TRAFFIC INTENSITY GENERATED BY ELEMENTARY SCHOOLS

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Abstract

This article addresses the issue of automobile traffic generated by commuting to elementary schools. Although elementary schools are significant traffic generators, especially during peak morning hours, they are not adequately considered in the current methodology for predicting traffic intensities. This article provides a brief overview of the current approach to the determination of traffic intensity and defines the methods used for data collection, these are properly discussed and evaluated.

Keywords

Trip generation. Elementary schools. School commuting. Traffic intensity. Travel mode. Trip generation. elementary schools. School commuting. Traffic intensity. Travel mode.

1 INTRODUCTION

The traffic generated by commuting to elementary school is an issue that the transport planning has been dealing with in recent years. In front of elementary schools, especially before morning classes, there is a large increase in traffic, including car traffic. Parents who are in a hurry or have nowhere to park often drop their children off directly in the lanes or at junctions, blocking traffic. Traffic calming measures are often introduced around schools to improve student safety, and school buses are frequently implemented in larger cities. According to data from the Czech Statistical Office (ČSÚ) [1] based on a questionnaire survey conducted in 2020, just under half of children walk to school, the second most common mode of transport being the car, which is used in 17% of cases. The data also show that schools in places with good public transport links, such as Prague, have a lower proportion of car trips. Children's choice of how to get to school, and their safety along the way, is a global issue. Research suggests that it also has a major impact on children's upbringing [2], and thus on their future behaviour and transport choices as adults.

In general, the proportion of car trips to school depends, among other things, on the accessibility of the school on foot (i.e. the compactness of the development and walking distances), the availability of safe routes to schools [3], [4], the size of the municipality, the location of the school within the municipality, and the number of schools in the area, i.e. the school's catchment area. Another obvious factor is the availability of reliable public transport [5]. Unfortunately, in recent years, there has been a tendency for urban residents to move to newly emerging satellite towns without adequate development of public transport and amenities [6], [7]. This has led to an increase in the number of students travelling longer distances to school; they are driven by their parents on their way to work [8]. Efforts to address the shortcomings of satellite towns [6], [7] should consist of completing the missing infrastructure, including elementary schools. However, as new schools are being built with some delay, and the only usable space left in the area is on the outskirts of the towns, the car is often the only effective way to get to school.

New urban development cannot proceed without a corresponding road network. Due to the increasing pace of construction of large housing estates and civic amenities, it is necessary to reliably estimate their impact on the road network at a time when these projects are only at the design and project preparation stage. Based on the expected impact of the development in question, it is then possible to take the necessary measures in good time to ensure the efficiency and cost-effectiveness of the entire transport system. A key means of identifying these impacts is to forecast the trips generated by the planned development of public facilities.

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Definition

Trip generation can be defined as a tool that allows us to estimate the number of trips originating from or destined to a particular location within a given time period. A related term is the **trip generator**, which can be described as the specific building that is the origin or destination of the trips. The rate of trips generated by a particular trip generator and the mode of transport used are determined by the type of building. For example, different types of public facilities – schools, hospitals, shopping centres, or also larger residential developments – generate traffic that differs in intensity, transport mode, or composition of the traffic flow, or even evolves differently over the course of the day. In addition to the type of building, trip generation is also dependent on the location of the generator within the urban area, the quality of the infrastructure for non-motorised transport, the availability of parking, or a reliable public transport network.

Current state of the issue

The trips generated and their associated traffic intensity in an area can be determined by traffic surveys. This method allows us to determine the real-time impact of the building under observation. However, if the building has not yet been constructed, forecasting methods are used [9].

Currently, there is only one certified methodology for such forecasts in the Czech Republic. This methodology is based on traffic surveys of existing buildings and facilities carried out between 2007 and 2011. After almost one and a half decades, the methodology is now considered outdated. Another problem with the existing methodology is the inadequate description of certain important public facilities that may generate a large number of trips [10], such as primary schools.

To provide a basis for the forecasting method specialised in educational institutions, an approach similar to the one used to develop the current methodology has been applied. This data collection phase needs to cover a variety of different schools representing various urban environments, school sizes, and transport options for students.

2 METHODOLOGY

As mentioned above, traffic surveys were used to provide the data needed for this research. All traffic surveys were conducted using the official guideline TP 189 – *Estimation of Traffic Intensities on Roads* as a starting template. As this guideline is mainly focused on road traffic, the methods described in it had to be modified to meet the challenges that schools can present. The methodology is briefly summarised below.

The selection of the surveyed schools was mostly based on their location and the characteristics of the urban area. When considering the population density of the area, the location of the municipality in relation to the capital city – Prague – was taken into account. Another important aspect of school choice was size; all the schools surveyed were similar in terms of student numbers. Finally, private and public transport options in the area were considered, including both car and non-car modes. The surveyed schools, along with brief information about their location and time of the traffic surveys, are presented in Tab. 1. School attendance – the total number of students on the survey day – is reported as well.

Once a school had been selected, a brief site reconnaissance was carried out to identify the typical behaviour of drivers and pedestrians, both adults and children. The aim was to prepare an effective strategy for the traffic survey itself. Typical drop-off and pick-up points were identified, as well as the usual pedestrian routes, public transport options, and the use and parking of bicycles.

For each selected school, a traffic survey was conducted on a certain weekday. Two main methods were used – manual counting and, in the case of more complex schools, camera recordings, which were later analysed by a member of the research team. The traffic surveys were carried out in two phases – in the morning and afternoon of the same day – in accordance with the school schedule. The start of the morning phase usually followed the opening of the school drop-off centre, which children often attend before their morning classes. The morning phase ended at the start of classes, usually at 8:15. During the morning traffic surveys, all modes of transport used and the number of students using them were recorded. This included pedestrians, bicycles and scooters, cars, and available public transport – buses or trains. The afternoon phase started around 11:30 and lasted until 17:00, when most of the children had finished their after-school activities. Only two groups were considered in the afternoon surveys: students picked up by car and those using other means of transport.

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Once the traffic surveys were completed, the data were analysed and interpreted.

Tab. 1 Summary of the schools surveyed.

School name	School location	Attendance (total students counted)	Survey date
Řevnice Elem. School	Řevnice	594	05/03/2024
Zdiměřice Elem. School	Jesenice-Zdiměřice	414	04/05/2024
Suchdol Elem. School	Praha-Suchdol	558	10/10/2024
Hanspaulka Elem. School	Praha-Dejvice	511	07/11/2024

3 DISCUSSION

The results and interpretation of each traffic survey conducted are summarised below, along with a brief description of the school, its urban area, and the conditions that influence the trip generation. Both morning and afternoon surveys are presented. The tables show the exact number of students for each mode of transport, while the graphs display the percentages for better understanding and comparison. Maps with isochrones of reachability are also included to describe the location of each school in relation to the surrounding urban area.

Řevnice Elementary School

The town of Řevnice is located about 10 km southwest of Prague. It has almost 3,800 inhabitants, and the residential areas consist mainly of single-family houses. County roads II/115, II/116 and the railway line no. 171 pass through the town. The nearest motorway connection is the D4 motorway, located approximately 7 km from Řevnice.

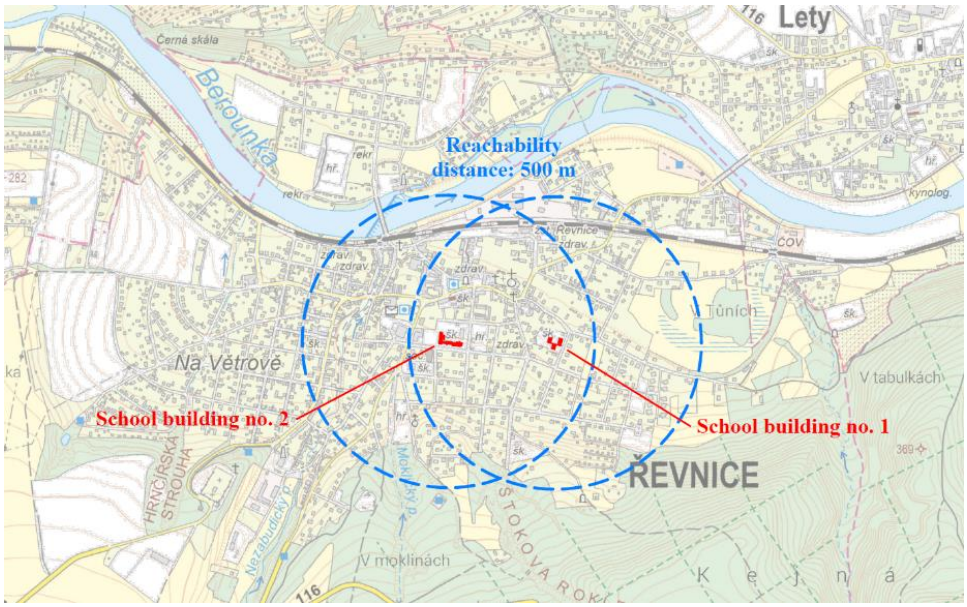

Fig. 1 Řevnice – school locations (red) and 500 m reachability isochrones.

In this case, the school itself is divided into two buildings about 350 metres apart, as shown in Fig. 1. The first building is used for grades 1 to 3, and the second for the remaining grades 4 to 9. The school is located in a residential area off the main roads, not far from the town centre. The catchment area of the school covers a large part of the residential neighbourhoods and, thanks to the railway connection, the outlying villages as well. The 500 m reachability isochrone shown in Fig. 1 illustrates the school's range. Both school buildings were surveyed at the same time and, for the sake of comparison with the other surveys, are presented together in this paper.

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Tab. 2 Total number of students – morning.

Mode of transport	Number of students
Pedestrian	318
Bicycle	20
Scooter	29
Car	134
Bus	25
Train	68

Tab. 3 Total number of students – afternoon.

Mode of transport	Number of students
Car	94
Other	500

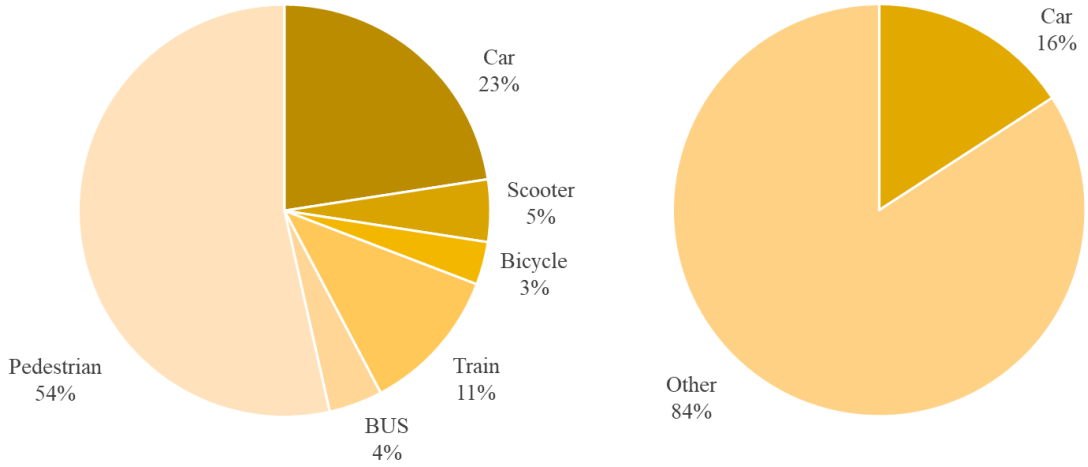

Fig. 2 Percentage of transport modes used – morning (left) and afternoon (right).

The results of the traffic survey in Řevnice show that the location of the school, which is central in relation to the residential area, is a sufficient reason for walking to school, as shown in Tab. 2, with more than 300 pedestrians recorded in the morning survey. With 54%, as shown in Fig. 2, walking is the predominant mode of transport in the morning. A specific feature of this particular school, which does not appear in the other surveyed schools, is the accessibility of the train. The results in Tab. 2 and Fig. 2 show that the train is also a convenient choice for almost 70 students, making it the most used form of public transport with 11% of all students. The lower number of cyclists and scooter users may be related to the rather cold and foggy weather on the day of the survey. The bus was used by only 25 pupils, which is only 4% of the school's population, possibly due to inefficient bus stop placement.

The main objective of this study, car trips, was favoured by 23% of students in the morning and 16% in the afternoon, as shown in Fig. 2. A possible explanation for the decrease in the afternoon could be the fact that parents drop off their children on their way to work, while in the afternoon, the school activities end before the parents go home, which is quite common at primary schools. The total number of students not using a car for their trip from school is 500, as can be seen in Tab. 3.

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Zdiměřice Elementary School

Zdiměřice is a part of the town of Jesenice, located around 1.5 km south of Prague. Due to its proximity to Prague, the village has developed quite rapidly, with a population of almost 1,700 in 2021. Similar to Řevnice, the majority of residential buildings are single-family houses. The local county road III/0033 runs through the village. As there is no railway line, the village is connected to Prague only by buses and private cars. The nearest motorway access points are the D0 or D1 motorways, both approximately 3 kilometres away.

The school in question was opened in 2022 on the northern edge of the village, directly along the main road to Prague. As part of the school site, a car park with 36 spaces for parents and 24 spaces for employees is located in front of the building. There are 5 K+R (Kiss & Ride) parking spaces on the main road. The location of the school on the edge of the village significantly reduces its accessibility for pedestrians, as can be seen in Fig. 3.

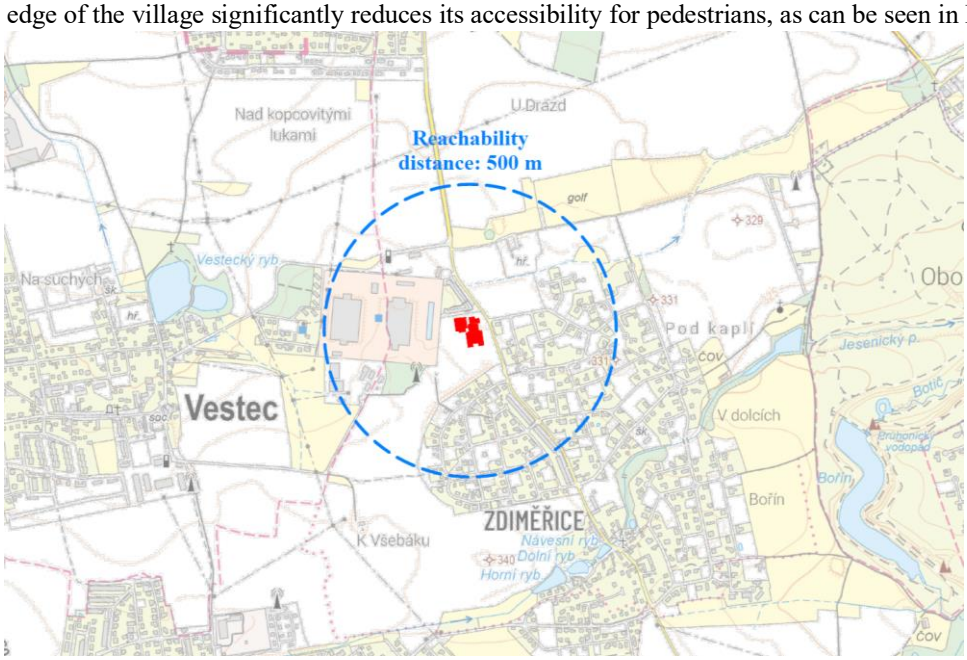

Fig. 3 Zdiměřice – school's location (red) and 500 m reachability isochrone.

Tab. 4 Total number of students – morning.

Mode of transport	Number of students
Pedestrian	143
Bicycle	16
Scooter	27
Car	184
Bus	44

Tab. 5 Total number of students – afternoon.

Mode of transport	Number of students
Car	223
Other	191

While analysing the results of the survey, the satellite location of the village in relation to Prague quickly became apparent, with cars quickly forming a major choice of transport. In the morning, as shown in Tab. 4, the car was the most frequently used mode of transport, with 184 students arriving by car. According to Fig. 4, this represents 44% of all students. During the morning traffic survey, congestion quickly developed due to the large number of cars turning into the school parking lot.

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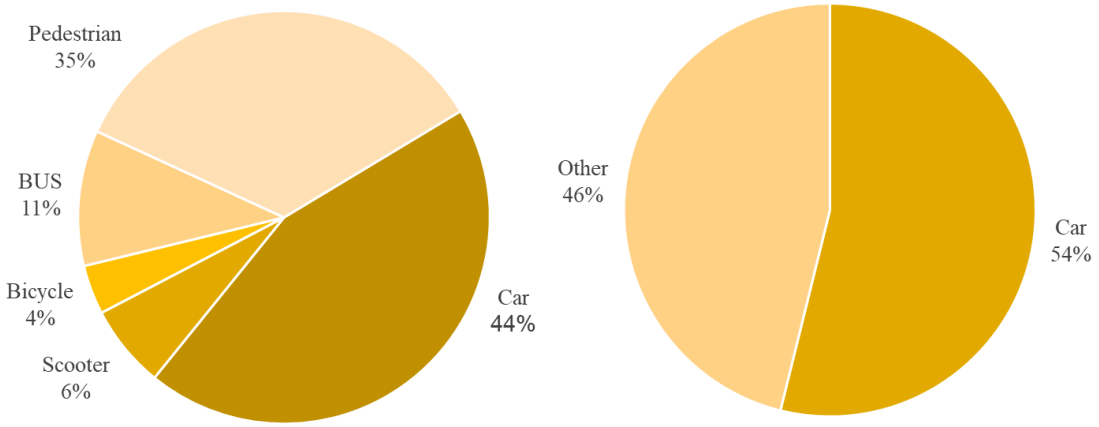

Fig. 4 Percentage of transport modes used – morning (left) and afternoon (right).

After dropping off their children, most parents continued their journey to Prague using the main road. Both entering and exiting the car park required a left turn, which quickly became a bottleneck in the traffic situation. As shown in Tab. 5, 223 students used a car on their way home in the afternoon, which is even more than in the morning (54%).

Due to the school's location in a residential area, albeit on the edge of the village, pedestrian access formed the second largest group, accounting for 35% of students, as shown in Fig. 4. The bus was used by only a tenth of the children, even though there was a dedicated school bus line, and the nearest bus stop was only 200 metres away. Despite the favourable weather conditions, the use of bicycles and scooters remained minimal. Employees' transport choices were also surveyed, with 95% using cars.

Suchdol Elementary School

Prague-Suchdol is part of the Prague 6 administrative district and is located on the northern edge of the city. The area has a distinctly suburban character, with a majority of detached houses or villas and a few occasional apartment buildings. The total population is almost 6,900. The main road through the area is II/241, and another road, II/242, runs along the district's border near the Vltava River. There is also a railway line along the riverbank, but it is not easily accessible from most parts of the district. This means that connections to the city centre are provided by buses and private cars.

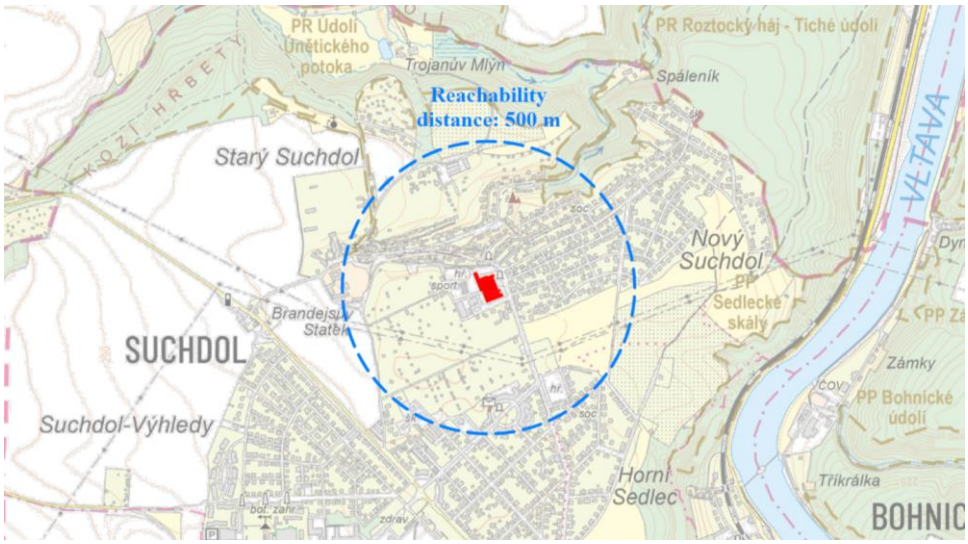

Fig. 5 Suchdol - school's location (red) and reachability isochrone of 500 m.

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The school is located in a cluster of residential buildings in the northern part of the district, also known as 'Old Suchdol', as illustrated in Fig. 5. At the time of the survey, some adjustments to the nearby streets were in progress, aimed at improving the safety of pedestrian crossings and limiting parking in front of the building. According to the employees interviewed, these adjustments have proved to be largely effective, as evidenced by the results of the survey.

Tab. 6 Total number of students – morning.

Mode of transport	Number of students
Pedestrian	183
Bicycle / Scooter	31
Car	88
Bus	256

Tab. 7 Total number of students – afternoon.

Mode of transport	Number of students
Car	129
Other	429

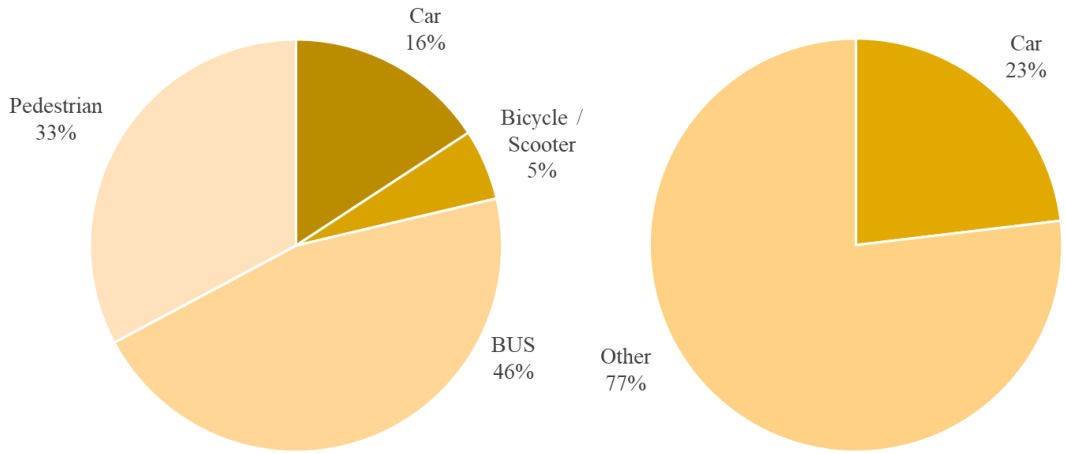

Fig. 6 Percentage of transport modes used – morning (left) and afternoon (right).

According to the results of the survey, only about 20% of all students used cars, as shown in Fig. 6, which is much less than in Zdiměřice, despite the similarity of the urban conditions. Although both schools are situated on the edge of residential areas, housing density in Suchdol is higher than in Zdiměřice. The increase in car usage in the afternoon is probably due to the weather conditions that worsened during the day. Despite the adjustments made to the street in front of the school, morning car traffic became chaotic, with several congestions caused mainly by parents parking or stopping at different places to drop off their children.

Due to the reliable and frequent bus service, this mode of transport became the most used with 256 students, as shown in Tab. 6. This bus line, which is primarily a connection between the central Prague and the campus of the Czech Agricultural University in Suchdol, proved to be very useful for the inhabitants of Suchdol as well. With a bus stop located directly adjacent to the school and buses arriving up to every 2 minutes, this form of transport was used by 46% of all students, as shown in Fig. 6. Walking was the second most common choice as, due to the convenient location of the school, as shown by the 500 m reachability isochrone in Fig. 5. Due to less favourable weather conditions, only 11 students used bicycles or scooters. In the afternoon, other means of transport continued to dominate, with 429 students, as shown in Tab. 7.

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Hanspaulka Elementary School

Hanspaulka Elementary School is located in the Prague district of Dejvice. Both single-family houses and larger residential complexes are located in the district itself, while the surveyed school is situated in a more upscale villa neighbourhood of the area. Currently, there are around 24,000 residents living in Dejvice. The main streets in the vicinity of the school are 'Na Pískách' and 'Šárecká' streets, both connected to the major arterial 'Evropská' street. This artery also includes both tram lines and a subway line beneath it. However, the school's immediate surroundings are only serviced by a bus line and individual cars. The school's position in the neighbourhood is shown in Fig. 7.

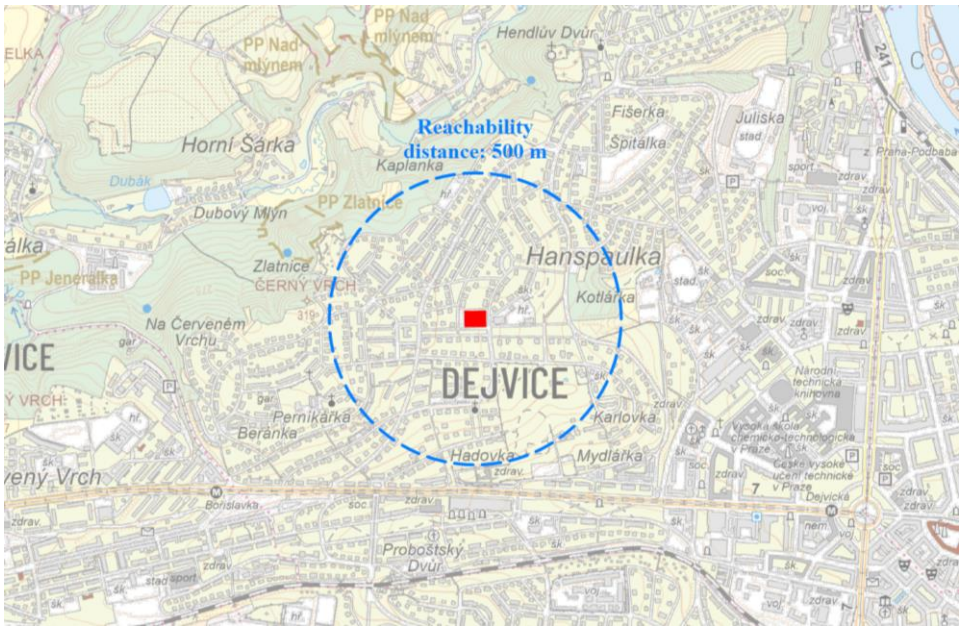

Fig. 7 Hanspaulka - school's location (red) and 500 m reachability isochrone.

Tab. 8 Total number of students – morning.

Mode of transport	Number of students
Pedestrian	324
Bicycle / Scooter	1
Car	110
Bus	76

Tab. 9 Total number of students – afternoon.

Mode of transport	Number of students
Car	90
Other	421

The location of the school within the neighbourhood once again proved to be an important reason for students to walk to school in the morning. As shown in Tab. 8, pedestrian traffic dominated the morning survey, with 324 students walking to school. With the 500 m isochrone of reachability shown in Fig. 7, the effective range of the school includes most of the Hanspaulka neighbourhood. Further coverage is provided by the bus, used by 15% of all students according to Fig. 8. Bicycles and scooters were used minimally, due to the rather hilly character of the area and also because of the unfavourable weather.

In this case, cars were used by 22% of students in the morning, with the percentage decreasing to 18% in the afternoon, according to Fig. 8. Despite the colder weather, the vast majority of students – 421 in total, as shown in Tab. 9 –used other means of transport for their journey home.

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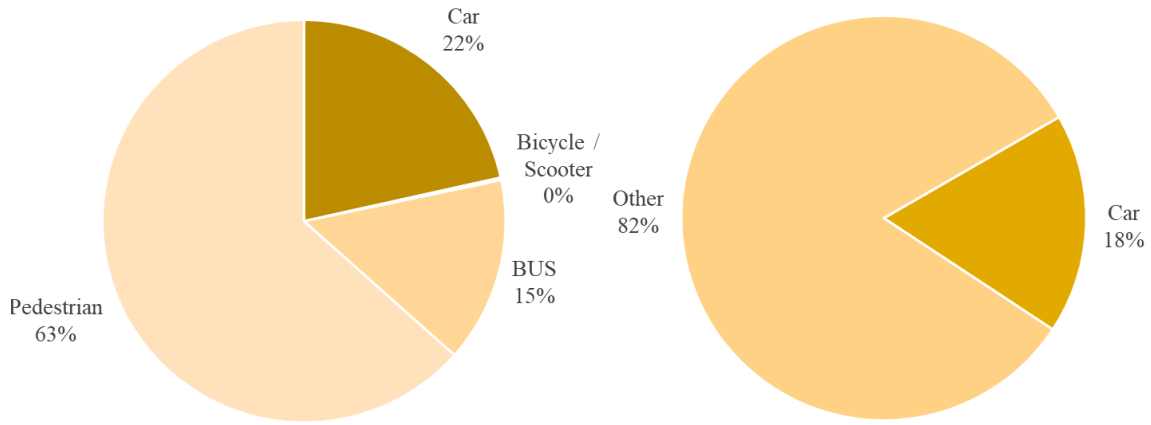

Fig. 8 Percentage of transport modes used – morning (left) and afternoon (right).

Summary

Considering the impact on the surrounding road network, morning trip generation has a greater effect over a shorter period of time than in the afternoon. Generally, after evaluating the surveys, the peak 15-minute morning interval occurs between 7:30 and 7:45, during which approximately 65% of car users arrive. This peak in traffic corresponds with the morning rush hour. On the contrary, the afternoon traffic is usually spread out more evenly and does not reflect the afternoon rush hour.

For general comparison between the surveyed schools, several values are presented in Tab. 10 below. In addition to the total car usage percentage and peak hour car intensity, we also established the average number of students per one car used, calculated as attendance per car intensity both for all of the school's students and for the car users separately.

Tab. 10 Car intensity and usage in the morning rush hour.

School name	Attend.	Total car usage %	Car intensity car / hour	Stud. per car avg. (school total)	Stud. per car avg. (car users only)
Řevnice E. S.	594	23 %	118	5.03	1.14
Zdiměřice E. S.	414	44 %	172	2.41	1.02
Suchdol E. S.	558	16 %	68	8.21	1.29
Hanspaulka E. S.	511	22 %	90	5.68	1.22

As presented in Tab. 10, the highest peak hour car intensity was achieved in Zdiměřice, with 172 cars per hour, and the lowest number of students per one car – the number of cars is nearly identical to the number of students arriving by car. The highest number of students per one car was reached in Suchdol, where the school with a size of 558 students generated only 68 car trips per hour – on average, every car was used by 1.29 students. In other words, while in Suchdol, every third car delivered 2 students, in Zdiměřice it would be every 50th car – that is 17 times more cars needed to deliver one more student than in Suchdol.

4 CONCLUSION

Elementary schools prove to be significant trip generators with a high variability of transport modes that may be used. Especially in suburban areas, these facilities can place considerable demands on the surrounding infrastructure. It becomes apparent that, to properly plan a new development of residential area and its public amenities, it is necessary to consider the possible types and intensities of traffic these facilities may produce. With the traffic surveys' outcomes summarised above, the overall findings may be presented as follows:

- The location of the settlement in relation to the regional capital affects the general usage of cars, which is also reflected in the number of car trips generated by the school itself, as observed in Zdiměřice and Suchdol. However, if the settlement does not incorporate typical satellite town characteristics and

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has effective public transport, especially in terms of connection to the regional capital, the number of car trips is significantly lower, as demonstrated in the case of Řevnice.

- Larger school catchment areas with a majority of separate smaller villages tend to generate more car traffic, which could be observed in Řevnice and Zdiměřice. Students living outside these settlements use cars much more often than the locals.
- The position of the school within the settlement – relative to main residential districts, neighbourhoods, and clusters – affects the usage of non-motorised transport. Generally, schools located around the centre are more accessible on foot, and walking is therefore a more popular option.
- Trips generated in the afternoon, which occur before the usual afternoon peak traffic hour, can often reach higher numbers than those in the morning. However, afternoon trips are usually spread out over a longer period of time and thus strain the road network less.
- Schools located on the outskirts of settlements, which are less accessible by non-motorised transport and which require parents to use the car, may influence parents' decisions to continue using the car for commuting to work. This behaviour was observed in Zdiměřice and should be further investigated.

Further research on this topic should widen the data set by conducting additional traffic surveys beyond those presented in this paper. With enough data, we can move toward creating patterns that will be able to predict the number of trips generated under different conditions outlined in the presented stages of this research. Finally, we will be able to make recommendations for updating the current methodology and provide tools to predict possible trip generation for future developments.

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