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THE IMPACT OF STREET HUMANISATION ON ROAD SAFETY

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Abstract. To enhance the safety and integration of vulnerable road users (pedestrians and cyclists) into the transportation system, a growing number of European cities, including Vilnius, are aligning their traffic management solutions with the concept of street humanisation. The Naujamiestis district is the first city district in Vilnius to undergo these changes. To assess the impact of street humanisation strategies on road safety, this preliminary paper analyses data from the road accident history database for the period 2018–2021 and results from instantaneous vehicle speed analysis. The results of the road accident database history are presented graphically and using heat maps. The data from the instantaneous speed analysis are analysed using the Kruskal-Wallis and Mann-Whitney-Wilcoxon non-parametric statistical criteria. The findings indicate that the concept of street humanisation is effective in enforcing 30 km/h speed limit. The analysis of road accident data history shows a decrease in the number of accidents and their consequences in the study area and the entire city of Vilnius between 2018 and 2022. However, it is currently challenging to determine whether street humanisation concept directly contributes to the decline in road accidents. Therefore, it is proposed to revisit the analysis in the future.

Keywords: road accidents, speed limit, street humanisation, traffic safety, vehicle instantaneous speed, vulnerable road users.

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Introduction

Throughout human history, cities have retained their roles as economic, cultural, and social hubs, consistently attracting individuals in pursuit of improved life prospects. In the current context, with a growing focus on climate change, an ageing population, and sustainability, urban areas offer the advantage of allowing people of all ages and socioeconomic backgrounds to travel independently without the need for car ownership. This is made possible through various transportation methods, such as walking, cycling, public transport, or other environmentally friendly options. In the European Union (EU) countries, sustainable mobility is further shaped by stringent policies on road safety, mobility, ecology, and sustainability.

While latest EU road accident data reveals a decrease in accidents between vulnerable road users (pedestrians and cyclists) and motor vehicles on rural roads, the numbers in urban areas have remained relatively stagnant since 2017 (Adminate-Fodor & Jost, 2020). A much bigger concentration of vulnerable road users, a lack of segregated movement between them and motor vehicles and a car-centric urban planning are to blame. High instantaneous vehicle speeds and generated kinetic energy can lead to severe or even fatal vulnerable road user injuries. Additionally, the existing urban transportation infrastructure is struggling to meet the growing mobility demand (for example, a lack of high-quality bicycle paths). Although throughout the years individual (mostly traffic calming) measures to reduce speed and improve safety for pedestrians and cyclists have been studied and successfully implemented, more and more European cities, including Vilnius, are concentrating on a recently renewed form of the 1960s concept of street humanisation. The concept consists of introduction of different measures such as implementing continuous 30 km/h zones, shared space zones, including changes to the traffic rules or other legislature.

So far, many studies have analysed the effects of individual measures, for instance, the effects of traffic calming measures on vehicle speeds and road accidents. However, not many studies have analysed the effects of all measures that contribute to humanisation of streets. The research outlined in this paper aims to primarily evaluate if the concept of street humanisation is effective in reducing road accidents and maintaining a 30 km/h motor vehicle operating speeds.

1. The background of street humanisation and its implementation practices in Lithuania

The concept of modifying urban spaces for vulnerable road users can be traced back to the urban planning model introduced by British architect Buchanan (1963). According to this model, vulnerable road users would have a space entirely separate from motor vehicles, potentially using a network of viaducts and overpasses. The Danish architect Gohl and the Dutch architect Boer are considered to be the pioneers of the modern theory of street humanisation, arguing that streets, like other urban public spaces, should be designed for the inhabitants.

In the today's context, only a small number of authors have tried to define this concept. Ahmed (2017) defines street humanisation as the redesign of urban spaces to enable safe and comfortable movement for vulnerable road users, such as pedestrians and cyclists, alongside motorised traffic (cars, freight and public transport). This approach also encourages the use of street space for various purposes, including recreation, social gatherings, shopping, and public events.

Meanwhile, Zalewski et al. (2019) characterise the concept of humanisation as involving a variety of organisational, legal, and engineering strategies. These strategies aim to decrease motor vehicle traffic while maintaining seamless delivery of goods and other services between different city areas.

To achieve effective street humanisation in relevant city areas (mostly residential and commercial areas), it is essential to introduce speed limits across the entire street network but also maintain proper city area function and ongoing development (Zalewski et al., 2019). Many cities in Europe and the United Kingdom are adopting 30 km/h speed limits within city districts rather than on individual street sections (Karndacharuk & Mctiernan, 2018). Brussels initiated its street humanisation efforts in January 2021, with Paris following suit in August 2021.

In Lithuania, street humanisation is a relatively new concept and existing legislation does not provide a specific definition. Vilnius City Municipality was among the early adopters to mention street humanisation as an urban mobility concept within its 2018 Sustainable Mobility Plan. The technical parameters, engineering solutions for road safety and other measures (compliant with existing legislation) for new or reconstructed humanised streets are outlined in the City of Vilnius Street Design Manual. However, in 2023, Vilnius city municipality efforts to humanise streets received negative backlash from the general public, emergency service and public transport drivers. The majority of complains where around insufficient carriageway width and the careless and excess use of traffic calming measures.

The legislation of speed limits within urban areas in Lithuania is rather ambiguous. Paragraph 129 of the Lithuanian Road Traffic Rules establishes a default speed limit of 50 km/h in residential areas. Some exceptions apply:

1. Different speed limits can be implemented in urban areas if road safety conditions allow (paragraph 131);
2. In residential zones, the speed limit for vehicles is 20 km/h, while pedestrians and cyclists have right of way (paragraph 176.1);
3. As of June 2022, in "cycling streets" the speed limit for motor vehicles is 30 km/h (paragraph 178^{3}.1).

In Spain, since 11 November 2020, a 20 km/h speed limit has been the default speed in single-lane, one-way streets, followed by a 30 km/h speed limit for single-lane two-way streets and a 50 km/h default speed limit, if the street has two or more lanes. A push for similar speed limit changes is currently discussed in Germany.

Latest research (Fridman et al., 2020) has shown that enforcing speeds of 20–30 km/h is a critical component of street humanisation, reducing serious or fatal injuries to vulnerable road users by 20–40%. Meanwhile, research on the use of traffic calming measures (Domenichini et al., 2019) shows that roadway narrowing is considered one of the main methods for enforcing speed limits on humanised, 30 km/h streets. Vertical traffic calming measures (such as raised crosswalks) act only as a momentary traffic calming measure.

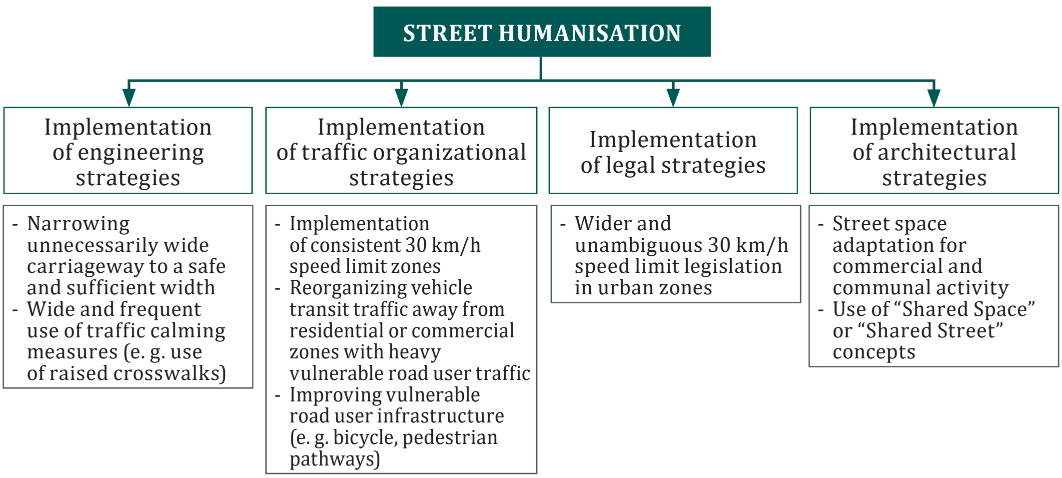

Figure 1. Strategies for street humanisation

To summarise the findings in current legislature and the literature review, a definition of street humanisation is suggested. This concept can be described as a method for improving mobility and overall quality of life of vulnerable road users in urban areas, through a variety of engineering, traffic management, legal and architectural strategies (see Figure 1).

2. Study area

The research was conducted in the Naujamiestis city district in the southern part of Vilnius (see Figure 2). The study area covers 0.70 km^2 and comprises 9 category D streets (the lowest category for motor vehicle streets). The total length of the network of category D streets included in the study area is 4.68 km. The study area is bounded by five streets of higher categories.

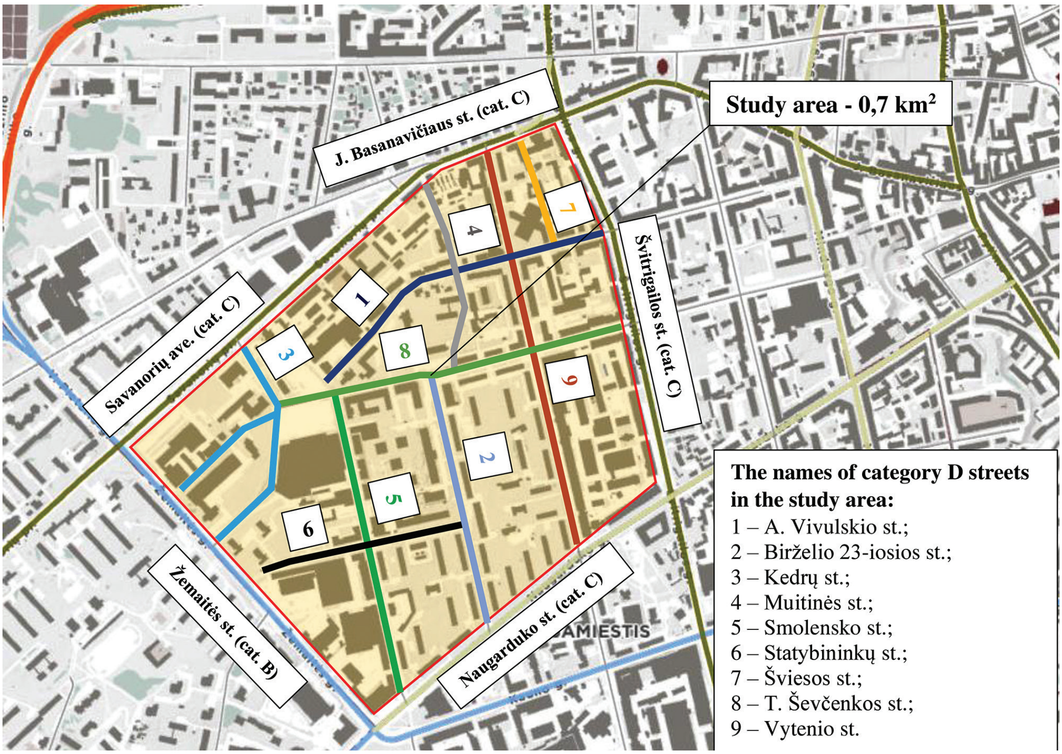

Figure 2. Study area, located in the Naujamiestis district of Vilnius city

The instantaneous speed study focuses on three sections of streets in the study area with varying levels of humanisation (see Table 1). Humanisation levels are determined by analysing how many engineering, traffic organisation and urban space rearrangement strategies are used (see Table 2, Figure 3). The strategies are outlined in Section 1. Legal strategies, as there are applied nation-wide, are currently excluded. The street sections are also selected to be within or on the borders of the study area.

Street section No. 1 (T. Ševčenkos st.) was determined to be the fully humanised street section of all, with a carriageway width of 5.50 m and a speed limit of 30 km/h. This street section was part of the mentioned street humanisation project and was fully reconstructed in 2023. During the reconstruction process, the old carriageway was narrowed down to a minimum, while fitting new parking lanes, pedestrian walkways and more room for outdoor cafes and foliage.

Street section No. 2. (Naugarduko st.) was determined to be as partially humanised street with an introduction of bicycle and parking

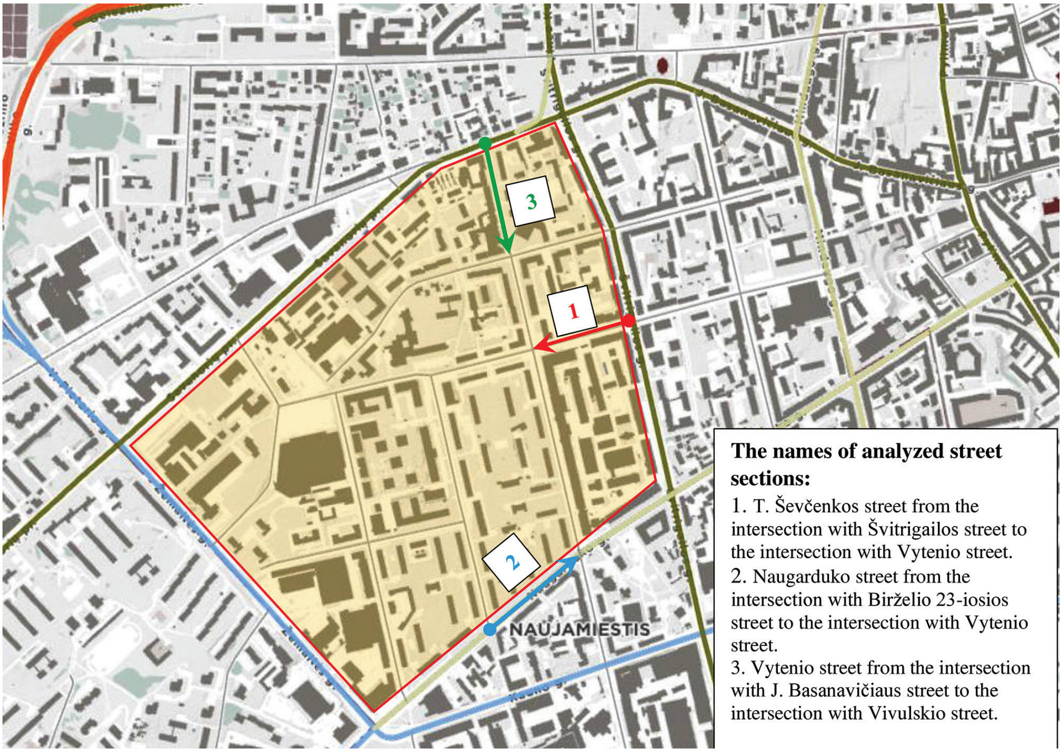

Figure 3. Analysed street sections in relation of the study area

Table 1. Researched street sections located in the study area

Name of researched street section	Researched street section length, km	Researched street section carriageway width, m	Researched street section start and end coordinates (WGS 84)	Photo of the researched street section
No. 1. T. Ševčenkos Street from the intersection with Švitrigailos Street to the intersection with Vytenio Street	0.192	5.50	54.677533, 25.267445 54.677071, 25.264273	
No. 2. Naugarduko Street from the intersection with Birželio 23-iosios Street to the intersection with Vytenio Street	0.213	6.50	54.672017, 25.262818 54.673347, 25.265616	
No. 3. Vytenio Street from the intersection with J. Basanavičiaus Street to the intersection with Vivulskio Street	0.215	10.0	54.680807, 25.262876 54.678769, 25.263677	

Table 2. Determination of street humanisation levels in the analysed street sections

		Street section No. 1	Street section No. 2	Street section No. 3
Engineering strategies	Is the carriageway width 5.50–6.50 m?	YES	YES	NO
	Are there any traffic calming measures installed?	YES	YES	YES
Traffic organisational strategies	Is the speed limit ≤30 km/h?	YES	NO	YES
	Quality of bicycle infrastructure	good[1)]	good	poor
	Quality of pedestrian infrastructure	excellent	good	poor
Urban space re-arrangement strategies	Is the street space suitable for commercial and social activity?	YES	NO	NO
Determined humanisation level of the street section:		**Fully humanised**	**Partially humanised**	**Non-humanised**

[1)] When the speed limit is ≤30 km/h, bicycle traffic can be organised with mixed traffic.

lanes, while retaining the same carriageway width. Instead of full street reconstruction, the new lanes were achieved using horizontal pavement markings. The new amenities were introduced in 2019.

Street section No. 3 (Vytenio st.) was determined to be the least humanised, with a wide carriageway length of 10.0 m with no separate bicycle infrastructure and poor-quality pedestrian walkways. This street section (in time of writing this paper) has yet to be reconstructed.

In all three street sections, several traffic calming measures have been detected. The measures are concentrated mainly in intersections with other streets in different forms of pedestrian crosswalks (raised crosswalks with (or without) traffic islands).

3. Methods

3.1. Data acquisition methods

The data for the road accident history analysis was obtained from the Vilnius Spatial Data Portal (open access). It is important to note that this analysis mentions two types of road accidents: 1) ***road accidents*** where at least one person is injured or killed (*RA*) and 2) ***property damage only road accidents*** where no road user injuries or deaths have been registered (*PDOA*). When these two types are analysed collectively, they are identified as ***all road accidents*** (*ARA*). The accident data is processed using *MS Excel* and *QGIS 3.20.2* software.

The instantaneous vehicle speeds were measured using a *Berkut R* radar speed measurement device. The measurements were carried out on two weekdays: 11 January and 22 February 2023. During the pre-analysis study area inspection, rush hour (from 5 p.m. to 6 p.m.) traffic in all three street sections moved in speeds below the lowest limit of the measuring device range (20 km/h). For this reason, the instantaneous speed measurements were carried out outside the morning and evening rush hour traffic continuously from 1 p.m. to 5 p.m. Also in this time frame, more substantial citizen activity is detected (for example, children are returning home from schools). The speed of vehicles was recorded at 3 or 4 measuring points in every studied street segment: one point at the beginning of the street section, from one to two points in the midpoint of each street section, and one point at the end of each street section. The measuring points were chosen regarding Dinh & Kubota's (2013) findings, where 85% of the vehicles reached their maximum travel speeds after passing the midpoint section of a 30 km/h street. The schemes of measuring points are provided in Figures 3–5.

The duration of the measurements at each point is 10 minutes. Only the speeds of the vehicles driving towards the measuring device were recorded. The results from the measuring device were recorded on survey forms. Afterwards, the data was processed using *MS Excel* and *Matlab R2021b* programs.

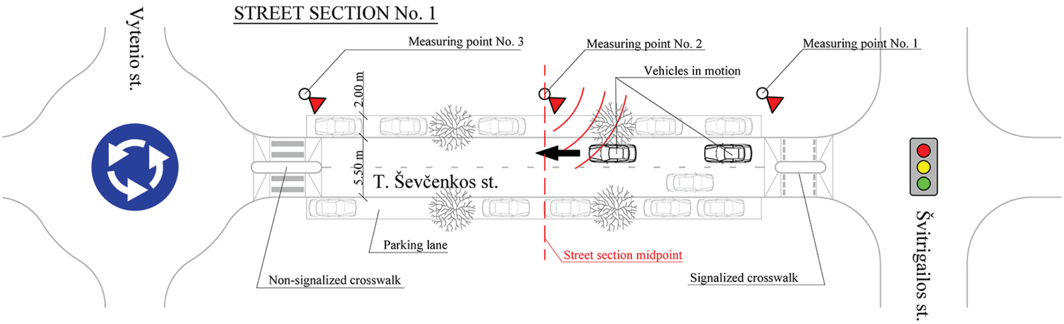

Figure 4. Scheme of street section No. 1 (T. Ševčenkos st., fully humanised) instantaneous vehicle speed measurement

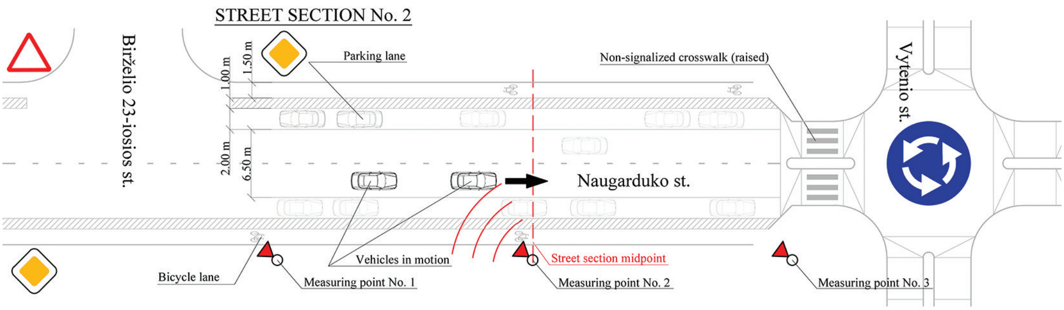

Figure 5. Scheme of street section No. 2 (Naugarduko st., partially humanised) instantaneous vehicle speed measurement

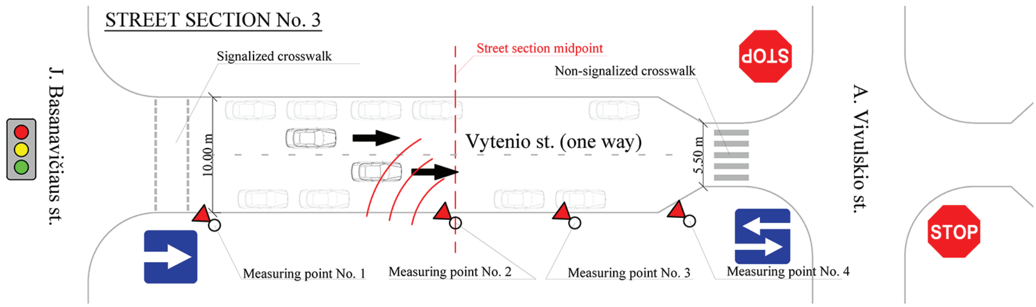

Figure 6. Scheme of street section No. 3 (Vytenio st., non-humanised) instantaneous vehicle speed measurement

3.2. Used statistical methods

The study hypothesised that the instantaneous vehicle speeds on fully humanised street section No. 1 (T. Ševčenkos st.) would be lower than on non-humanised street section No. 3 (Vytenio st.) or partially humanised street section No. 2 (Naugarduko st.).

To test the hypothesis of the study, the instantaneous speed data of the investigated sections was divided accordingly into separate data samples: X_1 (n_1 = 42), X_2 (n_2 = 116) and X_3 (n_3 = 136). Each data sample contained instantaneous vehicle speeds from all 3 or 4 measuring points within the analysed street section (see Equation (1)).

$$X_i = n_i = \left(A_1, A_2, ..., A_n\right), \tag{1}$$

where: A_n – recorded instantaneous speed data from n^{th} measuring point.

As the instantaneous speeds were measured on different street sections, the data samples were considered independent. The variables in the samples consisted of positive, integer values and were therefore assumed to be continuous. Before selecting the appropriate statistical method, the normality of the samples X_1, X_2 and X_3 was checked using the Kolmogorov-Smirnov test (K-S Test).

The results of the Kolmogorov-Smirnov p-value test showed that samples X_1, X_2 and X_3 did not satisfy the normality condition, i.e., the alternative hypothesis h = 1 was true: $p_{X1} = 1.8857 \times 10^{-38}$, $p_{X2} = 2.4042 \times 10^{-103}$, $p_{X3} = 7.5928 \times 10^{-121}$.

The assessment of the characteristics of the data samples and the conditions of normality concluded that it was not appropriate to use parametric statistical criteria (for example, Student's t-test or ANOVA) or any form regression analysis.

In this case, two non-parametric statistical criteria were chosen to test the research hypothesis: the Kruskal-Wallis H Test (see Equation (2)) and the Mann-Whitney-Wilcoxon test (see Equation (3)).

$$H = \frac{12}{n\left(n+1\right)} \cdot \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3\left(n+1\right), \tag{2}$$

where k – a number of variables; n_j – a number of observations of variable j, R_j^2 – the square of the sum of the ranks in sample j.

$$Z = \frac{U_1 - \mu}{\sigma}, \tag{3}$$

where

$$U_1 = R_1 - \frac{n_1\left(n_1+1\right)}{2}, \tag{3.1}$$

$$\mu = \frac{n_1 n_2}{2}, \tag{3.2}$$

$$\sigma = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}, \tag{3.3}$$

where U_1 – the value of the U statistic for the first sample of data; R_1 – the sum of the ranks assigned to the members of the first and second samples, respectively; n_1 – the size of the first sample; μ – the average of the U statistic; σ – the standard deviation of the U statistic.

The calculations evaluate the sample means of the instantaneous speeds of the street sections under study, and a statistical hypothesis is written down:

$$\begin{cases} H_0: \text{sample averages do not differ,} \\ H_1: \text{sample averages differ.} \end{cases}$$

The statistical hypothesis was tested in two steps:

1. Applying the Kruskal-Wallis criterion tests, to determine whether there was a significant difference between the averages of samples X_1, X_2 and X_3;
2. Applying the Mann-Whitney-Wilcoxon criterion tests, to determine whether the average of sample X_1 was smaller than the averages of samples X_2 or X_3.

For the purpose of testing the statistical hypothesis, the significance level was assumed to be α = 0.05.

4. Results

4.1. Instantaneous vehicle speed analysis results

The calculated p-value of the Kruskal-Wallis criterion indicated that the null hypothesis of equality of the averages of samples X_1, X_2 and X_3

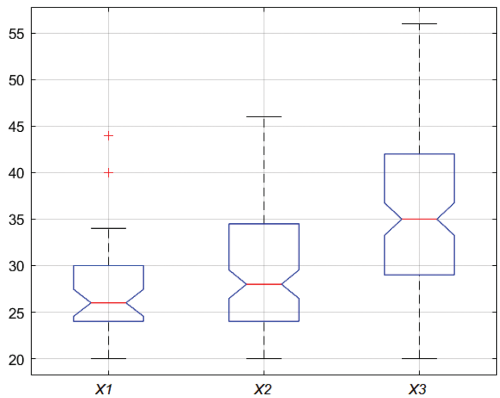

Figure 7. The boxplot of instantaneous vehicle speed datasets X_1, X_2 and X_3

was rejected. It was concluded that the instantaneous speeds of the studied street sections differed. This difference can also be seen in the bar charts of the samples (see Figure 7). The average instantaneous speed is $\bar{v}_{X1} = 26$ km/h in sample X_1, $\bar{v}_{X2} = 28$ km/h in sample X_2 and $\bar{v}_{X3} = 35$ km/h in sample X_3.

The analysis of the instantaneous speed data for samples X_1 and X_2 using the Mann-Whitney-Wilcoxon criterion resulted in a p-value of $p_{X1\text{-}X2} = 0.0512$, while the analysis for samples X_1 and X_3 resulted in a p-value of $p_{X1\text{-}X3} = 6.3894 \times 10^{-9}$. It can be observed that the averages of the X_1 and X_2 samples do not differ or differ slightly, i.e., the hypothesis H_0 is not rejected, which suggests that the instantaneous speeds in the street sections No. 1 and No. 2 differ very little. For samples X_1 and X_3, the hypothesis H_0 was rejected. It was concluded that the instantaneous speeds between sections No. 1, No. 2, and No. 3 differed. The fact that the averages of X_1 are smaller than those of X_3 was confirmed once again by checking the one-tailed Mann-Whitney-Wilcoxon p-value of $p_{X1\text{-}X3,\text{ one-tailed}} = 3.1947 \times 10^{-9}$.

4.2. Road accident history analysis results

The results of the road accident history analysis in Vilnius City for the period 2018–2022 showed (see Figure 8) that the number of *RA* in the study area had developed unevenly, with a decrease in the number of *RA* between 2018 and 2021 and an increase in 2022. Although with noticeable unevenness, the number of *RA* in the study area decreased by an average of 20% over the study period. In comparison, across the

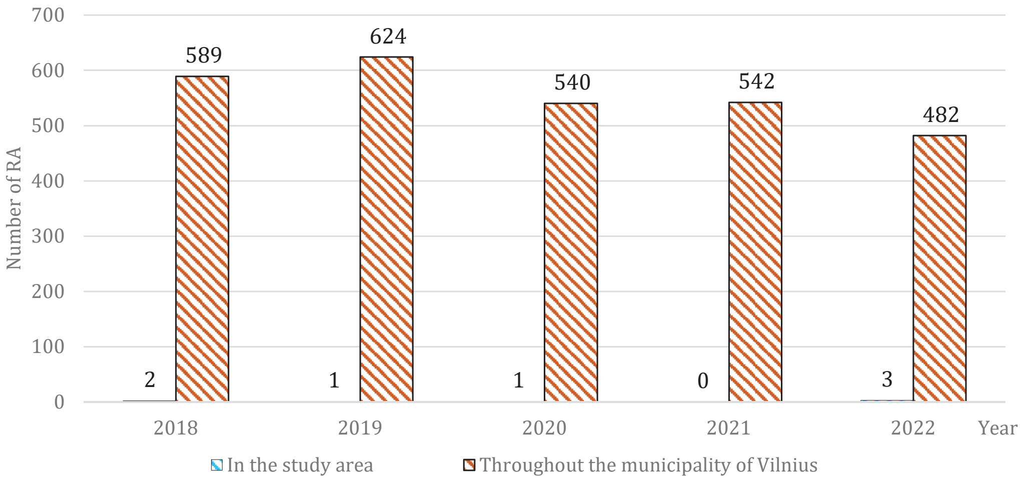

Figure 8. The number of *RA* in the study area and throughout Vilnius City Municipality for the period 2018–2022

entire Vilnius City Municipality, the number of *RA* decreased by an average of 4% between 2018 and 2022.

The number of *RA* in Vilnius City exhibited an uneven trend, including a 6% increase in 2019 compared to the data from 2018. Notably, the change in the number of *RA* was not synchronised between the study area and the entire city.

When analysing *PDOA* in the study area (see Figure 9), between 2018 and 2022, there was an average decrease of 20%. In contrast to the number of road accidents, the number of *PDOA* exhibited a consistent decline. However, in Vilnius as a whole, the number of *PDOA* decreased by 15% over the study period. It is worth noting that *PDOA* in the entire city displayed an uneven pattern, including a 24% increase in 2019 compared

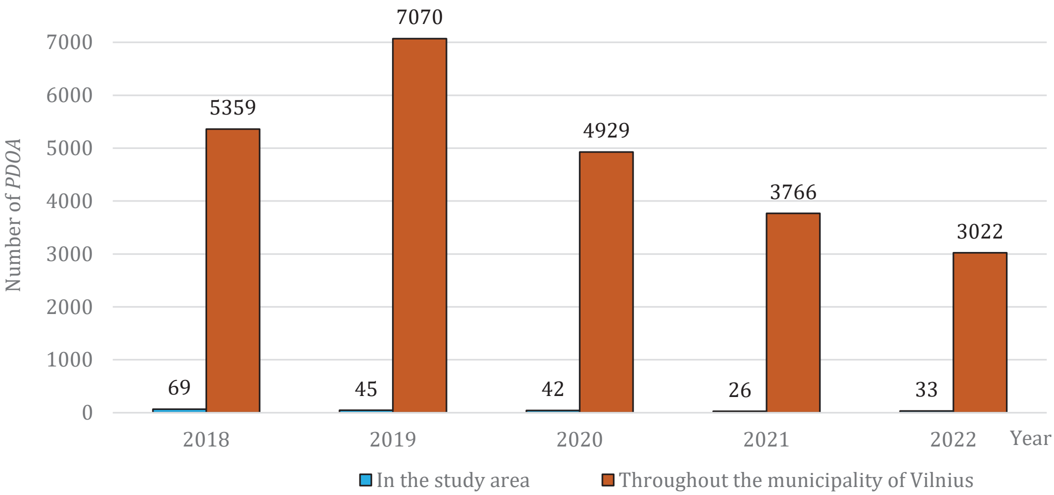

Figure 9. Number of *PDOA* in the study area and throughout the Vilnius City Municipality for the period 2018–2022

Table 3. The consequences of *ARA* in the study area and throughout the whole Vilnius City Municipality for the period 2018–2022

The consequences of *ARA*	Year				
	2018	2019	2020	2021	2022
Fatally injured road users throughout the whole Vilnius City Municipality	16	21	12	10	9
of which occurred in the study area	0	0	0	0	0
Non-fatally injured road users throughout the whole Vilnius City Municipality	652	664	574	496	465
of which occurred in the study area	2	1	1	0	3

to the data from 2018. In 2019, there was an overall increase in both *RA* and *PDOA*.

When analysing the consequences of all road accidents (see Table 3), during the study period, in the study area there were no fatalities; however, 7 injured road users were recorded. It can be noted that the number of injured road users in a district is directly related to the number of road accidents in the current year, i.e., one injured road user per road accident. Both the number of road accidents and the number of injured road users in the city district decreased by 20%. Throughout the city, the number of injured road users decreased by 7% on average over the period 2018–2022. Meanwhile, the number of road user fatalities decreased by around 16%.

An analysis of road accident types in the study area from 2018 to 2022 reveals that the district experiences a higher frequency of collisions with parked vehicles and general collisions. Incidents involving pedestrians and cyclists are relatively less common (see Figure 10). A more detailed examination of the data indicates that all accidents involving collisions with vehicles occurred only during *PDOA*. In contrast, collisions with vulnerable road users (pedestrians and cyclists) were predominantly associated with road accidents, accounting for 70% of all accidents in this category.

Regarding the timing of accidents, two-thirds of *ARA* in the study area occurred during daylight hours (see Figure 11).

When considering the meteorological conditions at the time of the accidents and the state of the pavement, it is notable that more than 50% of *ARA* in the district occurred under favourable traffic conditions (clear skies and dry pavement surface) (see Figures 12 and 13).

To visualise the number and severity of road accidents in the study, heat maps were created using *QGIS 3.20.2* software (see Figure 14).

The heat maps show that *PDOA* are most concentrated in the parking areas of commercial shopping centres or residential buildings. In contrast, road accidents tend to be concentrated at intersections with higher-category streets within the study area. Notably, it is observed that road accidents occur intermittently at these intersections. A noteworthy point is the significant decrease in the number of road accidents in 2022, coinciding with the onset of the COVID-19 pandemic and the associated quarantine restrictions at the time.

It is assumed that the improvement of infrastructure for vulnerable road users, the introduction of road safety measures and the improvement of traffic culture of road users had an impact on overall road safety and traffic arrangement. However, the implementation of street humanisation strategies in street section No. 1 (and beyond) were completed recently in 2023. Therefore, it is challenging to determine the

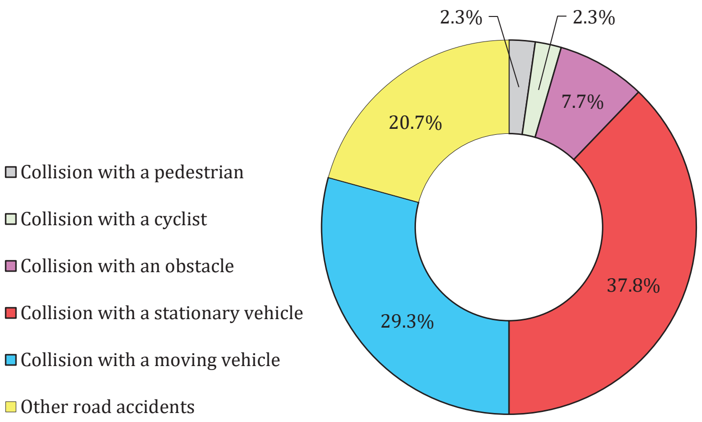

Figure 10. Distribution of *ARA* in the study area by accident type for the period 2018–2022

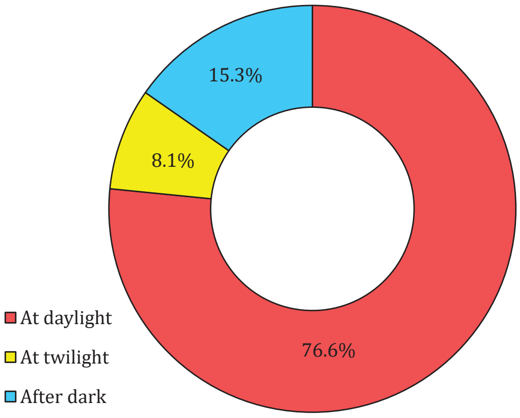

Figure 11. Distribution of *ARA* in the study area by time of day for the period 2018–2022

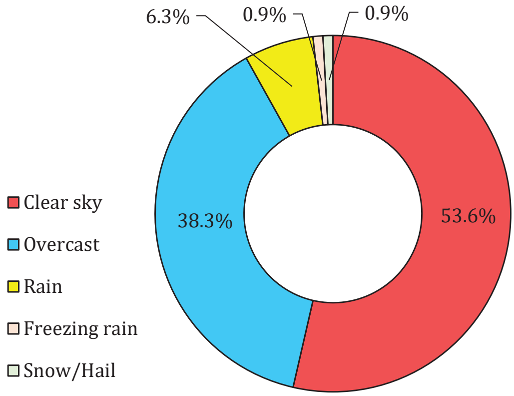

Figure 12. Distribution of *ARA* in the study area by weather conditions for the period 2018–2022

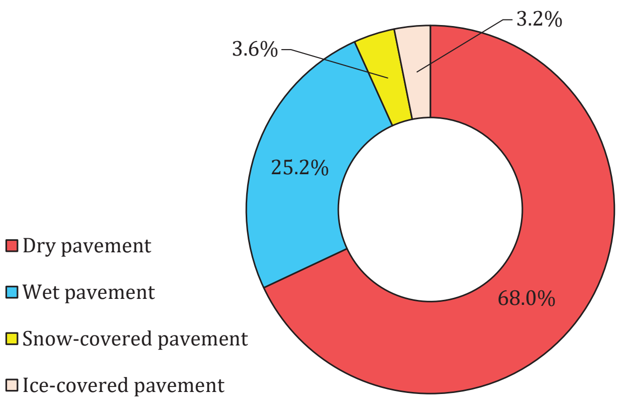

Figure 13. Distribution of *ARA* in the study area by pavement condition for the period 2018–2022

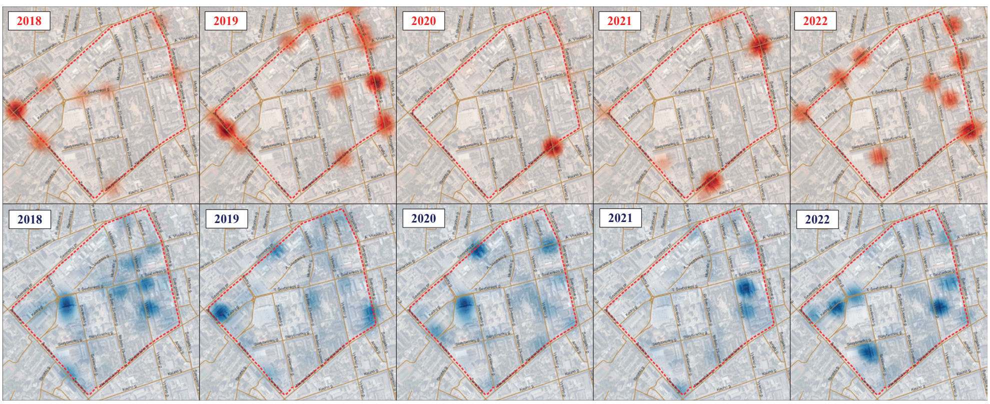

Figure 14. Heat map of *RA* (red) and *PDOA* (blue) in the study area for the period 2018–2022

impact of street humanisation on preventing road accidents in the study area solely based on the limited available data.

Discussion

The literature review and the study of instantaneous vehicle speeds and road accident data history only show that the concept of humanising streets is a very important process of redevelopment of urbanised areas, which is also an unavoidable procedure due to the poor safety conditions of vulnerable road users. The preliminary research carried out in this paper only confirms the effectiveness of engineering, traffic management, and architectural strategies in maintaining low motor vehicle speeds for vulnerable road users. The results are in line with those of other studies carried out by other authors.

However, it is important to consider the limitations and shortcomings of this study. The study area is in the early stages of the humanisation process and the number of redesigned streets is too small. Also, the streets that have already been reconstructed are in place as early as 2021–2023. This timeframe is too short to determine the actual impact on road accident occurrence. Right now, it is impossible to say whether the measures introduced have contributed to the spotted road accident decline.

Also, more sections of humanised streets should be included in further studies. It is also recommended that, where possible, the results of instantaneous vehicle speeds should be measured by other methods, such as GPS sensors or intelligent transport systems. Also, the introduction of more transport and socioeconomic variables (traffic flow, carbon emissions, etc.) is needed. It has been noted that studies of this kind do not take into account the impact of the humanisation of streets on journey times and costs. Moreover, it is important to investigate whether the carriageway width, road safety, and other measures on humanised streets do not impede the ability of emergency services to manoeuvre quickly and safely.

Conclusions

1. The road accident database history analysis reveals that property damage only accidents accounted for 97% of all road accidents in the study area. Although collisions with vulnerable road users (pedestrians and cyclists) were relatively infrequent. More the

50% of all road accidents in the study area occurred during daylight hours and in good driving conditions.

2. Over the period 2018–2022, there was a 20% decrease in the number of road accidents in the study area. Throughout Vilnius City, the number of road accidents decreased by only 4% over the same period. Technical accidents in the district also decreased by 20% and throughout Vilnius City by 15%.
3. The instantaneous vehicle speed analysis reveals that the concept of street humanisation is effective in maintaining 30 km/h or lower speed limit, regardless of whether the street was fully or partially humanised.
4. Currently, it is challenging to determine the impact of street humanisation on road accident prevention based on the available data. It is recommended to revisit this analysis in 3–5 years with a larger and more extended dataset to provide a more conclusive assessment.

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