

The Key Issues of Road Design Found from Road Safety Inspections and Road Safety Audits

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Abstract. In order to reduce accident rate on roads and streets more and more various road safety measures are being implemented each year. Nevertheless, road safety problem exists in most countries. For example, even though accident rate in Lithuania was almost halved (6372 to 3161 yearly accidents) from years 2004 to 2015, fatality rate is still quite high – 8.3 per 100000 people. New regulations, approved in 2008, dictate the need of carrying out road safety audits and road safety inspections for all road and street design projects. This paper presents most common road design errors and methods of fixing those errors based on Vilnius Gediminas Technical University Road Research Institute road safety auditors' experience from years 2011 to 2016. Most common safety problems are organized and presented in groups ordered by their importance. Recommendations on how to improve road safety audit and inspection procedures in the future are formulated, as well as suggestions on improving road project design stage by taking most common flaw priority into consideration.

Keywords: road safety audit; road safety inspection, road safety measures; road design recommendations.

Conference topic: Roads and railways.

Introduction

Society gets more and more mobile every day, but road safety problem is still as relevant as ever, despite numerous positive changes in some countries. For example, even though accident rate in Lithuania was almost halved (6372 to 3161 yearly accidents) from years 2004 to 2015, fatality rate is still quite high – 241 persons in year 2015 or 8.3 per 100000 people (in 2004 fatality rate was 21.9 per 100000 people) (Eismo įvykių statistika 2017). In Poland there were 2591 fatalities in 2016 (Policja.pl 2017). Taking in account that in population of Poland is larger than Lithuania (approx. 38.5 m people) (Business Insider Polska 2016), the Poland's fatality rate was ~6.7 per 100000 people.

An aim of one of the researches, carried out in Germany, was to find out injury rate of passengers involving passenger cars, showed a relative decrease in mortality, which was 68.8% from 1991 to 2011. Between 2006 and 2011, the percentage of severely injured traffic victims was less than half, both in terms of the whole body and individual body regions (Ernstberger *et al.* 2015).

Also, the fact that our society is getting older should be taken in account, as well as the increasing rate of traffic accidents involving elderly people. For example, a study in Iran revealed that 1306 elderly people were injured, which is 8.7% of all the injuries in traffic accidents. Total in-hospital mortality rate was 10.1% that was higher in old elderly pedestrians and motorcyclists in comparison to young elderly (16.1% vs. 7.9%) and other type of victims (Etehad *et al.* 2015).

There is a number of ways to increase road safety, which include physical means, e.g. traffic safety measures, penalty system for disobeying traffic rules, etc. Likewise, there are long-term solutions, as society education, road user training, legal base refinements, improvements of road design projects via road safety audits, etc.

Aim of this study is to make recommendations on improving the road design process, as well as improving road safety audits and inspections procedures.

Road safety improvement measures

In order to decrease traffic accident rate and consequences of traffic accidents, various physical traffic calming measures could be implemented. In some cases, those measures could be very effective, for example, one of the researches in Lithuania revealed that after installing of certain vertical traffic calming measures on the road sections, the number of fatal and injury accidents decreased by 60%, the number of people injured decreased by 63%, the number of people killed decreased by 82% (Jateikiene *et al.* 2016). Those measures can be implemented during road design stage as well as later if the need occurs.

Properly chosen road design elements during design stage can have a positive impact on road safety. For example, one of Australian studies regression analysis results suggest that crash rates vary significantly according to changes in road geometry factors at day-time, due to changes in the visual cues of drivers (Alian *et al.* 2016). While a research in Spain revealed that the road geometry design is found to have a significant impact on the different accident types (lane widths, superelevation and slope, the visibility range of the driver (direct and indirect visibility, visibility obstruction), shoulder lane width, median lane width, slow lane width, etc.). The overall results of the study show that narrow main lane, shoulder lane, median lane and slow lane, might increase the accident severity. Higher superelevation and steeper slope also will increase the severity of the accident (Dadashova *et al.* 2016a).

Moreover, proper speed limit must be set according to all the design elements being implemented. Ensuring maximum reliability of the driver's activity and is most likely to hold the set speed is an effective tool for improving traffic safety at the design stage of roads (Batrakova, Gredasova 2016).

On the other hand, only choosing the correct road design elements is not enough to totally negate traffic accidents. Other means must be implemented as well. For example, in order to decrease the rate of heavy accidents, a number of measures must be applied, amongst which are the enforcement of road safety policies and innovations in car engineering (Ernstberger *et al.* 2015; Dadashova *et al.* 2016a) and emergency medicine, alcohol level control, seat belt usage enforcement (Ernstberger *et al.* 2015), periodic medical examination (Etehad *et al.* 2015), information campaigns, local warning systems (Bergel-Hayat *et al.* 2013), driver behavior surveillance, legislative measures, investment in road maintenance, vehicle characteristics (Dadashova *et al.* 2016b).

The overall results show that road safety legislation, policy and institutional capacity related investment proposals are generally considered very effective for the improvement of road safety. On the other hand, it seems that most such investment proposals are considered relatively expensive to implement and effective on the long-term. Specifically, the overall results show that the investment proposals considered to provide high safety benefit at low cost, in most partner countries, are the legislation for infrastructure safety management and the legislation for efficient enforcement (Laiou *et al.* 2016).

Road safety legislation in Lithuania

On 19 of November 2008 European Parliament and the Council released a directive on road infrastructure safety management. This directive states that road safety experts should be trained and certified according to the Member States approved respective training programs and qualification means. This directive requires from all Member States that they prepare and implement road safety audit, inspection and other traffic safety-related procedures.

Lithuanian Law on Road Safety (Lietuvos Respublikos saugaus... 2000) requires all road (street) designs (new road or reconstruction of existing), to be audited road safety-wise.

On 4 of November 2011 Road Infrastructure safety management guidelines were approved. These guidelines determined road infrastructure management procedure application and road safety auditors' training course organizational arrangements, such as minimum requirements for a training course content, etc. Also these guidelines state that road infrastructure project road safety inspection or road safety audit must be carried out before starting road (street) construction, reconstruction or major repair works (Kelių infrastruktūros... 2011).

On 12 of June 2008 Road Safety Audit Requirements (Kelių saugumo audito... 2008) were approved. This document contains road safety audit procedure structure. Also, it describes what requirements road safety audit must meet.

On 26 of June 2008 Road Safety Audit Procedure Manual (Kelių saugumo audito... 2008) was approved. It describes national significance road safety audit task planning, organizing and executing. This document contains information on what is auditor's obligation. For example, an auditor must visit site during light and dark conditions to evaluate visibility and other road safety influencing factors. Also it states that an auditor must look at the site and through the eyes of different road users. Moreover, all the necessary documentation to be presented to auditor is listed here.

On 25 of February 2011 Road Safety Inspection Procedure Manual (Poveikio kelių saugumui... 2011) was approved. It describes national significance road safety inspection task planning, organizing and executing. Road safety inspections are to be carried out at the beginning of object planning stage before approving new road construction, existing road reconstruction or major repair project.

Road Safety Audit Procedure Manual and Road Safety Inspection Procedure Manual can be used by local and private road owners to apply to their projects, though it is not necessary.

It should be noted that traffic and meteorological conditions may vary depending on day of the week or season, for example, resort areas in Lithuania are especially calm in winter. Also Lithuanian weather conditions are very variable. Temperature can fluctuate from $-42.9\text{ }^{\circ}\text{C}$ (recorded in 1956 m. in Utena) to $37.5\text{ }^{\circ}\text{C}$ (recorded in 1994 m. in Zarasai) during a year (Galvonaitė *et al.* 2013). Furthermore, different types precipitation (rain, snow, hailstorms, etc.) is very common here. That is why it can be a challenge to evaluate site under all of these conditions, when usually only 10 working days are given to carry out a road safety audit.

As mentioned before starting from year 2008 there are regulations on road safety audit and inspection procedures for national roads. These regulations cover new road construction projects as well as road reconstruction and major repair projects. Though local authorities do not have to obey national road regulations for local roads, they do not carry out road safety audits for major repair projects. However, the main problem is that local authorities don't have any regulations on road safety audit and inspection procedures. That is why many municipalities still avoid exercising road safety audits and inspections. Sometimes they do not even know that those procedures are mandatory. Because of that, in order to decrease accident rate in urban areas, same manuals and guidelines on road safety audits and inspections should be implemented for local authorities.

What is worse, frequently auditors are presented with rough and incomplete projects, which do not include any traffic or pedestrian flow studies or miss some of required drawings (e.g. road profile or cross sections, etc.). That is why regulations on road design should include information on completeness of a project to be presented to auditors. Also, they should clearly describe what kind of studies must be carried out by the designer before submitting project for audit.

Methodology

In this study 147 road safety audits carried out in years 2011–2016 were analyzed. Audits were performed on projects of various national roads, streets, and local roads all across Lithuania.

In all these audits a total of 209 major issues and 1167 lesser issues were registered or approx. 9,34 issues per project. During analysis all road safety issues were grouped into 13 major categories, depending on a road (street, intersection, pedestrian path, etc.) element, relevant to the issue. After that issues were sub grouped to a total of 103 lesser categories depending on an issue type.

Also in this period a number of road safety inspections was carried out as well. Usually these inspections evaluate existing road condition rather than road design project. Auditors make an assessment on-site, analyze nearby territories, plan and predict those territories growth, come up with road safety issues and make suggestions on increasing the level of road safety at those sites.

Main issues found in projects during road safety audits

A large part of all the issues in analyzed projects was related to road sign and vertical marking usage. Over a quarter of all issues was about missing signs, incorrectly placed signs, etc. Also an issue related to pedestrians' and bicyclists' safety is common (18.1% of all issues), the most numerous sub-categories containing group. Next on a list is road markings issue related group (11.4% of all issues). Other road safety issue categories include alignment and profile geometry, traffic safety measure usage (speed humps, road narrowing, safety barriers, etc.), intersections, carriageway geometry and other. Figure 1 shows distribution of all road safety issues grouped into categories. Figures 2–6 show some of the most important categories safety-wise in detail.

Figure 2 shows the vastest safety issue group related to pedestrian and bicyclist safety. Most common issue with occurrence rate of over 25% is lack of tactile surfaces for people with disabilities. They became mandatory relatively recently and currently there is no clear regulation or guideline on usage of this type of surfaces. That is why engineers have a hard time choosing the right design decisions for people with disabilities. Second most common issue is unsafe pedestrian crossings. It is not only common but also more important consequence-wise, as accidents at pedestrian crossings tend to lead to fatalities. Solving the unsafe pedestrian crossing issues should be amongst priorities, meaning traffic calming measures (passive and active), crossing directional illumination and other measures should always be considered by designer.

Another important safety issue group is shown in Figure 3. One of the main reasons of traffic accidents in Lithuania is speeding. Drivers usually tend to speed on long straight road strip with flat pavement. Because of that, a very common case is when speed limit is being exceeded in small towns or other urban areas, which leads to traffic accidents. Frequently engineers do not design any traffic calming measures on roads and strips where speeding is expected. However, even those who do design those measures, often choose incorrect type for them. For example, they use traditional speed humps in dense urban area, where road narrowing would be more appropriate, or use only visual speed limiting measures instead of physical. This means that Lithuanian engineers are not up-to-date informed about newest traffic safety solutions, on their benefits and risks, as well as their application area. That is why organizing more free seminars about traffic safety measures for designers and other specialists might be a good idea.

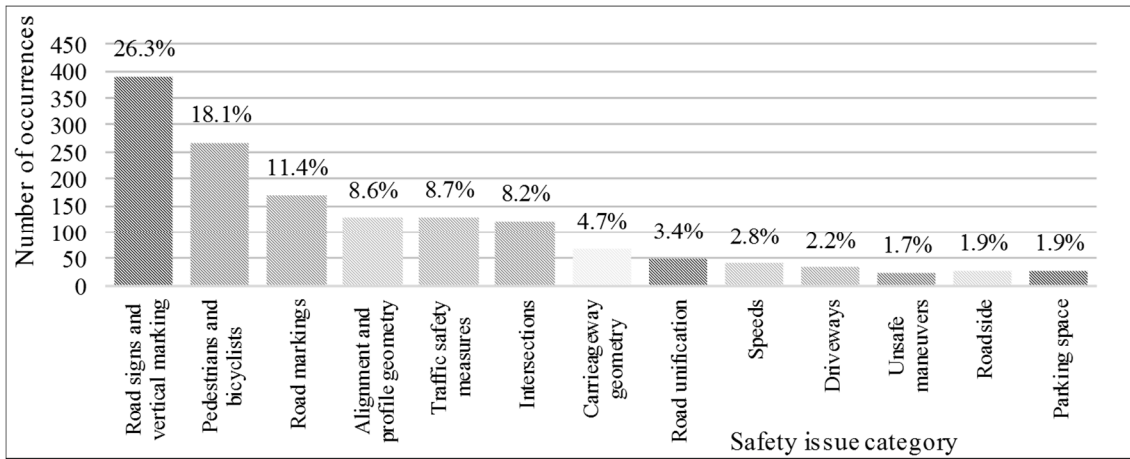
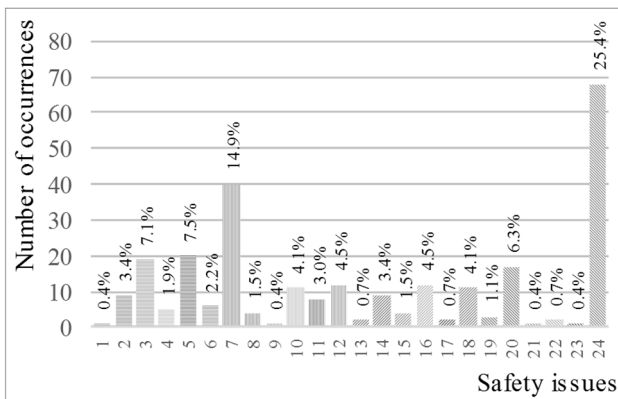
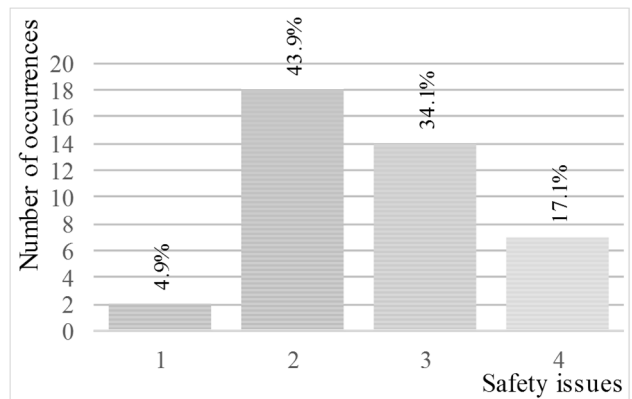


Fig. 1. Reported road safety issue number by category



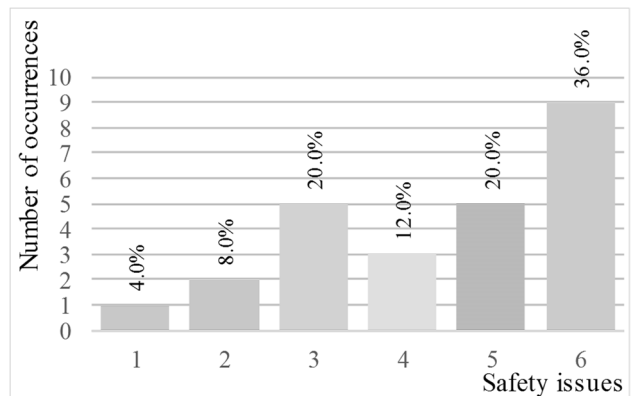
1	Bicycle crossing unsafe
2	Road sign might obstruct pedestrian visibility
3	Footpath or bikeway missing ramp at crossings
4	Pedestrians expected to travel via unsafe path
5	Pedestrians movements impaired due to path geometry or obstacles
6	Unsafe pedestrian crossing (unmarked)
7	Unsafe pedestrian crossing
8	Pedestrian crossing is too narrow
9	Excessive unmarked pedestrian crossing
10	Excessive pedestrian crossing
11	Missing illumination at pedestrian crossing
12	Possible pedestrian falling down high slope in frombridge
13	Bicyclists expected to rush into bike crossing
14	Pedestrians or bicyclists unseparated from motorised traffic
15	Footpath or bikeway unrecognizable (unmarked)
16	Pedestrian path does not lead to point of interest
17	Path crossing driveway height breaks
18	Footpath or bikeway too narrow
19	Obstacles on a path pavement
20	Path broken (unsmooth edges with sharp corners)
21	Path profile is broken (grade breaks without vertical curves)
22	Sudden height changes
23	Design path connects with existing abruptly
24	Missing or incorrect tactile surfaces for people with disabilities

Fig. 2. Road safety issues related to pedestrian and bicyclist safety



1	Speed limit in urban areas
2	Traffic calming measure type incorrect
3	Expected speeding in urban area
4	Expected speeding in rural area

Fig. 3. Road safety issues related to driving speeds



1	Expected prohibited dangerous maneuver
2	Expected prohibited dangerous turn
3	Entry/exit is not properly organized
4	Heavy traffic is not prohibited where it should be
5	Unsafe overtaking expected
6	Unsafe parking expected

Fig. 4. Road safety issues related to unsafe maneuvers

Figure 4 represents not the most extensive road safety issue category, but one of the most significant regarding to traffic accident rate and severity. Dangerous left turns, possible unsafe overtaking maneuvers and other actions are often not taken into account by designers, as it requires more deep thinking, which lets an auditor to look at the problem from different perspectives. Regular training courses for designers and auditors are relevant to develop this type of special thinking.

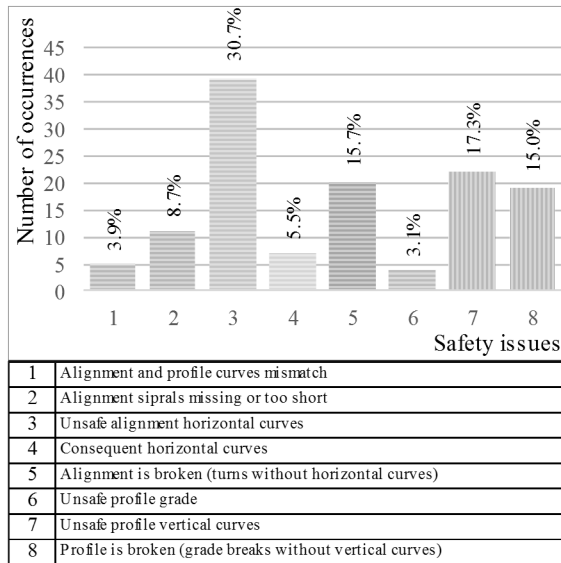


Fig. 5. Road safety issues related to alignment and profile geometry

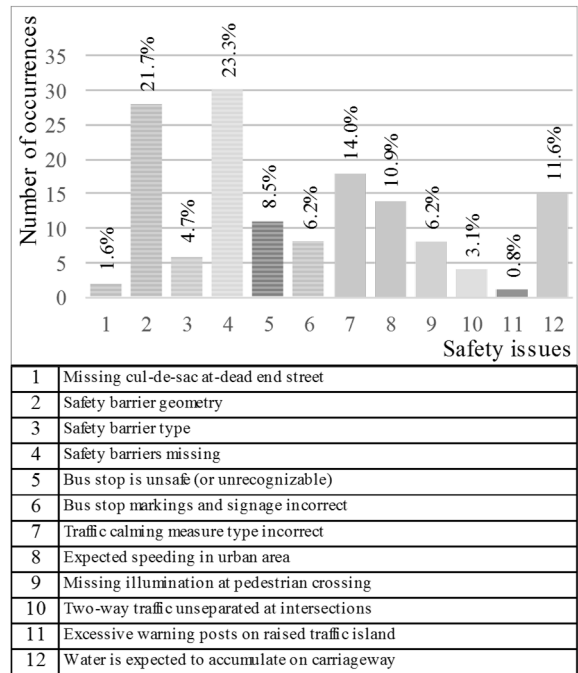


Fig. 6. Road safety issues related to traffic safety measures

One of the most important and frequent safety issue group is shown in Figure 5. It combines all safety issues related to road alignment and profile geometry. Very often designers disregard regulations and choose unsafe, lesser radius vertical or horizontal curve without limiting speed to safe levels even though this time regulations are very clear: under certain driving speed there must be certain curve. The reason for this, is that in Lithuania there is very unorganized land acquisition and management legislation. Constantly engineers must struggle trying to fit a road which is being reconstructed between private parcels. A very common case when parcel borders come right next to carriageway, so there is no space to fit bigger curve or straighten broken alignment. In addition, due to laws, it is not economical viable to start land acquisition process from private owners, as it is very costly and lengthy. So to overcome this issue, relevant laws should be updated to simplify the process for designing of public infrastructure on a private land.

Road safety issues related to traffic safety measures group is listed in detail in Figure 6. It is somewhat related to speed-relevant group, as it also depends on the correct usage of safety measures. The most dominant safety issue type are the ones associated with road safety barriers. As with traffic calming measures, designers often tend to choose incorrect barrier type or make it too short or too long. This happens for the same reasons, already mentioned before – lack of clear regulations on the aspect and the need of special thinking for engineer to pick optimal solution.

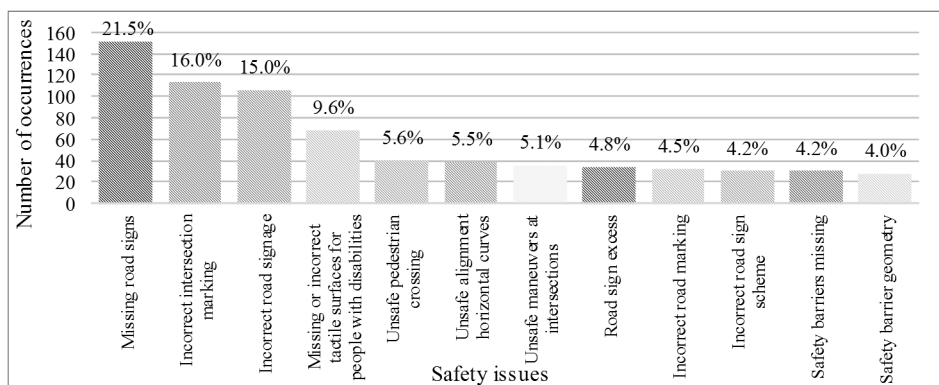


Fig. 7. Most common road safety issues

Figure 7 shows most commonly discovered road safety issue types. Most of those issues are usually just a note on wrong design decision, e.g. missing road signs or road markings, as well as incorrect usage of those elements. Those issues could have been avoided if the following 2 conditions were met:

- the guidelines were self-explanatory and informative enough to easily choose the right decision.
- the designer followed regulations and guidelines perfectly.

The conducted research shows that issues related to legislation imperfections are frequent in road and street design projects. Also the designers themselves disobey regulations sometimes. This can happen due to various reasons, for example, when designer cannot fit proper road design elements because of physical obstacles, private land, etc. Moreover, legal base in Lithuania is being changed constantly and sometimes it is hard to keep track of those changes and keep up to date with the newest regulations. Another road safety issue cause can be insufficient designers' experience or careless attitude towards their job. Because of all that legal base should be majorly updated, trying to avoid frequent changes. At the same time some kind of control measure should be implemented to enforce following of regulations. Also, it is important to constantly hold seminars and training courses for road designers and road safety auditors.

Conclusions and recommendations

- One of the main problems is that unlike national roads, local authorities don't have any regulations on road safety audit and inspection procedures. That is why many municipalities still avoid exercising road safety audits and inspections. Sometimes they do not even know that those procedures are mandatory. Because of that, in order to decrease accident rate in urban areas, same manuals and guidelines on road safety audits and inspections, based on the national road guidelines, should be implemented for local authorities.
- Currently road safety audit deadline is no more than 10 working days. Considering very fickle Lithuanian weather, for a proper evaluation of each given site, 10-day term is usually not enough, so it should be prolonged. A diverse assessment of site and project should improve auditor's understanding, which in turn improves road safety audit quality. On the other hand, increasing the deadline leads to higher expenditures.
- Often road safety auditors are presented with rough and incomplete projects, which do not include any traffic or pedestrian flow studies or miss some of required drawings (e.g. road profile or cross sections, etc.). That is why regulations on road design should include information on completeness of a project to be presented to auditors. Also, they should clearly describe what kind of studies must be carried out by the designer before submitting project for audit.
- As some of the road design elements became popular in Lithuania quite recently, for example tactile surfaces for people with disabilities currently there is no clear regulation or guideline on usage of this type of surfaces, that is why engineers have a hard time choosing the right design decisions for people with disabilities. Also frequently engineers do not design any traffic calming measures on roads and strips where speeding is expected. However, even those who do design those measures, often choose incorrect type for them. That is why additional regulations or updated old ones on some of design elements are required, as well as regular free seminars about traffic safety measures for designers and other specialists.
- Lithuania has very unorganized and complex land acquisition and management legislation. Constantly engineers must struggle trying to fit a road which is being reconstructed between private parcels. Due to laws, it is not economical viable to start land acquisition process from private owners, as it is very costly and lengthy. To overcome this issue, relevant laws should be updated to simplify the process for designing of public infrastructure on a private land.

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