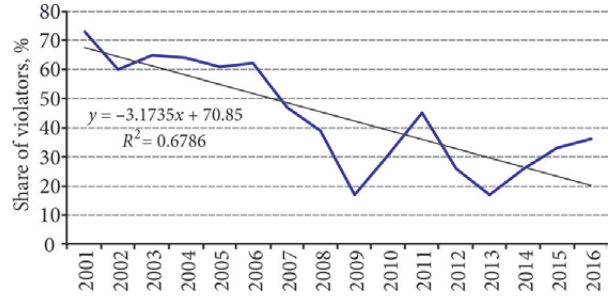

Fig. 4. Yielding to pedestrians at uncontrolled crossings in Estonia (2001–2016)

Respective data is presented in Fig. 4. Despite the fact that graph is uneven and has significant deviations, there is still a clear improvement trend. Deviations are explained by certain methodological issues as well as legislation issues (as for the traffic law 2011, the driver has to yield to a pedestrian who is about to step or has an intention to step at a zebra crossing. In many observational situations it is impossible to judge unambiguously whether the driver had to yield or not). The general improvement trend is very positive. Similarly to seat belt usage, the most rapid decrease in the share of violators took place in the first part of the observation period, but at the same time proportion of violations was far away from the minimum. Starting from 2010, the positive trend stagnated, and it is hard to forecast whether the SPI continues to improve or not.

What was done to improve this aspect of behaviour of drivers? Between 2001 and 2016, Estonian Road Administration regularly launched special social campaigns aimed at increasing safety at uncontrolled crossings, but one has to admit that enforcement failed to support these activities sufficiently. Traffic behaviour studies showed that between 2011 and 2015, the share of drivers who fail to yield to pedestrians was on average 29.4%. However, during the same period, only 0.5% of all the traffic fines were imposed on drivers who failed to yield to pedestrians.

The analysis shows that pedestrian safety is problem number one in road safety in Estonia. Between 2010 and 2016, the share of pedestrians in all the fatal accidents was between 18% and 36%. At the same time according to the European Commission, this proportion in the EU was 22% on average, and it is still considered to be too high. Despite all of the work done in the scope of ENRSP, pedestrian safety is still recognised as the main road safety problem of Estonia. According to Estonian Road Administration, more than 70% of all car-pedestrian collisions are happening on main streets of the four bigger cities (Tallinn, Tartu, Pärnu, and Narva) and most of them – at uncontrolled pedestrian crossings.

The SPI-s of the second group, which in 2001–2016 showed only that minor changes, are compliance of drivers and pedestrians with traffic lights. Figures 5 and 6 give respective data. Both graphs reveal slight improvement trends, but these are much weaker trends that those of the SPI-s discussed previously. To some extent, it is explained by a better initial benchmark – the danger from ignoring traffic signals seems to be very evident, and the situation when the majority of road users are ignoring traffic signals is complicated to imagine. Compared to seat belt usage and yielding at zebra crossings, there is no pronounced difference in behaviour trends before and after 2011 – changes were taking place slowly and gradually. It is worth mentioning that ENRSP did not foresee any particular measures for improving the behaviour drivers and pedestrians at controlled intersections. However, at the same time enforcement made more accent at these violations compared to yielding at pedestrian crossings. In 2011–2015, 7% of all the traffic fines were made to drivers ignoring traffic

signals and 4% to pedestrians ignoring traffic signals. Taking into account that 48% of all the traffic fines in Estonia are made for speeding, these percentages are pretty high.

To summarize, trends of behaviour of road users for the period from 2001 to 2016 were analysed in the context of compliance of drivers and pedestrians with traffic signals, usage of seat belts and yielding to pedestrians at uncontrolled crossings. The last two SPI-s showed rapid improvement trends, which stagnated after 2010–2011. The share of drivers and pedestrians ignoring traffic signals also decreased, but positive changes were taking place slowly.

5. Discussion

In this paper, there were highlighted trends of behaviour of road users observed so far. The question arises, what aspects of behaviour of road users to be dealt with to continue improvement of road safety? To answer this question, one needs first of all to have a deeper look at road safety statistics.

In fact, in 1991–2016 road safety in Estonia had improved dramatically, but these judgements are based mostly of on statistics of road accident fatalities. Traditionally road safety research focuses on traffic accidents rather than on the number of fatalities. It is particularly important in the case of small sample sizes, which is an issue for Estonia. Unlike data of road accident fatalities instead, trustful accidents statistics are available only since 2003. Respective data provided by Estonian Road Administration is in Fig. 7. As a reference on this figure, there are also given traffic injuries and fatalities. Since 2011, the number of injuries is slowly increasing, while the number of accidents is not changing. Also, the most significant shifts in fatalities took place before 2010 and in 2016 the number of fatal accidents increased. Given the tiny sample sizes and growing number of injuries, there is a likelihood that the positive trend in traffic deaths, which took place in 2011–2015 will change to negative during the next years.

So, to summarise, reducing the number of traffic injuries is crucial for further road safety improvements in Estonia.

In this paper, the Authors show that behaviour of road users improved in all of the studied aspects, and this played a certain role in the overall improvement of road safety. It is probable that the biggest contribution to road safety improvement was made by changes in seat belt use rates. Major improvements in road safety in Estonia coincide with the improvement of seat belt use rates. At the same time, some studies claim that adoption of lap/shoulder seat belts reduces the risk of life threatening injuries for front seat vehicle occupants by 45%, and the risk of moderate to critical injury by 50% (Chen *et al.* 2016). In this respect, there is a definite potential for improvement of seat belt usage on rear seats (by grown-ups), which is still very far from ideal. However, this is unlikely to have a considerable effect as there are very few vehicles with grown-up passengers in the rear seats. At the same time, the main problem of Estonian traffic is the high number of accidents, especially vehicle-pedestrian collisions. Seat belts are a passive road safety measure that helps to soften consequences of traffic accidents but fails to contribute to decreasing the number of accidents. In this context, yielding to pedestrians plays a more important role. Starting from 2010, the number of accidents at uncontrolled crossings is increasing, and the share of drivers who fail to yield is rather high. Analysis showed that amongst the other reasons, this is due to insufficient enforcement, but at the same time, enforcement is rather difficult because of legislation issues.

Fixing the legislation and bringing more focus of enforcement to behaviour of road users at pedestrian crossings is likely to have a significant effect on road safety

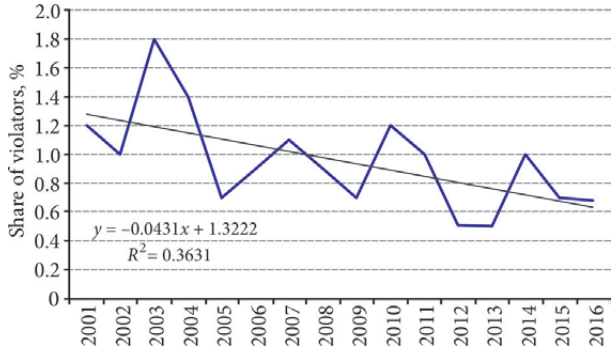

Fig. 5. Compliance of drivers with traffic lights in Estonia (2001–2016)

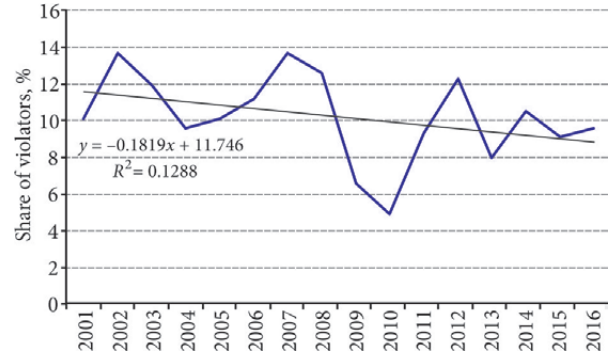

Fig. 6. Compliance of pedestrians with traffic lights in Estonia (2001–2016)

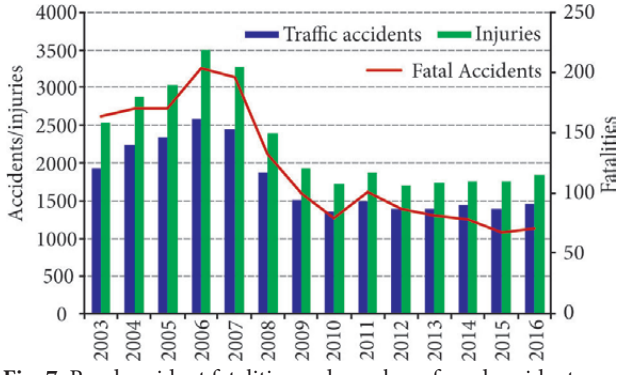

Fig. 7. Road accident fatalities and number of road accidents in Estonia(2003–2016)

statistics. However, in practice, it is rather difficult because of the bureaucracy machine and lack of police resources. One of the options is the application of alternative measures such as safer solutions for uncontrolled pedestrian crossings. The vision of the Authors of this paper for road safety improvement is rebuilding zebra crossings on main streets of bigger cities and applying contemporary Intelligent Transport System solutions to prevent vehicle-pedestrian conflicts. In this context, the question arises of how to assess the effectiveness of these measures in conditions where sample sizes are small, and traffic accident statistics are not sufficiently precise. Solving these issues helps the further improvement of traffic behaviour and with high probability the improvement of road safety.

6. Conclusions

1. Traffic behaviour is an important part of road safety paradigm and improving the behaviour of drivers and pedestrians favours the improvement of road safety.

2. Behaviour of road users is usually estimated in connection with violations of traffic regulations. The most common traffic behaviour study methods are survey and observation. Long-term traffic behaviour monitoring is performed only in Estonia and Finland.

3. Since 2001, Estonia has conducted annual statewide observation studies aimed at understanding trends in traffic behaviour. This behaviour is estimated through compliance with road traffic law. As for 2016, there are long-term trends available for compliance of drivers and pedestrians with traffic signals, usage of seat belts and yielding to pedestrians at uncontrolled crossings.

4. In 1991–2016, the usage of seat belts has improved dramatically. General improvement in seat belt usage happened before 2011, when most of the respective rates nearly achieved the maximum. At the same time usage of seat belts on rear seats has also significantly improved, but is still far from ideal.

5. Despite positive trend in yielding to pedestrians at the uncontrolled crossing, which took place between 2001 and 2009, the number of respective traffic accidents is increasing, and pedestrian safety is considered to be problem number one for road traffic in Estonia. One of the probable reasons for that is insufficient enforcement.

6. Behaviour of drivers and pedestrians at controlled intersections has shown minor improvements. Respective trends are slow, which can be explained besides the other things by specifics of violations at controlled intersections and absence of advocacy work.

7. It is crucial to reduce the number of traffic accidents, especially those, which lead to injuries, to continue improvement of road safety in Estonia. One of the options for achieving this goal is improving the behaviour of road users in the part of yielding to pedestrians at uncontrolled crossings.

References

Abbas, K. A. 2004. Traffic Safety Assessment and Development of Predictive Models for Accidents on Rural Roads in Egypt, *Accident Analysis and Prevention* 36(2): 149–163. https://doi.org/10.1016/S0001-4575(02)00145-8

Adminaitė, D.; Jost, G.; Stipdonk, H.; Ward, H. 2016. *Ranking EU Progress on Road Safety.* 10th Road Safety Performance Index Report. European Transport Safety Council. 39 p. Available from the Internet: http://etsc.eu/wp-content/uploads/10-PIN-annual-report-FINAL.pdf

Bao, S.; Xiong, H.; Buonarosa, M. L.; Sayer, J. R. 2015. Using Naturalistic Driving Data to Examine Drivers' Seatbelt Use Behaviour: Comparison between Teens and Adults, *Journal of Safety Research* 54: 69–73. https://doi.org/10.1016/j.jsr.2015.06.006

Chen, F.; Ma, X.; Chen, S. 2016. *Investigation of Interaction between Traffic Safety, Law Enforcement and Environment*. Colorado State University, Dept of Civil and Environmental Engineering. 55 p. Available from the Internet: http://www.ugpti.org/resources/reports/downloads/mpc16-311.pdf

De Winter, J. C. F.; Dodou, D. 2016. National Correlates of Self-Reported Traffic Violations Across 41 Countries, *Personality and Individual Differences* 98: 145–152. https://doi.org/10.1016/j.paid.2016.03.091

Elvik, R.; Hoye, A.; Vaa, T.; Sorensen, M. 2009. *The Handbook of Road Safety Measures.* Emerald Group Publishing Limited. 2nd edition. 1140 p. https://doi.org/10.1108/9781848552517

Evans, L. 2004. *Traffic Safety*. Bloomfield Hills, MI: Science Serving Society. 445 p.

Finley, K.; Riggs, S.; Otto, J.; Ward, N. J. 2015. *An Assessment of Traffic Safety Culture: Exploring Traffic Safety Citizenship. Task 1 Report: Literature Review.* Center for Health and Safety, Western Transportation Institute. 23 p. Available from Internet: http://www.mdt.mt.gov/other/webdata/external/research/docs/research_proj/tsc/8882-309-03_SAFETY_CITIZENSHIP_TASK_1_REPORT.pdf

Fu, L.; Zou, N. 2016. The Influence of Pedestrian Countdown Signals on Children's Crossing Behaviour at School Intersections, *Accident Analysis and Prevention* 94: 73–79. https://doi.org/10.1016/j.aap.2016.05.017

Gehlert, T.; Hagemeister, C.; Özkan, T. 2014. Traffic Safety Climate Attitudes of Road Users in Germany, *Transportation Research Part F: Traffic Psychology and Behaviour* 26 (Part B): 326–336. https://doi.org/10.1016/j.trf.2013.12.011

Gitelman, V.; Carmel, R.; Pesahov, F.; Chen, S. 2017. Changes in Road-User Behaviours Following the Installation of Raised Pedestrian Crosswalks Combined with Preceding Speed Humps, on Urban Arterials, *Transportation Research Part F: Traffic Psychology and Behaviour* 46 (Part B): 356–372. https://doi.org/10.1016/j.trf.2016.07.007

Johansson, R. 2009. Vision Zero – Implementing a Policy for Traffic Safety, *Safety Science* 47(6): 826–831. https://doi.org/10.1016/j.ssci.2008.10.023

Koekemoer, K.; Van Gesselleen, M.; Van Niekerk, A.; Govender, R.; Van As, A. B. 2017. Child Pedestrian Safety Knowledge,

Behaviour and Road Injury in Cape Town, South Africa, *Accident Analysis and Prevention* 99 (Part A): 202–209. https://doi.org/10.1016/j.aap.2016.11.020

Lawton, R.; Parker, D.; Manstead, A. S. R.; Stradling, S. G. 1997. The Role of Affect in Predicting Social Behaviours: the Case of Road Traffic Violations, *Journal of Applied Social Psychology* 27(14): 1258–1276. https://doi.org/10.1111/j.1559-1816.1997.tb01805.x

Lund, I. O.; Rundmo, T. 2009. Cross-Cultural Comparisons of Traffic Safety, Risk Perception, Attitudes and Behaviour, *Safety Science* 47(4): 547–553. https://doi.org/10.1016/j.ssci.2008.07.008

Madsen, T. K. O.; Lahrmann, H. 2017. Comparison of Five Bicycle Facility Designs in Signalized Intersections Using Traffic Conflict Studies, *Transportation Research Part F: Traffic Psychology and Behaviour* 46 (Part B): 438–450. https://doi.org/10.1016/j.trf.2016.05.008

Mattsson, M.; O'Brien, F.; Lajunen, T.; Gormley, M.; Summala, H. 2015. Measurement Invariance of the Driver Behaviour Questionnaire across Samples of Young Drivers from Finland and Ireland, *Accident Analysis and Prevention* 78: 185–200. https://doi.org/10.1016/j.aap.2015.02.017

Ostroff, C.; Kinicki, A. J.; Tamkins, M. M. 2003. *Organizational Culture and Climate*. John Wiley & Sons, Inc. 565–593. https://doi.org/10.1002/0471264385.wei1222

Özkan, T.; Lajunen, T. 2011. Person and Environment: Traffic Culture. *Handbook of Traffic Psychology*. Chapter 14: 179–192. https://doi.org/10.1016/B978-0-12-381984-0.10014-1

Porter, B. E.; Neto, I.; Balk, I.; Jenkins, J. K. 2016. Investigating the Effects of Rectangular Rapid Flash Beacons on Pedestrian Behaviour and Driver Yielding on 25 mph Streets: a Quasi-Experimental Field Study on a University Campus, *Transportation Research Part F: Traffic Psychology and Behaviour* 42 (Part 3): 509–521. https://doi.org/10.1016/j.trf.2016.05.004

Rowe, R.; Roman, G. D.; McKenna, F. P.; Barker, E.; Poulter, D. 2015. Measuring Errors and Violations on the Road: a Bifactor Modeling Approach to the Driver Behaviour Questionnaire, *Accident Analysis and Prevention* 74: 118–125. https://doi.org/10.1016/j.aap.2014.10.012

Rundmo, T.; Iversen, H. 2004. Risk Perception and Driving Behaviour Among Adolescents in Two Norwegian Counties before and after a Traffic Safety Campaign, *Safety Science* 42(1): 1–21. https://doi.org/10.1016/S0925-7535(02)00047-4

Simons-Morton, B. G.; Klauer, S. G.; Ouimet, M. C.; Guo, F.; Albert, P. S.; Lee, S. E.; Ehsani, J. P.; Pradhan, A. K.; Dingus, T. A. 2015. Naturalistic Teenage Driving Study: Findings and Lessons Learned, *Journal of Safety Research* 54: 41–48. https://doi.org/10.1016/j.jsr.2015.06.010

Valero-Moraa, P. M.; Tontsch, A.; Welsh, R.; Morris, A.; Reed, S.; Touliou, K.; Margaritis, D. 2013. Is Naturalistic Driving Research Possible with Highly Instrumented Cars? Lessons Learnt in Three Research Centres, *Accident Analysis and Prevention* 58: 187–194. https://doi.org/10.1016/j.aap.2012.12.025

Zohar, D. 2010. Thirty Years of Safety Climate Research: Reflections and Future Directions, *Accident Analysis and Prevention* 42(5): 1517–1522. https://doi.org/10.1016/j.aap.2009.12.019

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