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A METHODOLOGY FOR IDENTIFYING AND ANALYSING PROBLEMATIC INTERSECTIONS FROM THE PERSPECTIVE OF MICRO-MOBILITY SAFETY IN LITHUANIA

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Abstract. Micro-mobility is a rapidly growing mode of urban transportation, gaining popularity among users and urban development specialists. However, like many other types of transportation, it has both positive and negative aspects. One of the main concerns is the safety of micro-mobility users. As this mode of transport has gained popularity, the number of traffic accidents involving micro-mobility users has also increased. Statistics indicate that approximately 40% of all traffic accidents occur at intersections. For this reason, to ensure the safety of micro-mobility users, it is essential to strategically and effectively develop and improve existing infrastructure, especially at problematic intersections. However, no precise methodology would allow quick and easy identification of problematic intersections from a micro-mobility safety perspective. This paper presents a methodology for identifying problematic intersections using publicly available traffic accident data from Lithuania and the spatial analysis tool QGIS. Additionally, it demonstrates the practical application of this methodology in a selected area of Vilnius, where eight problematic intersections were identified. For one of these intersections, a solution is proposed based on the characteristics of the traffic accidents.

Keywords: micro-mobility, traffic safety, traffic accidents, problematic intersections, spatial analysis.

1. Introduction

Micro-mobility – a concept of urban transportation that refers to small, lightweight vehicles operated by road users personally and typically below 30 km/h. Vehicles included, but not limited to, are conventional bicycles, e-bicycles, kick scooters, e-scooters, skateboards, and other similar lightweight vehicles that can be privately owned or shared (Olabi et al., 2023).

If implemented correctly, this mode of transportation can bring various benefits to the mobility system and improve the general quality of life. For example, reduce traffic congestion, noise pollution, transportation footprint, improve air quality, sustainability, increase transportation accessibility, etc. (Olabi et al., 2023). However, like any other concept, it has its downsides. Probably the most notable one is the safety of micro-mobility users. This downside comes from the nature of this concept – people driving bicycles or e-scooters, even with a helmet on, are less protected compared to car or public transport users and are more likely to sustain injuries in the event of traffic accidents (Ioannides et al., 2022). Thus, indicating the need to ensure their safety for the successful integration into the existing mobility systems.

In recent years, micro-mobility has increased its popularity dramatically worldwide. Besides the technological advancements in non-motorised vehicle manufacturing, a crucial factor for this tendency was the technological advancement of shared micro-mobility. It allowed users to rent flexible, economically and environmentally friendly transport alternatives on demand, reducing the need to own them (Shaheen et al., 2020).

In Lithuania alone, the leading shared mobility company *Bolt* stated that in 2020, the total distance travelled using shared e-scooters was roughly 1.9 million kilometres. Meanwhile, in 2022, the total covered distance by *Bolt* shared micro-mobility options was around 7.4 million kilometres (Bolt, 2022). That is an increase of roughly 4 times in 3 years, and these are only statistics

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from one shared mobility company. Considering all the private micro-mobility usage and other shared mobility initiatives, it can be confidently stated that in Lithuania, the popularity of micro-mobility has been dramatically increasing. A similar increase in popularity can be observed in revenue statistics for shared scooter and bicycle concepts. In the United Kingdom, between 2019 and 2024, the revenue of e-scooter sharing increased approximately 4.5 times and is projected to increase 1.3 times more by 2029 (Statista, 2024-b). Meanwhile, in Germany, the bicycle-sharing revenue has increased by 30% over the same period and is projected to increase by 16% more by 2029 (Statista, 2025). The trends and forecasts indicate the increasing popularity of micro-mobility usage and the need to ensure sustainable policy developments for this mobility concept.

However, the sudden increase in the use of this environmentally friendly transport alternative has negatively impacted traffic safety in Lithuania and other parts of Europe. In Germany, between 2019 and 2023, traffic injuries involving electric bicycles increased by roughly 120%. Meanwhile, traffic injuries involving e-scooters between the years 2021 and 2023 have increased by 72% (Statista, 2024-a). In Lithuania, traffic accidents involving micro-mobility users have increased from roughly 8.7% to 14% of the total accidents from 2018 to 2021 (Transporto Kompetencijų Agentūra, 2023). This increase is partly the fault of Lithuania's driving culture and partly due to the lack of appropriate infrastructure, which should ensure transparent and safe micro-mobility traffic – roughly 39% of the total traffic accidents involving cyclists and 34% involving e-scooters occurred at intersections (Transporto Kompetencijų Agentūra, 2023). Additional research on e-scooter traffic accidents in Lithuania confirms that intersections are the most problematic points of urban transportation systems, with 45% of total traffic accidents involving e-scooters (Juodvalkienė et al., 2024). To continue, the number of accidents involving e-scooters has increased by 58.06%, while the number of injuries increased by 57.58%, and the number of fatalities has doubled in Lithuania between 2019 and 2020 (Jasiūnienė & Tumavičė, 2022).

Furthermore, research conducted in Bari, Italy, has shown that approximately 46% of total e-scooter traffic accidents occurred near or at road intersections, whereas 68% of recorded accidents at junctions occurred at unsignalized intersections (Longo et al., 2024). Similar research conducted in the United Kingdom showed that around 67% of crashes involving e-scooters occurred at road junctions (Li et al., 2025).

The statistics and research indicated that traffic accidents are increasing in Lithuania and other parts of Europe, where most traffic accidents involving micro mobility users occur at road junctions.

Therefore, knowing which intersections and how to improve them becomes crucial for successfully developing micro-mobility infrastructure. Traffic accident statistics can be a good initial indicator for problematic intersections. Therefore, this article proposes a methodological approach to identify and analyse problematic intersections regarding micro-mobility user safety using available traffic accident data in Lithuania.

Later, the application of the methodology is illustrated in a Vilnius case study, where a central part of Vilnius city is selected as an area of interest, and a possible solution based on traffic accidents is proposed for one selected intersection to improve the safety of micro-mobility users.

2. Traffic accident data

Like most countries, Lithuania collects and stores traffic accident statistics. As of 2022, the Lithuanian Government, together with the Lithuanian Police, has started publishing yearly traffic accident statistics in JSON format. Each JSON file contains the traffic accidents inside the Republic of Lithuania recorded by the Police.

Traffic accident data is available from 2013 to 2023. New sets of data are uploaded yearly.

Every traffic accident inside the provided data set contains information about the location, date, time, meteorological and traffic conditions, causes, number of people involved and their injuries (fatal or not), types of vehicles involved and other information.

The datasets must be filtered based on traffic accident types to distinguish traffic accidents involving micro-mobility users. All the traffic accidents involving micro-mobility users (bicycles, e-bicycles, e-scooters, etc.) in the available datasets are labelled as collisions with bicycles. This means it is impossible to distinguish between traffic accidents involving only cyclists, e-scooters, or other modes of micro-mobility.

From the available datasets of traffic accidents inside Lithuania during 2018–2023, the total number of traffic accidents recorded was 147599 (Policijos departamentas, 2023). Meanwhile, the yearly average was 24599 traffic accidents.

Distinguishing only traffic accidents involving micro-mobility users in the same period, the total number of accidents inside the whole territory of Lithuania is 3043, with an annual average of 507. Furthermore, the average percentage of accidents involving micro-mobility users is 2.1%. Table 1 below shows yearly traffic accident statistics inside the territory of Lithuania obtained from the available JSON datasets.

Table 1. Traffic accident statistics recorded over the whole territory of Lithuania for the years 2018–2023 from the available datasets

Year	2018	2019	2020	2021	2022	2023
Total	24703	28416	23022	23708	23510	24240
Micro-mobility users	428	457	517	544	561	536
% of all	1.7%	1.6%	2.2%	2.3%	2.4%	2.2%

3. Methodology

The following methodology is proposed to utilise the available traffic accident data in Lithuania to identify problematic intersections for the safety of micro-mobility users and gain insight into the current problems of selected intersections. The methodology can be divided into 3 phases: (1) data preparation, (2) spatial analysis and (3) traffic accident analysis for selected intersections. A complete overview of the proposed methodology is provided in Figure 1.

Phase 1: Data preparation

The first step of phase 1 is to obtain the JSON files for the traffic accidents inside the Republic of Lithuania. It can be downloaded from the publicly available Data.Gov.Lt website (https://data.gov.lt/datasets/509/).

The downloaded JSON files are then transformed into a Microsoft Excel table using a built-in Get Data function.

To continue, the table is filtered based on the type of accident only to contain accidents where micro-mobility users were involved – collisions with a bicycle. After obtaining the filtered list of accidents, the Microsoft Excel file is saved as a Comma-Separated Values (CSV) file, and phase 1 is complete.

Phase 2: Spatial analysis

Phase 2 is when the primary spatial analysis is conducted. The publicly available Geographical Information Systems software *QGIS* is used during this phase.

The prepared CSV data files are uploaded into the *QGIS* software through the Layer>Data Source Manager> Delimited Text option. When conducting this step, the prepared CSV data file is selected, the file format is chosen as a CSV (comma-separated values) and point coordinates are selected as follows: x field – *platuma* and y field – *ilguma*. Furthermore, it is important to choose the appropriate Geometry CRS – in Lithuania, the commonly used geometry is *EPSG:3346 – LKS94 / Lithuania TM*. If this step has been performed correctly, a point layer should be available where each point represents a traffic accident involving micro-mobility users.

If multiple datasets of different years are used, they should be combined using the built-in *Merge* function. After merging the point layers, it is important to filter out traffic accidents for the selected area of interest using *the* built-in *Intersect* function. This step will limit the computational time of the following step and provide a more accurate heatmap analysis.

Furthermore, to create a desired heatmap, a *QGIS Density Analysis Plugin* and its function – *Styled Heatmap (Kernel density estimation)* is used (https://github.com/hamiltoncj/qgis-densityanalysis-plugin/#readme). This function simplifies an existing *QGIS* algorithm based on a Kernel density estimation when creating heatmaps.

The plugin's function mentioned above is used for the merged and intersected point layer. In the options, the measurement unit can be selected, and cell/pixel dimensions in measurement units can be provided to determine the grid size. All options inside this function are rather case-specific and should be chosen individually. Nevertheless, a heatmap containing squares with given dimensions is provided after performing this function. By default, the lighter squares indicate fewer traffic accidents, and darker squares indicate more traffic accidents, which result in more problematic intersections.

The obtained heatmap is then examined visually to create an inventory of problematic intersections with several traffic accidents over the selected data period. Intersections are then ranked based on the number of traffic accidents, prioritising intersections with more traffic accidents.

Finally, it is important to check the validity of the intersection ranking. This step is conducted by examining recent developments of selected intersections. For example, suppose the intersection has been redeveloped within the selected data period. In that case, the traffic accident data becomes invalid because some accidents happened before redevelopment, and others happened after. In that case, one of the options is to remove the traffic accidents before redevelopments and perform the ranking procedure again or remove this intersection from the analysis entirely.

Phase 3: Traffic accident analysis for selected intersections

Finally, during the last methodological phase, traffic accidents within the selected intersections are analysed based on the available attribute data.

As mentioned, traffic accident data contains various characteristics of the accident, such as weather

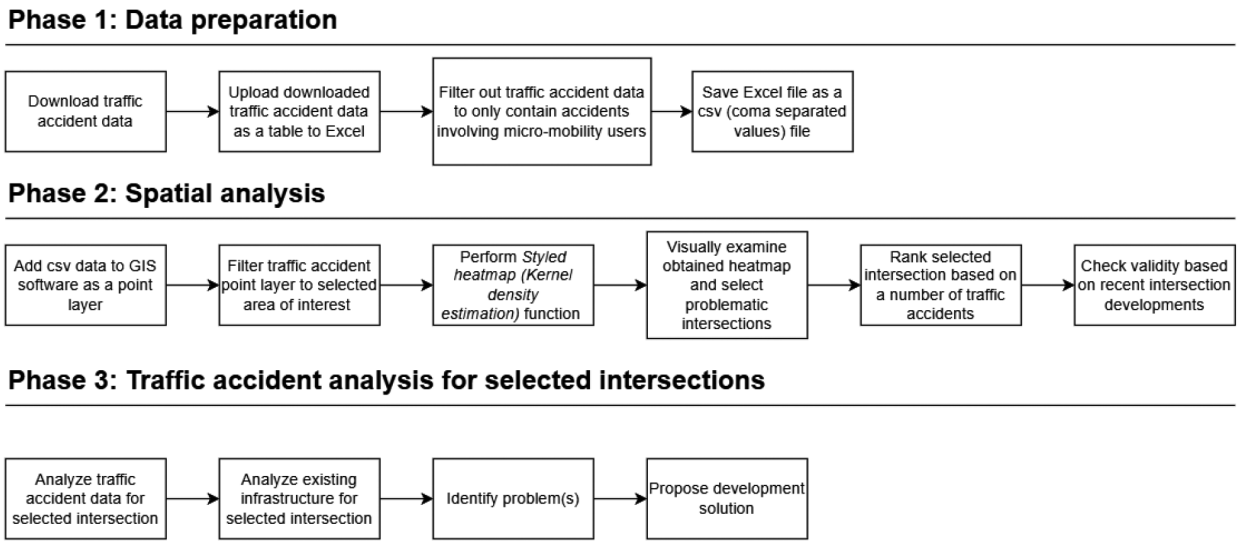


Figure 1. Proposed methodology

conditions, time of day, etc. Two of the most important attributes on that list are scheme 1 and scheme 2 attributes. They abstractly indicate how the accident happened, thus allowing researchers to paint a picture of the accident and indicate possible patterns.

Additionally, the selected intersection is analysed based on existing infrastructure to understand its problems better and propose a solution to tackle micro-mobility users' existing traffic safety problems.

This step crowns the proposed methodology, and the following chapter illustrates its applicability to a real-world scenario of Vilnius city.

4. Vilnius case study

A case study for the central part of Vilnius is considered to demonstrate the application of the proposed methodology. The selected area includes six traffic districts of Vilnius city: Žvėrynas, Naujamiestis, Senamiestis, the southern parts of Šnipiškės and Žirmūnai, and a small portion of Vilkpėdė (Figure 2).

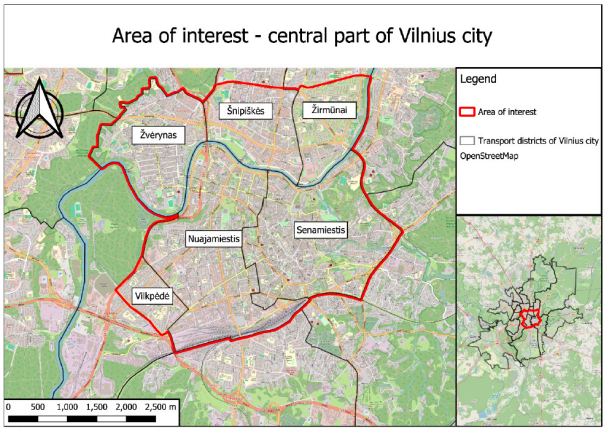


Figure 2. Area of interest for Vilnius case study

For this case study, it was decided to use 6 years of traffic accident data starting from 2018 and up to the newest available dataset of 2023. During the 6 years, 280 traffic accidents involving micro-mobility users in the selected area of interest occurred. That is roughly 9% of the total traffic accidents (3043) that happened in the whole territory of Lithuania involving micro-mobility users.

Figure 3 shows filtered, merged, and intersected data sets as a point layer. It shows all traffic accidents within the selected area of interest for each year considered in the analysis.

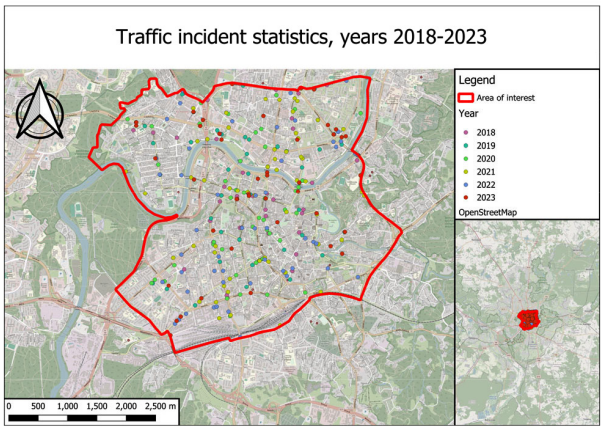


Figure 3. Traffic accident statistics over the years 2018–2023

A heatmap is generated to continue the analysis. This step used the mentioned *Styled Heatmap (Kernel density estimation)* function from the *QGIS Density Analysis Plugin*. The prepared traffic accident data for the selected area of interest was used for the input point layer. Cell size was determined based on randomly measured intersection sizes within the area and, in this case, was

selected as 50x50 meters. Additionally, the Uniform Kernel shape was chosen. The resulting heatmap is provided in Figure 4.

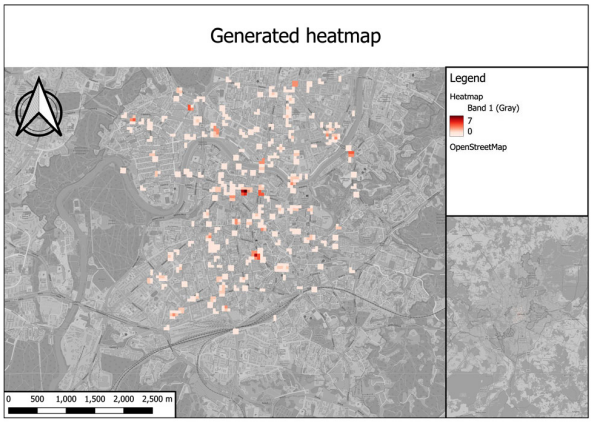


Figure 4. Generated heatmap

Furthermore, the visual examination of the generated heatmap has resulted in 8 problematic intersections. These intersections have between 3 and 4 traffic accidents related to micro-mobility users over the selected data period. Identified intersections were then ranked based on the number of traffic accidents, from the highest to the lowest. The resulting list can be found in Table 2, and the exact location of each intersection can be found in Figure 5.

Table 2. List of problematic intersections

Number	Intersection name	Number of accidents
1	Gedimino pr. – A. Jakšto st. – A. Stulginskio st.	4
2	Gedimino pr. – Vilniaus st. – Jogailos st.	4
3	Žirmūnų bridge – Olandų roundabout	4
4	Vingrių st. – Naugarduko st.	3
5	Sėlių st. – Blindžių st.	3
6	Pieninės st. – Saltoniškių st.	3
7	Minties st. – Apkasų st.	3
8	Kalvarijų st. – Upės st. – Žvejų st.	3

Finally, the validation of traffic accident data completes phase 2 of the proposed methodology. Validation is performed by analysing the selected intersections for the recent developments in the chosen period. This analysis is done via document and literature research.

Fortunately, no recent developments were found for this specific case study and selected intersections that would conflict with the recorded traffic accidents, indicating the validity of the selected intersections.

However, intersection number 7, between Minties and Apkasų streets, was redeveloped at the end of 2020

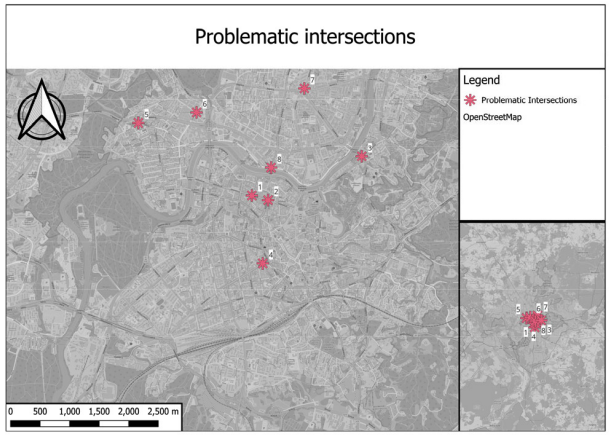


Figure 5. Problematic intersections

(Judu, 2020). Nonetheless, all traffic accidents recorded on that intersection happened after the redevelopment: 2 in the second half of 2021 and 1 during 2023. Thus, this indicates the possibility of unsuccessful development regarding micro-mobility user safety.

Intersection 7 is now selected as an example of the final methodological phase, phase 3, where the observed traffic accidents indicate the intersection's initial problematic condition. Here, the observed traffic accidents are analysed in schema 1 and schema 2, which abstractly indicate how the recorded accident happened.

In the case of intersection number 7, two traffic accidents occurred when a car made a right turn and one when a car made a U-turn. Unfortunately, the second attribute is only specific to one of the accidents when turning right, indicating that a collision between the micro-mobility user and a car occurred when a car was driving from the left. The other two accidents have a rather vague description: other collisions when turning right/left.

Furthermore, the selected intersection is analysed based on existing infrastructure. Figure 6 shows an aerial image of the intersection.

The intersection is a three-way controlled intersection. A two-way bicycle path crosses Minties Street on the right side of Apkasų Street. Pedestrian paths are on both sides of the streets, and a pedestrian crossing is located at Minties Street next to a bicycle crossing. The bicycle and pedestrian crossings have directional lighting, clear road signs, and markings.

To continue, the traffic flow at selected intersections is managed by a traffic light. When turning right onto Minties Street from Apkasų Street, there is a road sign warning car driver to be cautious about pedestrians and cyclists crossing the road at the same time. Google Street View analysis confirmed that cars on the Apkasų Street with the cycling and pedestrian lanes have the green light when turning right (Figure 7). This can become

a problem when a cyclist or e-scooter approaches the intersection at a high speed, and thus, the observed collisions happen.

The analysis clearly shows that the central conflict at this intersection is between vehicles and vulnerable road users when a vehicle turns right, and the analysed traffic accidents confirm this.



Figure 6. Aerial image of the intersection (source: Bing.com)

Using the aforementioned information about observed traffic accidents and the intersection's infrastructural context, a possible solution is proposed for this intersection: a protected cycling and pedestrian traffic signal that would allow the complete separation of car and vulnerable road user traffic, eliminating the main point of conflict between vulnerable road users and vehicles.



Figure 7. Apkasų and Minties Street intersection (source: Google Street View)

5. Conclusion and discussion

The proposed methodology uses publicly available traffic accident data in Lithuania, where micro-mobility users were involved. The data is used in *QGIS* software to create a heatmap, which helps to identify problematic intersections based on the number of traffic accidents. Identified intersections are then validated based on their recent developments. Finally, the selected intersections are analysed based on observed traffic accidents and the current infrastructural state to identify common problems and propose a solution to improve the safety of micro-mobility users.

This methodology can be applied to any part of Lithuanian territory due to the availability of traffic accident data.

The methodology can also analyse traffic accidents involving other road users, such as pedestrians, by modifying data filtering criteria.

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PROBLEMINIŲ SANKRYŽŲ IDENTIFIKAVIMO IR ANALIZAVIMO METODOLOGIJA LIETUVOJE MIRKOMOBILUMO SAUGOS POŽIŪRIU

J. PLAČIAKIS

Santrauka. Mikromobilumas – sparčiai populiarėjantis transporto būdas mieste ne tik tarp vartotojų, bet ir tarp miesto plėtros specialistų. Tačiau, kaip ir daugelis kitų transporto rūšių, šis gali turėti tiek teigiamų, tiek neigiamų aspektų. Vienas pagrindinių iššūkių – mikromobilumo vartotojų saugumas. Sparčiai išpopuliarėjus šiam transporto būdui, išaugo ir eismo įvykių, kuriuose jie dalyvavo, skaičius. Statistika rodo, kad apie 40 % visų šių eismo įvykių įvyko būtent sankryžose. Dėl šios priežasties, siekiant apsaugoti mikromobilumo eismo dalyvius, yra svarbu tikslingai ir pagrįstai plėtoti bei tobulinti esamą infrastruktūrą, ypač problemines sankryžas. Tačiau šiuo metu nėra tikslios metodikos, kuri leistų greitai identifikuoti problemines sankryžas mikromobilumo vartotojų saugos požiūriu. Šiame straipsnyje pristatoma metodika, kaip, remiantis viešai prieinama eismo įvykių statistika Lietuvos teritorijoje ir pasitelkus erdvinės analizės įrankį QGIS, galima nustatyti problemines sankryžas. Taip pat pateikiamas praktinis metodikos taikymo pavyzdys pasirinktoje Vilniaus miesto teritorijoje – identifikuojamos 8 probleminės sankryžos, o vienai iš jų siūlomas konkretus sprendimas, atsižvelgiant į eismo įvykių pobūdį ir charakteristikas.

Reikšminiai žodžiai: erdvinė analizė, eismo įvykiai, mikromobilumas, probleminės sankryžos, saugumas.