Acta Polytechnica CTU Proceedings **51**:81–93, 2024
https://doi.org/10.14311/APP.2024.51.0081

AN EXAMINATION OF DRIVING SPEED: THE ROLE OF PERCEIVABLE ROAD CHARACTERISTICS IN TOWNS

Martin Schano[a,*], Josef Nový[b], Jiří Zeisek[c]

[a] *Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Forensic Experts in Transportation, Pohraniční 1288/1, 405 02 Děčín 2, Czech Republic*

[b] *Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Software Engineering, Pohraniční 1288/1, 405 02 Děčín 2, Czech Republic*

[c] *Czech Technical University in Prague, Faculty of Transportation Sciences, Děčín Department, Pohraniční 1288/1, 405 02 Děčín 2, Czech Republic*

[*] corresponding author: schano@fd.cvut.cz

Abstract. Understanding the subjective perspectives of drivers is paramount in evaluating the factors affecting driving speed in built-up areas. Building on our previous work, where a wide set of infrastructure attributes was analysed, this paper delves deeper into the realm of driver perception. It seeks to answer how drivers' observations and awareness of their surroundings influence their speed choices.

We reconduct our previous analysis, emphasizing the driver's subjective viewpoint, contemplating the visible and perceivable elements of the road infrastructure rather than their objective presence.

This research aims to garner insights into how these subjective elements impact speed choices. This research has uncovered a number of interesting factors that have not been previously used in the calculation of road vehicle speeds. This more nuanced understanding is expected to lead to enhanced safety and efficiency in road traffic management, ensuring the road design aligns seamlessly with driver perception and behaviour.

Keywords: Speed of road vehicles, traffic engineering, road infrastructure.

1. Introduction

Modern traffic engineering has consistently focused on road designs that mitigate the risks of accidents, and in cases where they occur, reduce their aftermath. The intricate role of road infrastructure elements is fundamental, not just in their direct impact but also in their latent effects on driver behaviour. In the constantly evolving discourse surrounding road design parameters and their subsequent influence on drivers, a predominant challenge is the nuanced nature of human perception. Each driver, unique in their perception, reacts differently to distinct infrastructure parameters, a complexity further amplified by regional variations in driver populations.

While our previous research aimed at determining a comprehensive set of infrastructure parameters and understanding their correlation with driving speeds, there remained a gap in understanding the subjective views of drivers and how their perceptions translate into their chosen speeds. This paper seeks to bridge this gap. Instead of only focusing on objective parameters like the sheer presence of infrastructure elements, we delve deeper into how drivers perceive and interpret their surroundings.

This research undertakes a closer examination of how the perceptibility of road features influences speed choices. The nuances of driver perception and behaviour are indispensable, as they hold the key to designing roads that align seamlessly with users' expectations and behaviours, thereby enhancing safety and efficiency.

2. Literature review

Understanding the factors that influence a driver's choice of speed is crucial for a plethora of reasons. For one, vehicle speed is a fundamental factor in both the frequency and severity of road accidents [1]. A slight increase in speed can disproportionately elevate the risk of severe injuries and fatalities in the event of an accident. Hence, by investigating the reasons behind a driver's speed selection, we can better strategize ways to moderate it, ensuring roads are safer for all users.

The relationship between a driver's choice of speed and the road environment has been a cornerstone of transportation research. Such insights are invaluable to public administration, road management agencies, and urban planners. They provide a roadmap for informed decisions that can significantly reduce traffic-related incidents [2, 3].

Moreover, in our era of rapid technological advancements, these findings are not confined to the traditional aspects of road management. They play a critical role in supporting the mathematical modelling of road user behaviour. Such models can capture complex interactions between various road users, allowing

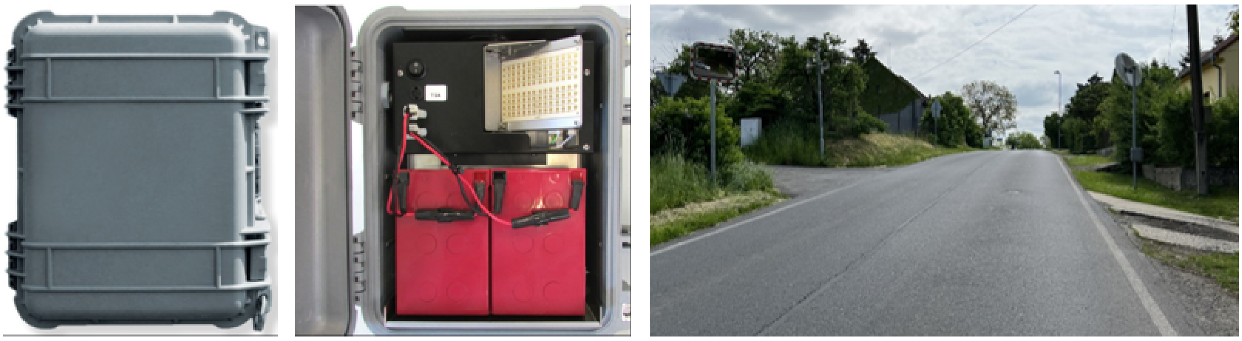

FIGURE 1. Traffic detector closed; Traffic detector open; Traffic detector installed and measuring.

for simulations that can test the efficiency and safety of road designs, traffic rules, and management strategies before they're implemented in the real world [4].

While there has been substantial research on roads outside of municipalities [5], largely attributed to their lower environmental complexity [6, 7], the intricate and dynamic nature of municipal areas poses unique challenges. Multiple modes of transport, the presence of pedestrians, varying road designs, and frequently changing traffic patterns make urban areas particularly complex. This complexity underscores the need for a deeper understanding of speed choices in these areas. Many researchers concur that to truly create safer and more efficient urban transport systems, the issue of driver speed selection within municipal boundaries warrants more extensive exploration [2, 4].

[8] aimed to identify roadway, roadside, and traffic control device variables that may affect the speed of drivers on suburban streets. This includes how speed may vary on different parts of the road, like curves versus straight sections. Multiple different groups of variables were investigated, among them were for example curve radius, angle and length, lane width, superelevation, median, bike lines, roadside development, roadside density, access density, traffic control devices. Some of the key findings were that posted speed limit, lane width, and road development (like nearby buildings and houses) significantly influenced speed.

[9] in their study capture variables like road attributes, traffic characteristics, and environmental factors. They introduced a model termed the ordered variant of the fractional split model. The model results highlight the role of various street characteristics including number of lanes, presence of parking, presence of sidewalks, vertical grade, and bicycle route on vehicle speed proportions. The researchers recognized that even after accounting for many observable factors in their models (for local roads and arterial roads), there's still some variation in speed distributions that the models can't capture. They postulated that these "unexplained variations" could be due to site-specific unobserved effects. In other words, each road or site might have its own unique characteristics that influence vehicle speeds. These could be factors like the presence of schools or hospitals nearby, unique local driving cultures, recent incidents affecting driver behaviour, etc. The researchers cautioned that if these unobserved effects were ignored, the resultant models would have biased effects. The uncovering of these site-specific effects is the goal of this paper.

3. METHODS

3.1. DATA ACQUISITION

The data collection method adopted for this study replicates the approach utilized in our previous research [10]. Briefly, an RTB Topo.box microwave traffic detector, visible in Figure 1, was employed to measure vehicles in both driving directions. This device not only gauges the speed of the vehicles but also discerns between different vehicle categories and measures pass-by noise. Designed to be discreet, especially in urban settings, it can be confidently stated that the detector did not influence drivers' behaviour due to its conspicuousness.

The efficacy and accuracy of this detector, as well as its potential limitations in different traffic volumes, have been detailed previously [10]. In this study, similar to our previous work, we did not distinguish between the passage of the Integrated Rescue System or other vehicles that inherently travel at higher speeds.

3.2. SITE SELECTION

Our research incorporated measurements from a total of 30 distinct sites. Each driving direction at these locations was evaluated separately, resulting in 60 unique speed measurements. Such a granular approach allows for a more nuanced understanding of driver behaviour, taking into account the distinct characteristics of each site.

Historically, the data collection was initially geared towards identifying and remediating at-risk sites on the road network, examples of which can be seen in Figure 2. As such, the locations were ones where there was an existing suspicion of drivers' non-compliance with the speed limit or other potential road traffic-related risks. While this may seem limiting, it offers

Děčín – Bynov, 50 000 inhabitants,
50.7814225N, 14.1537928E,
Class I road, 11 000 vehicles/day

Česká Kamenice –
Dukelských hrdinů st,
5 300 inhabitants,
50.8007408N, 14.4261522E,
Class I road, 11 000 vehicles/day

Nebočady, 312 inhabitants,
50.7307136N, 14.1902200E,
Class II road, 2 500 vehicles/day

Rohatce, 3 500 inhabitants,
50.4620761N, 14.2006550E,
Class III road, 1 500 vehicles/day

Česká Kamenice – Líska,
136 inhabitants,
50.8182297N, 14.4491669E,
Class II road, 3 500 vehicles/day

Staré Křečany – Panský, 12 inhabitants,
50.9504897N, 14.4665061E,
Class III road, 800 vehicles/day

FIGURE 2. Details of a small selection of the measured locations.
(Note: The list of sites provided above is illustrative and not exhaustive. For a complete list of sites, please see the appendix Complete List of Sites at the end of this article.)

a unique perspective, shedding light on areas that are potentially more prone to speed-related incidents. However, the distribution of the sites is not incidental and presumably carries a particular unknown bias.

The sites are predominantly situated in areas with heightened tourist activity, especially in proximity to the Bohemian Switzerland National Park. This location choice is significant as areas with increased tourist traffic might witness drivers who are unfamiliar with local roads and might not drive "by memory". Therefore, the behaviours recorded might differ from those on roads dominated by local traffic.

Road infrastructure in the Czech Republic is categorized into classes based on its purpose and transport importance. In this study, we primarily focused on:

- Class I roads, which cater mainly to long-distance and interstate transport,
- Class II roads, designated for inter-district traffic,
- Class III roads, which serve the purpose of linking municipalities with each other or connecting them to other main roads.

Most of the chosen sites represent thoroughfares of smaller towns and municipalities. These are typically directionally undivided roads with a maximum permissible speed of 50 kph. Such roads are especially interesting as they offer a mix of both local and non-local traffic, presenting varied driving patterns.

Incorporating this larger and more diverse dataset, especially with the application of Spearman's correlation coefficient, enriches our analysis. It provides more robust insights into the correlation between infrastructure elements and the speed choices drivers make. This, in turn, assists policymakers and traffic planners in making informed decisions to enhance road safety.

3.3. Set of tested attributes

In this study, various attributes of measured locations were tested, which were believed to influence the driver's subjective perception of safety and consequently their intuitive choice of vehicle speed. Attributes were chosen based on the results of our previous research [1], emphasizing the decoding of several ambiguities or intriguing findings. An example from previous results is the negligible influence of bus stops located directly in the driving lane of the measured vehicle, but a significant detected influence of bus stops in a separate bay, i.e., outside the driving lane. On the other hand, an interesting observation from the previous data set is that there was no correlation between lane width and driving speed, contrary to what the literature suggests. New attributes were carefully chosen to provide multiple ways to redefine these intriguing factors. Through this approach, we hope to uncover specific patterns and bring deeper understanding as to why certain factors influence or do not influence driver behaviour. In line with this, these attributes were chosen to be observable and perceptible from the driver's perspective. For instance, if the driver does not see an intersection, a door, or an exit from their view, these elements were not included in the evaluation.

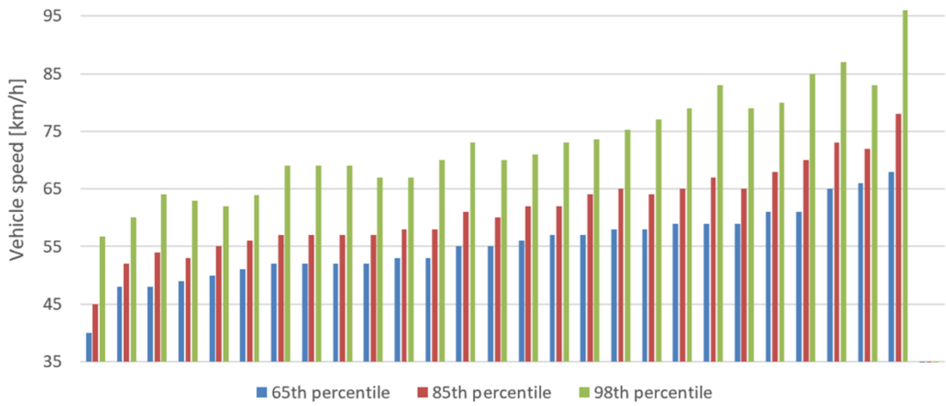

Figure 3. Speed distribution across the measured sites.

The assessed attributes can be categorized into several groups:

(1.) Pedestrian related attributes

- Nearest Sidewalk to Driving Lane [m]: Indicates how close the nearest sidewalk is from the driving lane.
- Building and Minor Structures Coverage [%]: The percentage of visible area covered by buildings and other small structures in relation to the total visible area.
- Urban Amenities Coverage [%]: Percentage coverage of urban amenities like benches, streetlights, and trash bins.
- Number of View-Obstructing Objects: Objects of sufficient size that could potentially hide a smaller person.
- Number of Pedestrian Entry Points: Places from which the entry of a pedestrian can be reasonably expected (doors, gates, emerging paths, etc.).

(2.) Vehicle related attributes

- Passing Sight Distance [m]: Describes the distance to the furthest point of the opposite driving lane that is fully visible from the driver's perspective.
- Stopping Sight Distance [m]: Describes the distance to the furthest point of the driver's own lane that is fully visible from the driver's perspective.
- Road Width for Legal Driving [m]: Width of the driving lane or strip where a driver can legally operate.
- Road Width for Safe Driving [m]: The drivable and paved part of the road, regardless of its legal status.
- Road Width for Emergency Driving [m]: The actual width available to a driver during an emergency. Exiting this space could lead to vehicle damage or leaving the roadway irreversibly.
- Number of Vehicle Entry Points: Points from which a vehicle entry can be reasonably expected (gate, driveway, etc.).

(Note: The list of attributes provided above is illustrative and not exhaustive. For a complete list of attributes and detailed descriptions, please see the appendix Complete Attribute Table at the end of this article.)

In total, 36 unique factors were defined, many of them measured at various distances from the measurement site, amounting to 128 evaluated attributes for each measured driving direction.

3.4. Data processing

To determine the relationships between the attributes of the measured sites and the chosen driving speed (distribution vissible in Figure 3), the Spearman correlation coefficient was used. This coefficient is standardly employed to measure the strength and direction of the relationship between two continuous variables and is suitable for revealing both linear and nonlinear correlations. The primary reason for its use was the expectation of a nonlinear relationship between the variables. An example can be the sight distance to oncoming vehicles. With increasing sight distance, the driver's sense of safety might increase, and thus the driving speed. However, this effect will not linearly increase to extreme values. For instance, the difference in driver's behaviour when changing the sight distance from 50 meters to 150 meters will be more pronounced than the difference when changing from 1 050 meters to 1 150 meters.

If there is a strong positive correlation between site attributes and the speed of passing vehicles, it can be assumed that an increase in the attribute value will lead to a higher speed of the passing vehicles. Conversely, a strong negative correlation would indicate that an increase in the value of a given attribute would result in a reduced driving speed. The Spearman coefficient is also robust against extreme values, which can often occur in the set of tested attributes.

Attribute \ Distance [m]	65th percentile					85th percentile					98th percentile				
	-100	-50	0	50	100	-100	-50	0	50	100	-100	-50	0	50	100
Nearest Sidewalk to Driving Lane [m]	-0,037	0,125	0,173	0,256	0,267	-0,028	0,128	0,172	0,252	0,262	-0,053	0,094	0,118	0,178	0,183
Number of View-Obstructing Objects	-0,197	-0,369	-0,081	-0,168	-0,183	-0,204	-0,370	-0,087	-0,165	-0,181	-0,232	-0,373	-0,112	-0,164	-0,157
Number of Pedestrian Entry Points	-0,003	-0,345	-0,083	-0,082	-0,088	0,000	-0,333	-0,075	-0,079	-0,088	-0,017	-0,309	-0,076	-0,092	-0,065
Building and Minor Structures Coverage [%]	-0,233	-0,370	-0,333	-0,406	-0,307	-0,233	-0,356	-0,313	-0,389	-0,291	-0,196	-0,311	-0,236	-0,321	-0,237
Urban amenities coverage [%]	-0,011	-0,225	-0,098	-0,269	-0,166	-0,027	-0,232	-0,095	-0,262	-0,154	-0,065	-0,232	-0,120	-0,232	-0,135
Distance from Bus Stop [m]	0,012	0,154	0,215			0,003	0,137	0,196			0,031	0,138	0,167		
Size of the Nearest Bus Stop [-]	-0,054	-0,180	-0,219			-0,047	-0,164	-0,202			-0,059	-0,147	-0,167		
Weighted Distance from Bus Stop [m]	-0,084	-0,225	-0,191			-0,073	-0,205	-0,172			-0,078	-0,180	-0,142		
Distance to Pedestrian Crossing or Crossing Point [m]	0,075	0,078	0,097			0,073	0,080	0,079			0,007	0,027	-0,019		
Size of Pedestrian Crossing or Crossing Point [-]	-0,073	-0,064	-0,021			-0,072	-0,065	-0,008			0,002	-0,007	0,067		
Weighted Distance to Pedestrian Crossing or Crossing Point [m]	-0,079	-0,083	-0,088			-0,078	-0,084	-0,070			-0,003	-0,023	0,026		

TABLE 1. Correlation coefficients for pedestrian related attributes.

Due to the presumed variations in behaviour of different types of drivers, it was decided to divide the speeds into three categories:

(1.) the 65th percentile of the speed of vehicles of all types, representing the regular speed of the majority of vehicles,

(2.) the 85th percentile of the speed of vehicles of all types, representing faster driving vehicles that appear more frequently, and

(3.) the 98th percentile of the speed of vehicles of all types, representing extreme speeds that are only occasionally observed at a given location.

The speed distribution across the measured sites can be seen in the figure below. The sites have a similar character and none of them show extremely different speeds or relationships between individual speed percentiles.

4. Results

The results are presented in the form of tables divided according to the nature of the attributes into attributes related to pedestrians, vehicles, road, and speed. For increased clarity, a colour scale is used starting at a coefficient of 0 in red colour (i.e., no correlation was found) to 0.6 in green colour (i.e., strong correlation). The interpretation of these coefficients is described in Figure 4. Positive correlation coefficients represent positive relationships between quantities (i.e., an increase in one correlates with an increase in the other) and negative coefficient values represent negative relationships (i.e., an increase in one correlates with a decrease in the other).

First set of results is related to pedestrians (see Table 1). Nearest sidewalk was not proven as a relevant element in this or previous study. However, it should be noted that the presence of sidewalks is

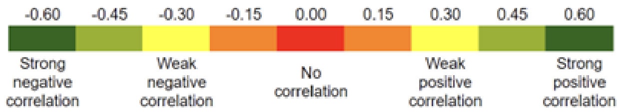

FIGURE 4. Colour palette used in correlation evaluation tables.

related to Road width attributes, which proved to be more relevant (see Table 2). Likewise, attributes related to pedestrian crossings were not shown to be relevant. Slightly higher correlations were identified in attributes related to bus stops. Positive correlations were in relation to distance, i.e., the closer, the lower the speed. Negative correlations were related to size, i.e., the larger and more equipped the stop, the lower the speed. The same was true for weighted distance. This is an attribute taking into account both size and distance. The value of the attribute increased with the increasing size of the stop and decreased with increasing distance from the stop. However, all correlations related to bus stops were relatively low and therefore less conclusive. This clarified the higher correlation with bus stops (0.347) identified in previous work by the authors, which was not confirmed with this expanded data set and is believed to be inaccuracy due to the smaller data set.

The highest correlations of attributes related to pedestrians were identified with the Number of View-Obstructing Objects, Number of Pedestrian Entry Points, and Building and Minor Structure Coverage. In all cases, a clear correlation was identified in the section approximately 50 meters before the measured site. Lower correlations with these attributes at other distances are attributed by the author team to the fact that the placement of the measuring device is not random and its placement in a higher-risk location, i.e., a place with a higher number of view-obstructing

Attribute \ Distance [m]	65th percentile -100	-50	0	50	100	85th percentile -100	-50	0	50	100	98th percentile -100	-50	0	50	100
Road Width for Legal Driving [m]	-0,035	-0,014	-0,095	-0,141	-0,019	-0,026	-0,006	-0,089	-0,137	-0,020	-0,070	-0,032	-0,144	-0,192	-0,085
Road Width for Safe Driving [m]	0,102	0,155	0,203	0,063	0,178	0,115	0,159	0,201	0,065	0,185	0,197	0,219	0,224	0,119	0,248
Road Width for Emergency Driving [m]	0,100	0,267	0,209	0,122	0,202	0,124	0,280	0,211	0,132	0,219	0,206	0,325	0,231	0,163	0,272
Curvature of the Visible Part of the Road	-0,210	-0,220	-0,381			-0,228	-0,231	-0,383			-0,261	-0,277	-0,432		
Length of the Straight Section [m]	0,069			0,461		0,086			0,459		0,167			0,501	
Route descent (-) / ascent (+)	-0,001		0,058		0,025	0,008		0,056		0,027	0,030		0,043		0,014

TABLE 2. Correlation coefficients for road related attributes.

Attribute \ Distance [m]	65th percentile -100	-50	0	50	100	85th percentile -100	-50	0	50	100	98th percentile -100	-50	0	50	100
Passing Sight Distance [m]	0,271	0,337	0,348	0,241	0,381	0,266	0,330	0,341	0,254	0,378	0,326	0,374	0,392	0,315	0,408
Stopping Sight Distance [m]	0,364	0,348	0,351	0,271	0,283	0,364	0,345	0,348	0,273	0,285	0,403	0,380	0,396	0,338	0,312
Number of Vehicle Entry Points	-0,168	-0,243	-0,125	-0,231	-0,119	-0,154	-0,230	-0,115	-0,234	-0,113	-0,130	-0,239	-0,127	-0,224	-0,040
Observable Area of the Nearest Intersection [m2]	-0,147	0,075	0,019			-0,149	0,070	0,021			-0,102	0,104	0,097		
Distance to the Nearest Intersection [m]	0,239	-0,022	0,054			0,240	-0,012	0,058			0,179	-0,027	-0,008		
Weighted Distance to the Nearest Intersection [m]	-0,253	0,037	0,017			-0,254	0,029	0,017			-0,203	0,051	0,087		
Proportional part of the road covered by safety barriers [%]	-0,253	0,037	0,017	-0,210		-0,254	0,029	0,017	-0,228		-0,203	0,051	0,087	-0,261	
Presence and Quality of Horizontal Road Marking [-]	-0,005	0,065	-0,064	-0,106		-0,007	0,062	-0,065	-0,099		-0,021	0,061	-0,035	-0,084	

TABLE 3. Correlation coefficients for vehicle related attributes.

objects and pedestrian entry points, is always preferred. The effect of these attributes is more visible at lower percentiles. This is expected as the faster drivers tend to ignore a lot of potential risks.

Within vehicle-related attributes (see Table 3), lower correlations can be seen with intersection-related attributes and safety barriers attribute. Minimal correlations were identified with the presence and quality of road marking. Slightly higher correlations can be seen with the Number of Vehicle Entry Points, which represents the number of intersections, driveways, garage exits, etc.

By far the highest correlations within this category of attributes were identified with Stopping Sight Distance and Passing Sight Distance. Of these two, Stopping Sight Distance had a slightly higher influence. For higher percentiles, the correlation value further increases slightly.

Regarding road-related attributes (see Table 2), even in this expanded data set, Road Width for Legal Driving (in most cases single line width) was shown to be insignificant. Significance gradually increases with Road Width for Safe Driving, which is the drivable and paved part of the road, regardless of its legal status. The highest correlation among the road width attributes was identified with Road Width for Emergency Driving. This is the actual width available to a driver during an emergency (paved or unpaved). It is usually the width between fixed obstacles, a slope, a guardrail, etc. Exiting this space could lead to vehicle damage or leaving the roadway irreversibly.

	65th percentile	85th percentile	98th percentile
Change in Maximum Allowed Speed [km/h]	-0,241	-0,231	-0,160
Distance from the Speed Limit Change Before [m]	-0,157	-0,153	-0,095
Distance from the Speed Limit Change After [m]	-0,143	-0,145	-0,118

TABLE 4. Correlation coefficients for speed related attributes.

Curvature of the Visible Part of the Road was also identified as a significant attribute. With increasing percentile, the influence of this attribute increases. The most significant attribute in this section was the Length of the Straight Section. However, it is interesting that only the length of the section being entered into has a significantly strong correlation, not the length of the section being exited. This noticeable difference is not caused by any observable trend in the measured locations.

From the last part of the attributes related to speed (see Table 4), a relatively low effect of changes in the allowed speed can be seen. In this part, it is necessary to say that many measured locations were on the outskirts of towns, as well as many deep inside towns. Several unsurprising trends can be observed such as that vehicles drive faster than they would normally through the measured location when the allowed speed is reduced close before the measured location. Similarly, for higher percentiles, there is a reduction in compliance with traffic signs regarding the maximum allowed speed.

From the results presented above, the variance in the importance of individual factors for different groups of drivers represented by different percentiles is evident. For ease of interpretation of these results, we have included below a summary of the most significant factors affecting the various driver groups.

	65th percentile	85th percentile	98th percentile
Length of the Straight Section [m]	0,461	0,459	0,501
Curvature of the Visible Part of the Road [°/m]	-0,381	-0,383	-0,432
Passing Sight Distance [m]	0,381	0,378	0,408
Stopping Sight Distance [m]	0,364	0,364	0,403
Building and Minor Structures Coverage [%]	-0,406	-0,389	-0,321
Number of View-Obstructing Objects [pcs]	-0,369	-0,370	-0,373
Number of Pedestrian Entry Points [pcs]	-0,345	-0,333	-0,309
Road Width for Emergency Driving [m]	0,267	0,280	0,325
Presence and Quality of Horizontal Road Marking [Scale, 1 = Best, 5 = Worst]	0,261	0,260	0,311
Urban amenities coverage [%]	-0,269	-0,262	-0,232

Table 5. The highest identified correlation coefficients.

5. Discussion

This publication has undoubtedly brought new insights into the area of driver's choice of driving speed, but it has also brought a number of challenges. This work was significantly complicated by the difficulty of defining the correct attributes across a heterogeneous environment. Particularly in the Czech Republic, the road network often contains elements that fundamentally complicate the comparison of various factors affecting driving speed, the comfort or feeling of safety for the driver. Examples of such elements include the absence of traffic signs or absence or wear of road markings. In some towns there are extensive sections of roads without proper differentiations between areas for vehicle movement, parking, or pedestrian traffic. Sometimes, there are even contradictions between traffic signs and road markings.

Spaces within municipalities are often not significantly different from the surrounding roads. Especially in the high-risk locations used in this study, it is common for some important elements of the urban street network to be missing. This offers the potential to evaluate the absence of individual factors on one hand, but on the other hand, it presents a significant challenge in the proper definition of such factors so that they are measurable by the same rules at all locations.

The authors originally planned to subsequently use the data and results of this study in the design of mathematical models for calculating speed characteristics in complex and heterogeneous conditions. This activity will certainly be performed, however, based on the increasing complexity with the growing number of locations and their variability, there arises a requirement for a deeper understanding of the observed phenomena. As part of continuing research activities, the author's team plans parallel activities using a simulated virtual environment with full control over the characteristics of the street network, including associated risks like pedestrian activity. This will fundamentally increase the number of assessed attributes and, above all, at least partially automate their collection. This will be necessary because the depth of the issue at hand requires a significantly larger amount of data for proper and reliable evaluation of the observed phenomena.

6. Conclusions

In this article, a number of factors that influence the driver's decision-making have been uncovered. Factor that appears as relevant in a multitude of publications, the width of the driving lane, was again manifested as insignificant based on the available data. It seems that other factors associated with the reduction of lane widths, such as narrowing the roadway, directional division of lines, inclusion of a parking lane which adds a number of objects generating pedestrian activity right next to the driving lane and at the same time adding view-obstructing objects, are much more significant than the reduction of the lane width itself.

Among the most significant identified factors (see Table 5) are undoubtedly the Number of View-Obstructing Objects, Number of Pedestrian Entry Points, Building and Minor Structures Coverage, Passing Sight Distance, Stopping Sight Distance, Curvature of the Visible Part of the Road, Length of the Straight Section behind the measured location, but not before. Based on these attributes, we believe that strong assumptions can be made about driver's behaviour in relation to driving speed. However, we recommend adding a number of other factors with lower but still relevant correlation (at least 0.2+) to the evaluation, as well as to any potential mathematical modelling of speed parameters.

Regarding the individual assessed speed percentiles, it can be said that with higher driver speeds, the relevance of factors such as Number of View-Obstructing Objects, Number of Pedestrian Entry Points, and other factors associated with pedestrian activity decreases. In contrast, the importance of attributes such as Passing Sight Distance, Stopping Sight Distance, Curvature of the Visible Part of the Road, Length of the Straight Section behind, increases, which represents a higher ability to safely achieve higher speeds (safely in relation to the individual vehicle and its travel, not to the surroundings and other participants). Therefore, it can be claimed that although the set of factors affecting speed for these individual types of drivers overlaps considerably, it is not the same. By modifying certain road infrastructure factors, it is possible to target the reduction of predominantly one group with less effect on the other. Conversely, there are also factors whose modification may aim to reduce average speeds, may not be so effective at reducing the highest speeds.

Acknowledgements

This paper was supported by the project "Simul-UK: Simulační prostředí v Ústeckém kraji" (CZ.02.01.01/00/23_021/0009003) funded by the Programme Johannes Amos Comenius of the Ministry of Education, Youth, and Sport, supported by EU funds.

References

[1] J. de Oña, L. Garach, F. Calvo, T. García-Muñoz. Relationship between predicted speed reduction on horizontal curves and safety on two-lane rural roads in Spain. *Journal of Transportation Engineering* **140**(3):04013015, 2014. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000624

[2] V. Martinelli, R. Ventura, M. Bonera, et al. Effects of urban road environment on vehicular speed. Evidence from Brescia (Italy). *Transportation Research Procedia* **60**:592–599, 2022. https://doi.org/10.1016/j.trpro.2021.12.076

[3] M. Bassani, D. Dalmazzo, G. Marinelli, C. Cirillo. The effects of road geometrics and traffic regulations on driver-preferred speeds in northern Italy. An exploratory analysis. *Transportation Research Part F: Traffic Psychology and Behaviour* **25**:10–26, 2014. https://doi.org/10.1016/j.trf.2014.04.019

[4] M. Budzynski, A. Gobis, L. Guminska, et al. Assessment of the influence of road infrastructure parameters on the behaviour of drivers and pedestrians in pedestrian crossing areas. *Energies* **14**(12):3559, 2021. https://doi.org/10.3390/en14123559

[5] M. AbuAddous. Operating speed prediction models for tangent segments: A brief review. *Civil Engineering Journal* **7**(12):2150–2164, 2021. https://doi.org/10.28991/cej-2021-03091784

[6] D. D. Dinh, H. Kubota. Profile-speed data-based models to estimate operating speeds for urban residential streets with a 30 km/h speed limit. *IATSS Research* **36**(2):115–122, 2013. https://doi.org/10.1016/j.iatssr.2012.06.001

[7] A. Thiessen, K. El-Basyouny, S. Gargoum. Operating speed models for tangent segments on urban roads. *Transportation Research Record* **2618**(1):91–99, 2017. https://doi.org/10.3141/2618-09

[8] K. Fitzpatrick, P. Carlson, M. Brewer, M. Wooldridge. Design factors that affect driver speed on suburban streets. *Transportation Research Record* **1751**(1):18–25, 2001. https://doi.org/10.3141/1751-03

[9] N. Eluru, V. Chakour, M. Chamberlain, L. F. Miranda-Moreno. Modeling vehicle operating speed on urban roads in Montreal: A panel mixed ordered probit fractional split model. *Accident Analysis & Prevention* **59**:125–134, 2013. https://doi.org/10.1016/j.aap.2013.05.016

[10] M. Scháno, J. Nový, O. Smišek. Infrastructure elements influencing the driving speed of road vehicle drivers in towns. In *2023 Smart City Symposium Prague (SCSP)*, pp. 1–7. 2023. https://doi.org/10.1109/SCSP58044.2023.10146116

A. Appendices

A.1. Complete list of sites

Bynov - Tesco,
50 000 inhabitants,
50.7810211N, 14.1483714E,
Class I road,
19 000 vehicles/day

Bynov - Penny,
50 000 inhabitants,
50.7814225N, 14.1537928E,
Class I road,
11 000 vehicles/day

Bynovec,
260 inhabitants,
50.8187456N, 14.2637433E,
Class III road,
3 000 vehicles/day

Česká Kamenice - Děčínská,
5 300 inhabitants,
50.7957347N, 14.4010736E,
Class I road,
9 000 vehicles/day

Česká Kamenice - Dukelských hrdinů,
5 300 inhabitants,
50.8007408N, 14.4261522E,
Class I road, 11 000 vehicles/day

Česká Kamenice - Huníkov,
5 103 inhabitants,
50.7803444N, 14.4232939E,
Class II road,
1 800 vehicles/day

Česká Kamenice - Líska,
136 inhabitants,
50.8182297N, 14.4491669E,
Class II road,
3 500 vehicles/day

Děčín - Březiny,
47 180 inhabitants,
50.7643703N, 14.2440031E,
Local road,
80 vehicles/day

Děčín - Teplická st,
50 000 inhabitants,
50.7807731N, 14.1744458E,
Class I road,
13 000 vehicles/day

Děčín - Ústecká st,
50 000 inhabitants,
50.7588311N, 14.1952261E,
Class I road,
13 000 vehicles/day

Hrobce,
557 inhabitants,
50.4581042N, 14.2288236E,
Class III road,
1 500 vehicles/day

Huntířov,
788 inhabitants,
50.7890875N, 14.3041481E,
Class I road,
7 000 vehicles/day

Huntířov - Nová Oleška,
100 inhabitants,
50.8091094N, 14.3193789E,
Class III road,
500 vehicles/day

Krásná Lípa,
3 500 inhabitants,
50.9147525N, 14.5280589E,
Class II road,
1 200 vehicles/day

Labská Stráň,
220 inhabitants,
50.8484664N, 14.2375072E,
Class III road,
600 vehicles/day

Libouchec,
1 800 inhabitants,
50.7583161N, 14.0407161E,
Class I road,
7 000 vehicles/day

Nebočady,
312 inhabitants,
50.7307136N, 14.1902200E,
Class II road,
2 500 vehicles/day

Radouň - south,
240 inhabitants,
50.4769986N, 14.3959911E,
Class III road,
2 600 vehicles/day

Radouň - north,
240 inhabitants,
50.4825800N, 14.3972947E,
Class III road,
2 000 vehicles/day

Radouň - west,
240 inhabitants,
50.4792278N, 14.3909700E,
Class II road,
700 vehicles/day

Radouň - east,
240 inhabitants,
50.4792314N, 14.3983997E,
Class II road,
600 vehicles/day

Rohatce,
3 500 inhabitants,
50.4620761N, 14.2006550E,
Class III road,
1 500 vehicles/day

Staré Křečany - Panský,
12 inhabitants,
50.9504897N, 14.4665061E,
Class III road,
800 vehicles/day

Varnsdorf, Československých letců,
14 837 inhabitants,
50.9007831N, 14.6191850E,
Class III road,
3 800 vehicles/day

Varnsdorf, nám. E. Beneše,
14 837 inhabitants,
50.9115747N, 14.6202553E,
Local road,
5 100 vehicles/day

Velká Bukovina,
523 inhabitants,
50.7304247N, 14.3966356E,
Class II road,
2 300 vehicles/day

Velká Bukovina - Karlovka,
523 inhabitants,
50.7425131N, 14.3977703E,
Class II road,
2 300 vehicles/day

Volfartice,
734 inhabitants,
50.7279236N, 14.4587536E,
Class III road,
1 900 vehicles/day

A.2. Complete attribute table

Attribute name	Attribute description
Nearest Sidewalk to Driving Lane [m]	Nearest Sidewalk to Driving Lane [m] is the distance between the closest sidewalk and the farthest edge of the driving lane, that is, the width available to the driver between the closest sidewalk.
Number of View-Obstructing Objects	The Number of View-Obstructing Objects is a metric that quantifies the total count of visible objects along the roadside that are tall or wide enough to obstruct a driver's direct line of sight, potentially concealing a child from view. This includes, but is not limited to, parked vehicles, large street furniture like advertising boards or bus shelters.
Number of Pedestrian Entry Points	The number of entry points visible from the driver's perspective on the right side of the road such as doors and gates.
Building and Minor Structures Coverage [%]	Measured within the driver's field of view. The specific value of this attribute corresponds to the ratio of the horizontal plane of view from 0-100 [%] and the weight coefficient. The weight is 2 for larger objects, especially buildings, and 1 for smaller objects, representing a maximum value of 300 [%].
Urban amenities coverage [%]	Coverage by urban amenities elements in the driver's field of view [%] such as bench, trash can, flower pot.
Distance from Bus Stop [m]	The distance to the nearest visible bus stop.
Size of the Nearest Bus Stop [-]	The size of the nearest bus stop by score. Scoring includes various elements related to the bus stop's location, design, and visibility features. The higher the value, the bigger and more equipped the bus stop is.

Attribute name	**Attribute description**
Weighted Distance from Bus Stop [m]	The combination of the size and distance from the nearest bus stop entails that the larger the size, the greater the weighted distance. Conversely, the further the stop, the smaller the weighted distance.
Distance to Pedestrian Crossing or Crossing Point [m]	The distance to the nearest visible Pedestrian Crossing or Crossing Point [m].
Size of Pedestrian Crossing or Crossing Point [-]	The size of the nearest pedestrian crossing or crossing point. Scoring includes various elements related to crossing's design, safety features, and visibility. The more elements the higher the value.
Weighted Distance to Pedestrian Crossing or Crossing Point [m]	The combination of the size and distance from the nearest pedestrian crossing or crossing point is such that the larger the size, the greater the weighted distance. Conversely, the further the crossing, the smaller the weighted distance.
Passing sight distance [m]	The Passing Sight Distance represents the maximum visible length of the road from the driver's position to opposite line.
Stopping sight distance [m]	The Stopping Sight Distance represents the maximum visible length of the road from the driver's position to the driver's line.
Number of Vehicle Entry Points	The Number of Vehicle Entry Points quantifies the potential locations along a roadway where vehicles may enter the traffic flow, including driveways, side streets, and other access points..
Observable Area of the Nearest Intersection [m2]	The Observable Area of the Nearest Intersection measures the total visible area from the driver's perspective at the closest intersection, encompassing the full expanse of the junction where two or more roads meet, including pedestrian crossings and merging lanes.
Distance to the Nearest Intersection [m]	The Distance to the Nearest Intersection indicates the linear distance from a given point on the road to the closest intersection ahead or behind.
Weighted Distance to the Nearest Intersection [m]	The Weighted Distance to the Nearest Intersection adjusts the plain distance measurement by accounting for the size and complexity of the intersection.
Proportional part of the road covered by safety barriers [%]	This attribute describes the percentage of the road's length that is equipped with safety barriers designed to prevent vehicles from leaving the roadway or colliding with obstacles and also any barriers preventing pedestrians from entering the roadway. Vehicle barriers have higher value than pedestrian barriers. The value of the attribute is the sum of both visible pedestrian and visible vehicle barrier length.
Presence and Quality of Horizontal Road Marking [-]	The Presence and Quality of Horizontal Road Marking assesses both the existence and the condition of painted road markings such as lane lines, pedestrian crossings, and other symbols. Additional features like reflective surface add to the value of the attribute.
Road Width for Legal Driving [m]	The width of the driving lane or band that a driver can legally use. This is the width between the road marking separating the opposite direction and the road marking or the edge of the paved road. In the absence of a separating lane marking, it refers to the width between the V4 road marking or the edge of the paved road.
Road Width for Safe Driving [m]	The width of the paved and drivable part of the road, regardless of whether the driver can legally move on it. This is space for emergency maneuvers, assuming the driver might ignore traffic rules.

Attribute name	Attribute description
Road Width for Emergency Driving [m]	The width practically available to a driver in a crisis situation. Going beyond this space ends either with vehicle damage or irreversible exit from the road. Typically, it includes the unpaved road section, the space between the nearest solid obstacles (including high curbs), slope fills, or cuttings, etc.
Curvature of the Visible Part of the Road	The Curvature of the Visible Part of the Road describes the degree and extent of any bends or turns in the segment of the road that is visible to the driver. The value is calculated as the sum of all bends or turns in degrees divided by the total length of visible part of the road.
Length of the Straight Section [m]	The Length of the Straight Section measures the distance over which the road extends in a straight line without any curves.
Route descent (-) / ascent (+)	This attribute records the gradient of the road in terms of descent or ascent, expressed as a negative or positive value respectively.
Change in Maximum Allowed Speed [km/h]	The Change in Maximum Allowed Speed denotes any official alteration in the speed limit, either an increase or a decrease, which drivers must adhere to. The decrease in maximum allowed speed in the vicinity has a negative value of the attribute. The increase has a positive value.
Distance from the Speed Limit Change Before [m]	The Distance from the Speed Limit Change Before measures the length of road prior to reaching the measured site and after the speed limit change.
Distance from the Speed Limit Change After [m]	The Distance from the Speed Limit Change After measures the length of road prior to reaching the speed limit change and after the measured site.