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ORIGINAL SCIENTIFIC PAPER

Contemporary Procedures for Traffic Data Collection With a Special Emphasis on the use of Drones

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Abstract: Traffic planning represents a key component of urban and regional development, requiring a comprehensive analysis of socio-demographic, spatial, and economic factors. The research is focused on the application of contemporary methods of traffic data collection, with particular emphasis on the use of drones in detecting the effects of specific traffic-calming measures. Specifically, two locations in Podgorica were analyzed, each featuring different types of speed-reduction devices: rubber elements and an asphalt platform. Aerial footage was captured using a "DJI Mini 3" drone, and the data were processed with the DataFromSky software. Statistical analysis was conducted using a t-test, which revealed statistically significant differences in vehicle speeds at the analyzed locations, with slightly lower speeds recorded at the site featuring rubber elements. The advantages of drones over fixed cameras lie in their flexibility, unobtrusiveness, and ability to capture real driving behavior, although there are temporal limitations on recording and challenges related to adverse weather conditions (rain and wind). The results indicate a high applicability of drones in the quantitative analysis of traffic flows, as well as the importance of appropriate method selection depending on the analytical objectives. The obtained data contribute to more accurate calibration of traffic models in software such as VISUM, AIMSUN, and PTV Vistro, thereby enhancing the quality of strategic planning decisions in urban traffic management.
Key words: traffic planning, drones, DataFromSky, traffic-calming measures, statistical analysis.

INTRODUCTION

Traffic planning is a complex scientific field that constitutes an integral part of development control, primarily within cities and subsequently within broader spatial units such as regions and states. This process is based on phenomena that are predictable and stable over longer periods of time (Vračarević&Basarić, 2014). As population mobility increases, the need to develop the transport system also grows, arising as a result of well-designed activities. The planning process begins with understanding the socio-demographic, spatial, and economic parameters within which the transport system operates. After that, it is necessary to identify the problems, challenges, and opportunities in the performance of the transport system in a given context, whether at the level of a state, province, region, or community. This typically involves conducting an analysis and evaluation of changes in the performance of the transport system, as well as examining the existing and anticipated challenges the system faces (Meyer, 2016).

Understanding the nature of the challenges a community faces represents an important starting point for the subsequent steps in the planning process. After that, the next phase involves developing a vision for the area covered by the study. Once the vision is established, it is further elaborated in detail so that the goals and tasks within traffic planning can later be clearly defined. The process of data collection and analysis, which is carried out after the goals and tasks have been determined, is based on understanding the current state of a transport system as well as the impact of certain changes planned for the future (Meyer, 2016).

An increase in the number of vehicles on the street network leads to numerous problems, such as insufficient parking capacity, the formation of traffic congestion that results in increased fuel consumption and heightened environmental pollution. In order to address these issues in the long term within the traffic planning process, it is essential to ensure reliable data collection as well as their adequate processing and interpretation. Today, various modern methods exist for traffic data collection, such as video and infrared cameras, radar devices, and similar technologies. One approach to collecting traffic data is the use of drones, which enable aerial recording of traffic flow. This paper presents precisely this methodology of data collection, where, for the purpose of researching the impact of two different traffic-calming elements on vehicle speed (deceleration) values in the traffic flow, an aerial recording was made using a "DJI Mini 3" drone. The research was conducted in the territory of the capital city of Montenegro, and the recorded video was processed using DataFromSky software. Specifically, the study observed rubber traffic-calming elements installed on Bulevar Crnogorskih Serdara and an asphalt platform located on Cetinjski put.

The results obtained through the research may be of considerable value for the implementation and planning of various traffic-calming measures in the future on the territory of Podgorica, as well as throughout Montenegro, in accordance with the effects achieved by installing the elements observed in the study.

METHODS OF DATA COLLECTION IN TRAFFIC

A large number of traffic data collection methods exist today, ranging from manual to fully automated procedures enabled by the development of modern technologies and devices. The advancement of intelligent transportation systems, which are increasingly discussed today, requires high-quality real-time traffic data. Various methods are used for traffic data collection. One of the most widespread is the use of inductive loops installed within the roadway, which record the passage of vehicle axles over them (Guillaume, 2008).

Several types of counters installed in the pavement can be distinguished, including pneumatic tubes, piezoelectric sensors, magnetic loops, and others. These counters are typically installed to obtain traffic flow data over a longer period on the observed road section. Additionally, traffic data collection can also be performed manually, as well as through the use of infrared cameras, handheld or stationary radar devices, and similar tools. Such methods are generally suitable for short-term data collection, making them useful for various research applications in the field of transportation.

Floating Car Data

This method of data collection is based on the principle of locating vehicles on the road network through mobile phones or GPS technology. The collected data related to the vehicle's location, speed, direction of movement, etc., are anonymously transmitted to a processing center. As for GPS technology, it was until recently available only in certain types of vehicles (such as taxi vehicles). The accuracy of this system is quite high (the error usually does not exceed 30 m).

Data collection using mobile phones refers to determining their position in space. This method of traffic data collection is advantageous because it does not require the acquisition of any additional devices or equipment. However, the system is characterized by lower accuracy in data collection (the error may reach up to 300 m) (Guillaume, 2008).

A Brief Overview of Previous Research

Numerous studies have used simple video techniques, in which the recorded footage was later analyzed manually in order to obtain the necessary data. The costs associated with this method of data collection are low compared to other methods, as it requires minimal human resources. However, manual processing of the recorded video is a time-consuming procedure. For this reason, various software packages have emerged to process recorded video footage, such as TRAIS, COUNTcam, Traffic Vision, TRAZER, MediaTD, Picomixer STA, etc. (Guillaume, 2008).

Real-world traffic conditions typically differ from homogeneous traffic conditions, in which speed is constant, driver behavior is uniform, and vehicle dimensions do not vary. Therefore, when collecting data for heterogeneous traffic flow, it is crucial to use appropriate methods that ensure sufficient accuracy of the obtained data. In field conditions, data commonly collected include vehicle speed, flow, density, direction of movement, distribution of traffic load at intersections by movement directions, and similar parameters (Jayaratne et al., 2020).

Within this study, the TRAZER software, the TIRTL (the infrared traffic logger) device, and the Google Distance Matrix API were tested for data collection in the territory of Sri Lanka. The research was conducted at a total of three locations. The data obtained using TRAZER and the API depend on the geometric parameters of the roadway, whereas the data obtained using the TIRTL technology do not. Therefore, the first two methods were applied at only one location. The analysis was carried out by comparing the data collected using the aforementioned methods with the data obtained through manual traffic counting (Jayaratne et al., 2020).

USE OF SURVEILLANCE CAMERAS AND UNMANNED AERIAL VEHICLES IN TRAFFIC

The installation of surveillance cameras at specific cross-sections of roadways has become increasingly common in recent times. There are many reasons for their growing use, primarily reflected in the detection of various traffic violations committed by drivers and in facilitating the clarification of traffic accidents. In addition, these cameras, when combined with different software tools, can also be used to collect various types of data relevant from the perspective of traffic planning, such as traffic flow, speed, traffic composition, and similar indicators (Slika 1). Their main advantage lies in the fact that they allow for 24-hour monitoring of traffic flows, 365 days a year, which provides continuity in collecting the desired data. On the other hand, the primary drawback of using surveillance cameras includes the relatively high costs of installation as well as the application of software required for automatic data processing. Accordingly, many locations are equipped with fixed cameras that record video footage 24 hours per day. In addition to their function in monitoring and detecting violations, surveillance cameras are increasingly used as intelligent sensors for estimating traffic density, thereby contributing to more efficient traffic management (Hu et al., 2023). Furthermore, research shows that speed enforcement cameras contribute to reducing vehicle speeds and the frequency of traffic accidents — a systematic review indicated that their application can reduce average speed by up to 15%, while the number of fatal and serious-injury crashes may decrease by as much as 44% (Wilson et al., 2010).

Figure 1. Fixed camera installed on a motorway section

Drones are unmanned aerial vehicles, meaning that no onboard pilot is required for their operation—control is instead carried out through a remote-control system. Andrijašević et al. (2024) used a drone for the purposes of a study conducted in Bar (Montenegro). Specifically, the impact of rumble strips on reducing vehicle speed in the area of pedestrian crossings was examined, and it was determined that a statistically significant difference exists between vehicle speeds before and after the strips, with the average post-strip speed being approximately 5 km/h lower.

The main advantage of this method of traffic data collection lies in the fact that a drone can be quickly and easily positioned at any location where specific data are required, which is not the case with fixed cameras. On the other hand, the greatest drawback of drones is the time-limited aerial recording, which depends on the capacity of the battery with which they are equipped. Modern lithium-ion batteries provide an autonomy of approximately 40 to 60 minutes, which is sufficient for most traffic research, but may present a challenge when long-term observation of traffic flow is necessary. In addition, this effective time must be further reduced by the period required for drone positioning — which typically does not take longer than 3 to 5 minutes after takeoff from the ground.

The sensitivity of drones to adverse weather conditions, such as windy or rainy weather, should also be emphasized—conditions that do not pose a significant problem for fixed cameras. Although more advanced and expensive drone models exist, offering moisture resistance and improved stabilization in windy conditions, the issue of strong wind gusts that may cause unintentional drone displacement during recording has not yet been fully resolved. For this reason, a very important technical component of modern drones is the gimbal—a three-axis camera stabilizer (roll, pitch, and yaw) that enables the camera to remain in a stable, fixed position regardless of the drone's movement. Thanks to this feature, it is possible to obtain clear and undistorted video footage even under mild turbulence, which is crucial when the recorded material is used for quantitative traffic flow analysis in specialized software.

One of the greatest advantages of drones in the field of traffic data collection lies in their small dimensions and low visibility — they are often not detectable to the naked eye from the driver's position. This means that drivers are usually unaware that they are being observed, which enables the collection of data on their real behavior, unlike fixed cameras whose locations are relatively quickly memorized by drivers, thereby influencing adjustments in their driving behavior. Consequently, the data obtained through aerial drone recording objectively reflect the actual state of the traffic flow at the location under investigation.

MATERIALS AND METHODS

As part of this research, an analysis was conducted to examine the influence of different traffic calming elements—raised asphalt platforms and rubber elements in the form of bumps on the roadway—at two locations in the capital of Montenegro, Podgorica, on vehicle speed and deceleration values within the traffic flow, as well as a mutual comparison of the obtained results. These types of measures are typically used for traffic calming in Montenegro. Both locations share similar geometric characteristics (physically separated carriageways with two traffic lanes each, approximately the same roadway width, no significant longitudinal gradient, etc.). The data were obtained using the DataFromSky software, in which the video footage previously recorded from the air by a drone, at a recording height of approximately 250 m above the roadway, was processed. Thanks to this method of data collection, real traffic-flow data were obtained, without any change in driver behavior resulting from awareness of being recorded. The main objective of the research is to determine the differences in vehicle speeds and decelerations at cross-sections placed at different distances from the traffic calming element (0, 10, and 20 m).

Data collection was carried out using a DJI Mini 3 drone, shown in Figure 2. This unmanned aerial vehicle weighs only 248 grams. It is equipped with a camera designed for photography at 12 MP with up to 60 fps, and for recording high-resolution 4K HDR video at up to 30 fps, with a field of view of up to 115 degrees. The drone can reach a speed of 5 m/s during ascent, while its maximum descent speed is 3.5 m/s. In horizontal flight, it can achieve speeds of up to 16 m/s. The gimbal ensures smooth and stable footage, even when flying in windy conditions.

Figure 2. Aircraft Used for Aerial Video Recording

DataFromSky

DataFromSky (DFS) is a software tool that offers various analytical solutions dedicated to traffic management (Figure 3). It provides high-quality processing of video recordings of traffic areas. The operation of the software is based on artificial intelligence. On the basis of the recorded video footage, it enables the determination of a wide range of traffic flow parameters that can later be highly useful in different types of analyses, such as: vehicle type and count in the traffic stream, speed, acceleration/deceleration values, following distance, time headway, time spent in a stationary position, trajectories, etc.

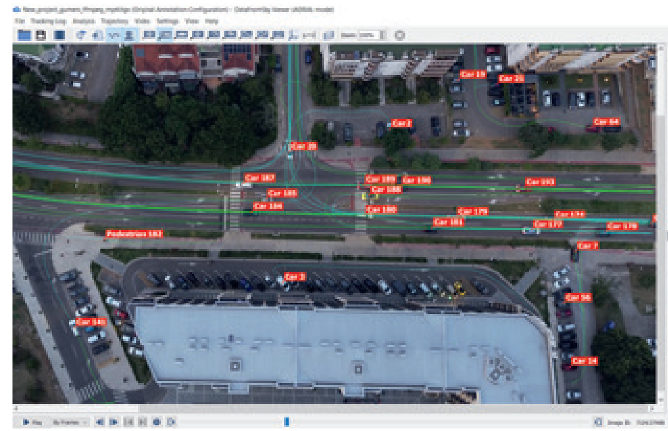

Figure 3. Interface of the DFS software

To record vehicle passage at a specific cross-section within the DFS software, we use so-called gates, which are defined as virtual points or sections placed at characteristic locations for the purpose of tracking the movement of objects such as pedestrians, cyclists, vehicles, and other traffic participants. Thus, gates can be placed not only at roadway cross-sections but also at the approaches/exits of an intersection, thereby enabling the determination of traffic load distribution by movement directions. In this way, traffic counting at intersections with high traffic volumes is significantly simplified, which—when performed manually—is especially challenging at roundabouts with a large central-island radius and a higher number of arms (Figure 4).

Figure 4. Gates Placed at a Roundabout

A very important parameter of the traffic flow is the vehicle speed. In order to obtain this value in the DFS software, expressed in km/h, it is necessary to perform so-called georeferencing, that is, to enter the coordinates of several points in space so that the software can recognize the mutual distances between them and thus determine the distance traveled per unit of time. Therefore, during field research, it is essential to determine the coordinates of at least four points in space. These should be characteristic points that can later be easily identified on the video recording (e.g., edge of the roadway, edge of the median island, traffic sign, street-lighting pole, etc.).

The coordinates are entered in the WGS 1984 coordinate system.

RESULTS

The research was conducted at two locations featuring different types of traffic-calming elements in Podgorica, on boulevard-type roadways. Figure 5 shows the location on Bulevar Crnogorskih Serdara, in the Gintaš–Union direction (hereinafter Location A), where rubber traffic-calming elements are installed, while Figure 6 shows the location on Cetinjski put, in the Budva–Center direction (hereinafter Location B), where an asphalt platform is placed. Both locations share similar geometric characteristics of the roadway. Within the DFS software, a total of six gates were defined (three for each direction) for each location. The gates marked as 0 m represent cross-sections placed exactly at the position of the traffic-calming element and act as exit gates for vehicles traveling in that lane. The gate positioned 20 m from the observed element serves as the entry gate, as vehicles encounter it first while moving along the roadway. Between these two cross-sections lies the 10 m gate, positioned exactly midway between the entry and exit gates.

Figure 5. Location A – Bulevar Crnogorskih Serdara

Figure 6. Location B – Cetinjski put

At both locations there are two traffic lanes for each direction of travel. Location A is an intersection where there was no substantial interference from vehicles on the minor approach, whereas at Location B there is a minor approach on the right-hand side for vehicles travelling from the City Centre direction. It may also be noted that here, too, there was no significant level of interference from vehicles on the minor approach, since on Cetinjski put the traffic lanes are physically separated, and it is therefore not possible from the minor approach to perform a left-turn manoeuvre towards the city centre. The speed limit indicated by traffic signs is 30 km/h at both locations. The height of the rubber traffic-calming elements is 5 cm, while the height of the asphalt platform is 4 cm, with an approach gradient of 1:10. As regards the asphalt platform, a pedestrian crossing is located on it, whereas the rubber elements are positioned immediately in front of the pedestrian crossings.

The statistical analysis of the data was conducted using the Statistica software. In order to ensure the relevance of the analytical results, vehicles whose minimum speed between the gates was below 4 km/h were excluded from the compiled database at the initial stage of data processing, as it is assumed that these vehicles were yielding to pedestrians crossing the roadway at marked pedestrian crossings, and therefore were moving at such low speeds.

The observed sample size at Location A, where rubber traffic-calming elements are installed, amounts to 407 vehicles, while at Location B, where the asphalt platform is located, it includes 293 vehicles. According to the data collected during the study, traffic frequency by direction at Location A was 194 vehicles (47.7%) in the Gintaš direction and 213 vehicles (52.3%) in the Union direction. At Location B, 154 vehicles (52.5%) were traveling from the Centar direction, while slightly fewer vehicles—139 (47.5%)—were traveling from the opposite direction (Budva). The average speed between the entry and exit gates at Location A was 21.51 km/h, while at Location B this value was 25.07 km/h, indicating a difference of 3.56 km/h. The average deceleration at Location B was –1.352 m/s^2, whereas at Location A it was –0.966 m/s^2, which means that vehicles experience greater deceleration at the location with the asphalt platform.

Speeds at the cross-sections

Speeds at the cross-sections vary depending on the distance between the individual cross-sections and the type of speed-calming device installed at the observed locations. Based on the data (Figures 7 and 8), the differences in speeds at the cross-sections can be observed in more detail by examining the Box & Whisker speed diagrams. The diagrams present the median values, the speeds corresponding to the 25%–75% range of the analyzed vehicle sample, as well as the minimum and maximum vehicle speeds recorded at each cross-section. The median represents a measure of central tendency in statistics—that is, the middle value of a dataset when the values are arranged in ascending order.

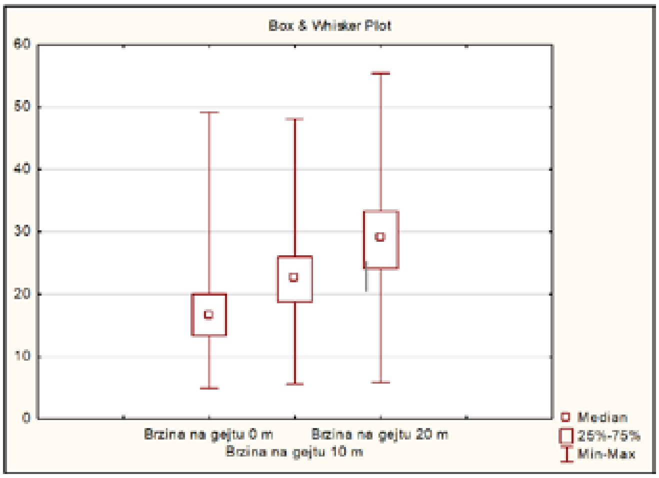

Figure 7. Box & Whisker Diagram for Speeds at Different Cross-Sections – Location A

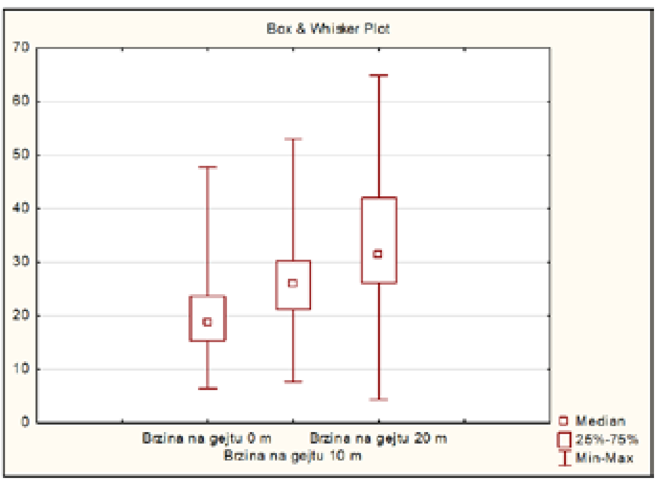

Figure 8. Box & Whisker diagrams for speeds at different cross-sections – Location B

The speeds of vehicles when passing over traffic-calming elements for 25% to 75% of the analyzed vehicle sample at Location A range between 13 km/h and 20 km/h, while at Location B the vehicle speeds are slightly higher, ranging from 16 km/h to 23 km/h. Observing the median value at the 0 m gate, we can note that the difference between the two locations is not large. The median at Location A is 17 km/h, whereas at Location B it is 19 km/h. Furthermore, it can be observed that at the 10 m gates there are differences between the speeds of vehicles representing 25% to 75% of the analyzed sample. At Location A, speeds range from 18 to 26 km/h, while at Location B they range from 22 to 31 km/h, indicating that vehicles were traveling at higher speeds at this cross-section (10 m gate – Location B). The median value at the 10 m gate is also higher at Location B, amounting to 27 km/h, while at Location A it is lower by 4 km/h. For the most distant cross-section — the 20 m gate — the median value is 32 km/h at Location B and 29 km/h at Location A. The speeds for 25% to 75% of the analyzed vehicle sample are higher at Location B, ranging from 27 km/h to 42 km/h, whereas at Location A speeds for the same percentile range from 24 km/h to 33 km/h. **Therefore, it can be concluded that the speeds at Location A (with rubber traffic-calming elements) are lower compared to Location B (with the asphalt platform).**

DISCUSSION

Based on the conducted research and the review of modern methods for traffic data collection, it can be concluded that certain methods offer different levels of suitability for specific planning objectives. Manual counts and drones are particularly useful for obtaining data on the distribution of traffic flows at intersections, with drones offering a significant advantage in terms of efficiency and the ability to cover complex intersections (Guillaume, 2008). For example, manual traffic counting is nearly impossible at large roundabouts that have two or more circulating lanes.

On the other hand, automatic traffic counters, such as inductive loops and radars, represent the most reliable solution for calibrating traffic models due to their ability to continuously collect large volumes of data (Guillaume, 2008). Software tools such as TRAZER and devices such as TIRTL provide additional information on traffic flow composition and speed, while the Google Distance Matrix API can be used to determine travel times and origin–destination matrices, with certain limitations regarding account availability and spatial coverage (Jayaratne et al.,2020).

Such data are essential for input and calibration of models in software packages such as VISUM, as well as other tools used for traffic network simulation and planning, including AIMSUN, TransCAD, and PTV Vistro (Shepelev et al.,2020). Their accuracy directly influences the quality of predictions that support strategic decision-making—from determining roadway capacities and traffic flow distribution to optimizing traffic signalization. Precisely calibrated models enable the identification of traffic bottlenecks, the prediction of the effects of new infrastructure solutions, and the testing of various scenarios without the need for costly and time-consuming field interventions.

Therefore, it can be concluded that the proper selection of data-collection methods—depending on the objective of the analysis (e.g., capacity assessment, traffic-flow distribution, travel-time estimation, or evaluation of infrastructural interventions)—can significantly enhance the accuracy, efficiency, and relevance of the planning process in urban environments. Combining traditional and modern methods, such as the use of automatic traffic counters, drones, and geolocation data, provides a multidimensional insight into complex traffic systems and facilitates data-driven decision-making.

CONCLUSION

Several modern procedures for traffic data collection have been presented in this paper. Special emphasis was placed on the use of drones, which make it possible to record aerial video footage and thereby collect the necessary data. Through subsequent analysis of the recorded footage in the DFS software, various traffic flow parameters can be obtained, such as traffic flow composition, distribution of traffic load at the intersection, vehicle speeds and acceleration/deceleration values at characteristic cross-sections, vehicle trajectories, and similar indicators.

On both locations observed in this study, the vertical traffic signage defines a speed limit of 30 km/h. At Location A, 45.2% of vehicles exceeded the speed limit, while at Location B the percentage of speeding vehicles was 55.6%. These values were obtained at the entry gate (gate 20 m). This indicates a higher share of speeding at the location with the asphalt platform. Based on the obtained results, it can be concluded that platforms significantly influence vehicle deceleration within the traffic flow. They affect not only the speeds during the passage over the speed-calming elements themselves, but also have a notable impact at 10 m and 20 m upstream of the element. The results of the analysis showed that, for the observed locations, rubber elements are more effective in reducing vehicle speeds compared to the asphalt platform, as speeds recorded at Location A were lower than those at Location B by approximately 3 km/h at gate 0 m. These results may be useful in planning future traffic-calming measures in urban areas of Montenegro, where excessive vehicle speeds represent a pronounced problem.

The study also highlights the significant potential of drones and specialized software solutions in the context of contemporary traffic planning. Their ability to provide high-quality aerial footage, together with their ease of use and minimal influence on driver behavior, makes them an exceptionally valuable tool for analyzing traffic flows, evaluating existing solutions, and subsequently calibrating transport models.

In conclusion, it can be stated that modern data collection methods—when carefully selected in accordance with the objectives of the analysis—represent a powerful tool in the hands of transport engineers and planners. By combining technology, statistical methods, and real-world field data, it becomes possible to make more reliable and efficient decisions that contribute to the long-term improvement of traffic safety and network performance. **This paper was carried out within the project "Development and Implementation of Sustainable Transport and Logistics Technologies in Teaching and Practice" (Department of Transport, Faculty of Technical Sciences, University of Novi Sad, 2025).**

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