



University of Pristina  
Kosovska Mitrovica



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# Sustainable Transportation within the framework of Green Deal

## LABORATORY MANUAL



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**UNIVERSITY OF PRIŠTINA – KOSOVSKA MITROVICA**  
**FACULTY OF TECHNICAL SCIENCES**



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## 1. INTRODUCTION

The contemporary development of traffic and transport is increasingly directed towards the concept of sustainable mobility, which implies harmonising the needs for the movement of people and goods with the requirements of environmental protection, traffic safety, energy efficiency, digitalisation and social accessibility. In this context, higher education plays a key role in preparing professionals who will be capable of analysing, planning and improving transport systems in accordance with European trends and the principles of the Green Deal.

The Laboratory Manual was prepared within the Erasmus+ project SPHERE – Sustainable Transportation within the Framework of Green Deal, project number 101128065, whose broader objective is to improve the quality of higher education in the field of sustainable transport, strengthen the relevance of curricula for the labour market and society, and promote modern scientific methods and good European practices in the field of traffic and transport. According to the official project description, SPHERE is focused on the development and improvement of curricula, the training of professionals in the field of transport, and the transfer of knowledge in line with current scientific and professional achievements in the field of sustainable transport.

The particular significance of this manual lies in the fact that it connects theoretical knowledge in the field of sustainable transport with practical work in a laboratory environment. The equipment procured within the SPHERE project enables students, teachers, researchers and professionals to gain a deeper understanding of contemporary challenges in the field of traffic through practical exercises, measurements, simulations and analyses. In this way, the laboratory becomes a space for the application of knowledge, the development of research competencies, the testing of different scenarios and the creation of solutions that can contribute to a safer, more efficient and more sustainable transport system.

The Laboratory Manual is intended for undergraduate and master's students, teachers, teaching assistants, researchers, as well as professionals in the field of traffic and transport who participate in training and professional development. Its primary purpose is to provide clear guidelines for the use of laboratory equipment, define possible areas of application and enable a standardised approach to carrying out practical activities. In addition, the manual should encourage the development of an interdisciplinary approach, since sustainable transport integrates traffic engineering, urban planning, environmental protection, traffic safety, information technologies and public policies.

Through the description of equipment, examples of laboratory exercises and possible application scenarios, this manual should contribute to the modernisation of the teaching process and the strengthening of users' practical competencies. At the same time, it represents one of the results of institutional strengthening and capacity building of higher education institutions within the SPHERE project. The procured equipment is

not only technical support for teaching, but also a basis for the development of new research, the preparation of professional analyses, the implementation of training and cooperation with the economy, the public sector and other stakeholders.

Based on the above, the Laboratory Manual has a dual role. On the one hand, it represents a practical guide for working with the equipment procured within the SPHERE project. On the other hand, it highlights the importance of laboratory work in the process of educating professionals who will be equipped to respond to contemporary challenges of sustainable transport, traffic safety and green mobility. In this way, the manual contributes to the long-term sustainability of the project results and their application in teaching, research and professional practice.

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## 2. LABORATORY FOR TRAFFIC AND TRANSPORT

At the Faculty of Technical Sciences, University of Priština with temporary seat in Kosovska Mitrovica, within the international Erasmus+ project SPHERE – Sustainable Transportation within the Framework of Green Deal, the Laboratory for Traffic and Transport has been established as a modern teaching and research unit intended to improve education, research and the practical application of knowledge in the field of sustainable transport.

The establishment of this laboratory represents an important step in strengthening the institutional capacities of the Faculty for the modern study of traffic and transport systems. Its establishment is based on the need to connect theoretical knowledge in the field of transport with practical work, measurements, simulations, data analyses and the application of modern equipment. In this way, the laboratory becomes a space in which the teaching process, scientific research and professional practice complement one another and are directed towards solving real problems in the field of mobility, safety, efficiency and sustainability of transport systems.

The basic idea of the laboratory is to enable students, teachers, researchers and professionals to work in an environment that meets the contemporary needs of the traffic and transport profession. In such an environment, it is possible to analyse the existing state of the transport system, examine the behaviour of road users, consider the impact of infrastructure on safety and mobility, assess the environmental consequences of traffic, develop scenarios of sustainable urban mobility and apply digital tools in the process of traffic planning, modelling and management.

The laboratory is particularly significant because it enables the application of an evidence-based approach. Modern transport planning and management cannot be based solely on assumptions, but requires the collection of relevant data, their processing, interpretation and application in the decision-making process. In this regard, the procured equipment enables various aspects of traffic to be observed in a systematic and measurable manner: from the characteristics of traffic flows and user behaviour, through infrastructure conditions, to the impact of transport on the environment and quality of life in urban areas.



**Figure 1.** Laboratory for Traffic and Transport

The equipment procured through the SPHERE project plays a key role in the development of practical competencies. It enables the implementation of laboratory exercises, field research, demonstration activities, student projects, professional analyses and scientific research. Special emphasis is placed on the application of the equipment in the areas of sustainable transport, urban mobility, active modes of movement, public transport, traffic safety, traffic analytics, digitalisation of transport infrastructure and the assessment of the impact of traffic on the environment.

Within the laboratory, it is possible to develop and implement various types of practical tasks. Students can learn how to collect and analyse data on traffic flows, how to assess conditions for walking and cycling, how to evaluate the functioning of public transport, how to analyse conflict situations and risks in traffic, and how different scenarios of traffic organisation can be simulated using software tools. In this way, the laboratory enables abstract concepts from teaching to be transformed into concrete experiences, measurements and results.

The particular value of the laboratory lies in its interdisciplinary role. Sustainable transport encompasses several interconnected areas: traffic engineering, urban planning, traffic safety, environmental protection, energy efficiency, digitalisation, public

policies and social accessibility. Therefore, the laboratory is not limited to a single course or one narrow field, but represents a common basis for the development of various educational and research activities. It enables students to view transport as a complex system in which technical solutions must be aligned with users' needs, environmental protection, safety requirements and the principles of social equity.

The Laboratory for Traffic and Transport should contribute to the improvement of the teaching process through the introduction of modern learning methods. Instead of passive acquisition of knowledge, students are encouraged to actively participate in the research process: to ask questions, define problems, collect data, analyse results, draw conclusions and propose improvement measures. Such an approach is fully aligned with the need to educate professionals who will be capable of responding to the challenges of modern mobility, including increasing motorisation, congestion, pollution, traffic unsafety, insufficient accessibility of public transport and the need for a greater share of active modes of movement.



**Figure 2.** Control Desk in the Laboratory for Traffic and Transport

The significance of the laboratory is particularly pronounced in the context of developing sustainable urban mobility. Modern cities face numerous challenges, such as excessive use of private cars, reduced air quality, noise, traffic congestion, insufficiently safe conditions for pedestrians and cyclists, and unequal accessibility of transport services. Through laboratory work, it is possible to analyse these problems, test different solutions and develop recommendations that contribute to a more efficient, safer and more environmentally friendly transport system.

One of the important functions of the laboratory is to support the development of active mobility. Walking and cycling represent the most sustainable forms of movement, but their development requires high-quality, safe and accessible infrastructure. In this regard, the laboratory enables the analysis of pedestrian and bicycle flows, assessment of the level of service, identification of spatial barriers, examination of safety risks and formulation of measures to improve movement conditions. This is particularly important for urban areas where it is necessary to create conditions for short trips to be made to a greater extent on foot, by bicycle or by other sustainable modes of movement.

In addition to active mobility, the laboratory also has an important role in the analysis of public transport. Public transport represents one of the basic elements of a sustainable transport system, as it enables the transport of a larger number of passengers with lower consumption of space and energy per user. Through laboratory and field activities, it is possible to analyse the accessibility of stops, service quality, regularity, reliability, line occupancy, connectivity with other modes of transport and the possibilities of integrating public transport with walking, cycling and new forms of mobility.

The laboratory also enables the development of knowledge in the field of traffic modelling and simulation. By applying modern software tools, it is possible to create digital models of intersections, street networks, corridors and urban zones, as well as to examine the effects of different organisational and infrastructural measures. Simulations make it possible to assess, before implementation in practice, the consequences of changes in traffic regimes, the introduction of public transport priority, changes to signal plans, the arrangement of pedestrian and bicycle areas, or the application of traffic calming measures. In this way, the laboratory contributes to making higher-quality and better-argued decisions.

An important segment of the laboratory's work relates to traffic safety. Sustainable transport cannot be viewed separately from safety, because a transport system that produces a high level of casualties cannot be sustainable. Laboratory equipment and working methods enable the analysis of road user behaviour, identification of high-risk locations, assessment of the impact of infrastructural elements on safety, and the analysis of speeds, conflicts and other risk indicators. Such results may be useful in teaching, research, preparation of studies, as well as in cooperation with local self-governments and other institutions responsible for improving traffic safety.

The laboratory also has a significant role in the field of environmental protection. Transport is one of the important sources of harmful gas emissions, noise, energy consumption and occupation of space. Therefore, it is important for future professionals to understand how different forms of movement, traffic organisation, vehicle fleet structure and user habits affect the environment. Through practical activities, it is possible to analyse the environmental aspects of transport, compare different mobility scenarios and assess measures that contribute to reducing the negative impacts of traffic.

In addition to its teaching and research functions, the laboratory has the potential to become a place of cooperation between the Faculty, the public sector, the economy, professional organisations and the local community. Problems in the field of traffic and transport often go beyond the academic community and require cooperation among different stakeholders. The laboratory can serve as a platform for the implementation of joint projects, professional training, workshops, demonstrations, analyses and consulting activities. In this way, knowledge developed in an academic environment can be transferred into practice and used to solve specific problems in local and regional transport systems.

It is particularly important that the laboratory enables the strengthening of the connection between education and labour market needs. Modern employers in the field of traffic and transport increasingly seek professionals who, in addition to theoretical knowledge, also possess practical skills: working with equipment, collecting and processing data, using software tools, preparing analyses, interpreting results and preparing professional recommendations. Work in the laboratory enables students to acquire precisely these competencies, which contributes to their better preparedness for professional challenges after completing their studies.

The equipment catalogue presented in the continuation of this manual includes various technological resources selected in accordance with the objectives of the SPHERE project and the needs of developing modern teaching and research in the field of sustainable transport. Each piece of equipment has its specific purpose, but their greatest value is achieved through integrated application. By combining different devices, instruments and software tools, it is possible to obtain a more comprehensive insight into the functioning of the transport system and to better understand the relationships between infrastructure, users, vehicles, the environment and management measures.

In this regard, the Laboratory for Traffic and Transport represents more than a technically equipped space. It is the basis for the development of a modern educational model in which knowledge is acquired through research, experiment, analysis and application. Its development contributes to strengthening the role of the Faculty of Technical Sciences as an institution that actively participates in the modernisation of teaching, the development of scientific research and the promotion of sustainable, safe and efficient transport.

In essence, the establishment of the Laboratory for Traffic and Transport within the SPHERE project represents a significant investment in the future of education and

research in the field of traffic and transport. It enables the principles of sustainable transport to be viewed not only as a theoretical concept, but also as a practical framework for the analysis, planning and improvement of real transport systems. Through the work of the laboratory, conditions are created for the development of new teaching content, the improvement of existing study programmes, the implementation of high-quality research, the training of professionals and support for the local community in the process of transition towards more sustainable mobility.

### 3. EQUIPMENT IN THE LABORATORY FOR TRAFFIC AND TRANSPORT

The equipment in the Laboratory for Traffic and Transport was procured with the aim of supporting modern teaching, research and professional work in the field of sustainable transport. In accordance with the objectives of the Erasmus+ project SPHERE – Sustainable Transportation within the Framework of Green Deal, the equipment is focused on developing the practical competencies of students, teachers, researchers and professionals in the areas of digitalisation of transport infrastructure, traffic flow analysis, traffic safety, environmental protection, mobility management and the application of modern technologies in the planning of sustainable transport systems.

Modern transport systems require the application of precise measuring devices, digital tools, software for analysis and simulation, as well as equipment that enables field data collection, processing and visualisation. Therefore, the equipment procured through the SPHERE project was selected to enable the connection of theoretical knowledge with practical work. Its application makes it possible to analyse real traffic and transport problems based on data, develop sustainable mobility scenarios and train future professionals to apply modern methods in the planning, management and improvement of the transport system.

The particular value of this equipment lies in the fact that it enables an integrated approach to transport analysis. Sustainable transport does not only imply reducing negative impacts on the environment, but also developing a safer, more accessible, more efficient and technologically advanced system for the movement of people and goods.

Therefore, the laboratory equipment can be used for different types of activities:

- field measurements,
- digital surveying of space,
- analysis of traffic infrastructure,
- reconstruction of traffic events,
- assessment of movement conditions,
- route planning,
- support for teaching,
- preparation of student papers, scientific research projects and professional analyses.

Within the SPHERE Erasmus+ project, the following equipment and software were procured:

- Geosun GS-260X LiDAR Scanning. Digital surveying and 3D mapping of transport infrastructure, traffic corridors, urban areas and road elements for the purpose of analysing conditions for sustainable mobility.

- PC Crash 15.0 Expert (3D). Software for 3D analysis and simulation of traffic accidents, assessment of safety risks and support for measures aimed at improving traffic safety.
- EPSON WF-100W Printer. Mobile printing of measurement results, reports, field forms, sketches and teaching materials during laboratory and field work.
- KINGSTON U3 V30 microSDXC 512GB Canvas Go Plus 170R A2 + adapter SDCG3/512GB. Storage and transfer of large amounts of field data, videos, photographs, LiDAR data and materials for the analysis of transport infrastructure.
- GARMIN DriveSmart 76 MT-D. Navigation, route planning, accessibility analysis and support for field research in the field of mobility and transport.
- InfiRay AL25 Thermal Imaging Monocular. Thermal observation and analysis of visibility conditions, identification of road users and support for safety research under different environmental conditions.

The equipment procured through the SPHERE project represents the basis for the development of laboratory work in the field of sustainable transport. It enables the transport system to be viewed as a space that should be analysed from multiple perspectives: infrastructural, safety, environmental, technological and user-oriented. In this way, the laboratory gains the capacity to support various types of teaching and research activities, from simple practical exercises to complex analyses of transport infrastructure and traffic processes.

### 3.1. The Role of Equipment in Teaching, Research and Professional Practice

The equipment in the laboratory enables the development of practically oriented teaching. Students can become familiar with modern devices and software used in professional practice, while also understanding their application in the field of sustainable transport through practical tasks. This is particularly important because modern education in the field of traffic and transport requires students not only to be users of theoretical knowledge, but also active participants in the process of measurement, analysis, simulation and drawing conclusions.

In terms of research, the equipment enables the implementation of various studies and analyses. It is possible to investigate the quality of infrastructure for pedestrians and cyclists, analyse traffic conflicts, examine visibility conditions, assess safety risks, perform digitalisation of traffic corridors and develop scenarios for the improvement of the transport system. Such research can serve as a basis for scientific papers, master's theses, doctoral dissertations, student projects and professional studies.

In practical application, the laboratory can provide support to local self-governments, public institutions and other stakeholders. Based on data collected and processed in the laboratory, it is possible to prepare recommendations for improving traffic infrastructure, enhancing safety, developing active mobility, optimising routes, arranging pedestrian and bicycle areas and planning measures to reduce the negative impacts of traffic on the environment.

### 3.2. Connection with Equipment from Other Erasmus+ Projects

Although the focus of this manual is on the equipment procured within the SPHERE Erasmus+ project, it is important to emphasise that the Faculty of Technical Sciences also possesses other equipment procured through previous Erasmus+ projects, which may be useful for teaching, research and practical work in the field of sustainable transport.

Through the Erasmus+ project TRAFSAF, equipment was procured that is particularly important for researching driver behaviour and traffic safety, including a driving simulator and equipment for educational demonstrations, such as goggles for simulating the influence of alcohol. This equipment can complement the activities within the Laboratory for Traffic and Transport, especially in research related to the human factor, risk perception, reaction time, driver behaviour and education on safe participation in traffic. In the context of sustainable transport, such equipment is significant because it supports the development of a safer traffic system and the improvement of traffic behaviour culture.

Through the Erasmus+ project DGTRANS, additional equipment was procured, primarily related to the safety of dangerous goods transport, but by its function it can also be used in the broader context of sustainable transport. This equipment includes a multifunctional diagnostic device, network equipment for connectivity and monitoring, a noise level meter, a smart security camera, a particle counter and air quality analyser, a tablet device for field work, a protective coating thickness gauge, an external SSD for data storage, a tester for vehicle batteries and electrical systems, a graphics tablet, an action camera and a GPS device for navigation and route tracking.

This equipment can be useful as a supplement to SPHERE laboratory activities, especially in analyses related to the impact of traffic on the environment, noise monitoring, air quality assessment, field data collection, route tracking, vehicle roadworthiness and the digital visualisation of risks. In this way, equipment procured through different Erasmus+ projects can be used in an integrated manner for the development of modern teaching and research in the field of transport.

The equipment procured within the SPHERE Erasmus+ project represents a key basis for the work of the Laboratory for Traffic and Transport in the field of sustainable mobility. Its application enables the digitalisation of infrastructure, safety analysis, route

planning, data processing, visualisation of results and the development of practical competencies of students and professionals. At the same time, the possibility of connecting it with equipment from other Erasmus+ projects further expands the capacities of the laboratory and enables a more comprehensive consideration of the traffic system.

In the following chapters, each device and software package will be presented separately, with a description of its purpose, method of application and possibilities for use in teaching, research and professional work in the field of sustainable transport.

#### 4. LiDAR SYSTEM

Geosun GS-260X LiDAR Scanning represents one of the most important devices procured within the Erasmus+ SPHERE project, as it enables modern digital surveying, mapping and analysis of transport infrastructure. It is a compact medium-range LiDAR system intended for the collection of high-precision spatial data in the form of a point cloud. According to the available technical data provided by the manufacturer, the system integrates a laser scanner; a GNSS/INS unit for positioning and orientation, a camera and a data storage unit, enabling dynamic collection of 3D data in real space. The device is lightweight, with an approximate mass of about 1.1 kg, a maximum range of up to 300 m and the possibility of being mounted on different platforms, including a vehicle, a multirotor aircraft and a VTOL platform.



**Figure 3.** LiDAR system

In the context of the Laboratory for Traffic and Transport, this device has exceptional value because it enables traffic infrastructure to be viewed not only descriptively or through traditional field notes, but as a precise digital model. In this way, students and researchers can analyse streets, intersections, road sections, pedestrian areas, bicycle paths, public transport stops, parking areas, zones of conflicting movements and other elements of the transport system based on actually measured spatial data.

LiDAR technology is of particular importance for sustainable transport, because modern mobility planning requires accurate, detailed and spatially precise data. Decisions on improving pedestrian infrastructure, developing bicycle corridors, organising public transport, traffic calming, improving safety and reducing the negative impacts of transport must be based on a reliable analysis of the existing situation. The Geosun GS-260X enables precisely such an approach, as it can be used to obtain 3D representations of space containing information on the position, shape, height, width, slope and mutual relationships of infrastructure elements.

#### 4.1. The Role of LiDAR Technology in Sustainable Transport

Sustainable transport implies the development of a system that is safe, accessible, efficient, environmentally friendly and adapted to the needs of different categories of users. In order to plan and improve such a system, it is necessary to understand the real characteristics of the space in which traffic takes place. Traditional methods of field surveying are often time-consuming, limited in scope and dependent on a large number of manual measurements. LiDAR systems enable faster, more detailed and more objective collection of spatial data.

By applying the Geosun GS-260X, it is possible to create a digital basis for the analysis of transport infrastructure. This is particularly important in situations where it is necessary to examine whether safe and continuous conditions exist for pedestrians, cyclists, public transport users, persons with disabilities and other vulnerable road users. For example, based on LiDAR scans, it is possible to analyse sidewalk width, the position of obstacles, height differences, gradients, sight distance, the position of traffic signs, intersection geometry and spatial conditions for the movement of non-motorised users.

In the field of sustainable transport, this device can be particularly useful for:

- digitalisation of traffic infrastructure;
- analysis of pedestrian and bicycle corridors;
- assessment of accessibility for persons with reduced mobility;
- analysis of public space in relation to mobility;

- identification of infrastructural deficiencies;
- traffic safety assessment;
- analysis of sight distance and visibility;
- planning of traffic calming measures;
- development of 3D models of streets, intersections and corridors;
- support for GIS analyses and spatial planning;
- preparation of data for traffic simulations;
- visualisation of the existing and planned state of infrastructure.

In this way, the LiDAR system is not only a device for surveying space, but also a tool that enables better, more evidence-based and more sustainable decisions in the field of transport.

## 4.2. Significance of the Geosun GS-260X for Teaching

One of the main objectives of the Laboratory for Traffic and Transport is to improve the teaching process through practical work. The Geosun GS-260X enables students to become familiar with technology that is increasingly being applied in modern traffic engineering, geoinformatics, infrastructure planning and traffic safety.

Instead of learning about road geometry, intersections, sight distance, pedestrian infrastructure or bicycle paths only from textbooks and images, students can learn based on a real digital model of space. Such an approach significantly improves the quality of teaching, as it enables the connection between theory and practice.

Students can learn:

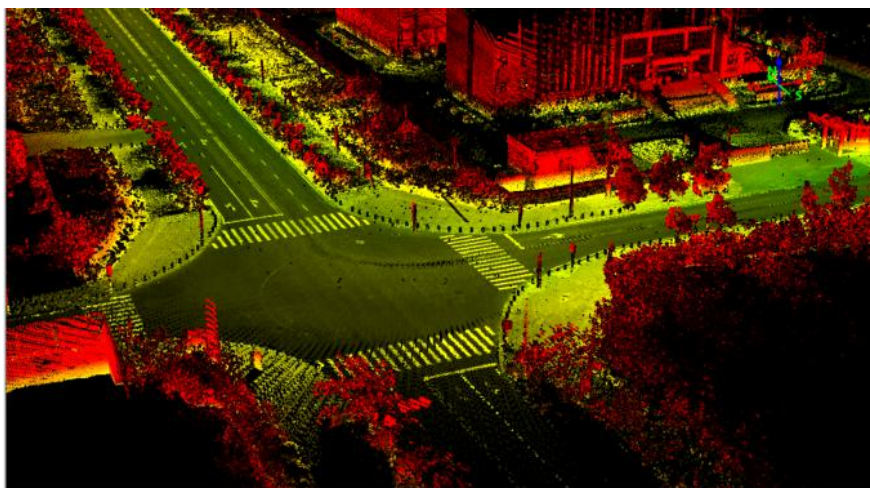
- how to plan field surveying;
- how to prepare equipment for LiDAR scanning;
- how to define the scanning area;
- how to collect spatial data;
- how to generate a point cloud;
- how to perform basic data processing;
- how to identify elements of traffic infrastructure from a point cloud;
- how to measure widths, heights, distances, gradients and spatial relationships;
- how the obtained data are used for the analysis of safety and sustainable mobility;
- how to present results in reports, maps, models and presentations.

A particular advantage of this device is that it enables the development of a research-oriented way of thinking among students. They do not receive ready-made data, but learn how to collect, verify, process, analyse and interpret data themselves. In this way, competencies that are necessary for a modern traffic engineer are developed: precision, systematic work, analytical thinking, spatial understanding, working with digital data and the ability to propose measures based on evidence.

### 4.3. Examples of Student Activities with the Geosun GS-260X

In teaching and laboratory exercises, the Geosun GS-260X can be used for a large number of practical activities. These activities can be adapted to different courses, levels of study and research topics.

Students can perform LiDAR scanning of a selected intersection and, based on the obtained 3D model, analyse its geometric characteristics. Lane widths, turning radii, the position of pedestrian crossings, the distance of traffic signs, pedestrian space, the position of curbs and sight distance can be measured.



**Figure 4.** Intersection Scanned Using a LiDAR System

This activity is significant because intersections represent some of the most complex and highest-risk points in the traffic network. Through the analysis of a 3D model, students can observe how intersection geometry affects the movement of vehicles, pedestrians and cyclists, as well as which elements may pose a safety risk.

LiDAR scans can be used to analyse pedestrian movement conditions. Students can measure sidewalk width, identify obstacles, analyse the continuity of pedestrian areas, the position of pedestrian crossings, gradients and access points for persons with disabilities.



**Figure 5.** Data for pedestrian crossing

This activity is directly related to sustainable transport, because walking represents the most basic and most sustainable mode of movement. However, for walking to be a real alternative to short car trips, the infrastructure must be safe, accessible and comfortable. The Geosun GS-260X enables such conditions to be analysed on the basis of precise spatial data.

Students can scan existing or planned bicycle corridors and analyse whether spatial conditions exist for the safe movement of cyclists. The width of the bicycle path, separation from motor traffic, intersections with pedestrian and motorised flows, obstacles, gradients and route continuity can be examined.

This type of exercise is important because the development of bicycle traffic requires well-planned infrastructure. LiDAR data can help determine whether a certain space is suitable for introducing a bicycle path, expanding an existing path or improving safety at conflict points.

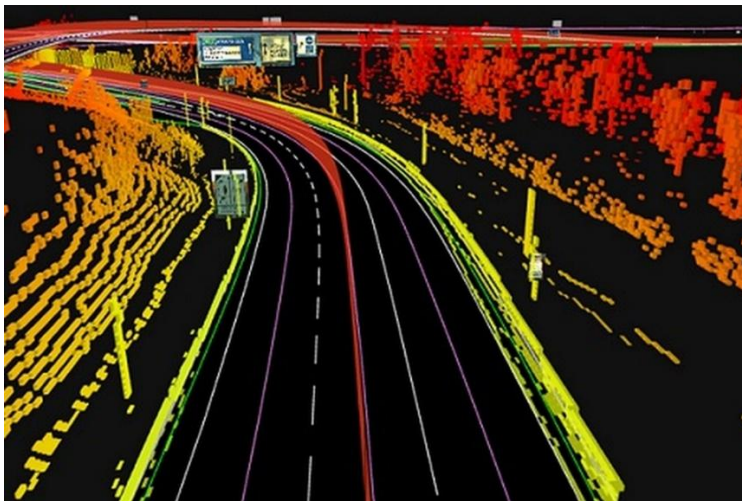
Public transport is one of the key elements of a sustainable transport system. Students can use the Geosun GS-260X to scan public transport stops and their surroundings. The analysis may include access to the stop, the width of pedestrian areas, the position of the

shelter, the safety of pedestrian crossings near the stop, passenger waiting space, distance from intersections and the possibility of integration with walking and cycling.

Sustainable transport must be accessible to all users, including children, elderly people, persons with disabilities and persons with reduced mobility. LiDAR technology enables precise analysis of gradients, height differences, curbs, ramps, obstacles and other elements that affect accessibility.

Students can analyse whether a particular street, sidewalk, stop or public space is adapted to all categories of users. Based on the results, they can propose measures such as removing obstacles, arranging ramps, widening sidewalks, improving access to pedestrian crossings or better positioning of urban equipment.

Traffic safety largely depends on sight distance and visibility. The Geosun GS-260X can be used to scan space and analyse whether drivers, pedestrians and cyclists have sufficiently good visibility at intersections, pedestrian crossings, curves, access points and other critical locations.



**Figure 6.** Data for roadway

Students can identify objects that obstruct sight distance, such as parked vehicles, vegetation, fences, poles, advertising panels or improperly positioned equipment. Such analysis has direct application in traffic safety and can serve as a basis for proposing improvement measures.

Based on LiDAR scanning, it is possible to create a digital model of an existing street and then analyse different improvement scenarios. For example, students can examine the possibility of introducing a bicycle path, widening sidewalks, reducing the number of

traffic lanes, arranging public transport stops, establishing traffic-calmed zones or redesigning an intersection.

This activity is particularly important because it teaches students that sustainable transport is not only a technical issue, but also a process of finding a balance between different needs: vehicle movement, pedestrian safety, space for cyclists, public transport, greenery, parking, noise, emissions and the quality of public space.

#### 4.4. Significance for Scientific Research

The Geosun GS-260X can significantly improve scientific research in the field of traffic and transport. Precise spatial data enable the development of research dealing with the relationship between infrastructure and road user behaviour, the impact of road geometric characteristics on safety, the assessment of conditions for active mobility, and the development of methodologies for the digital analysis of transport space.

The device can be useful in research related to:

- pedestrian and cyclist safety;
- analysis of school zones;
- analysis of public transport zones;
- identification of unsafe infrastructure elements;
- risk assessment at intersections;
- analysis of horizontal and vertical road elements;
- assessment of visibility conditions;
- development of 3D databases on traffic infrastructure;
- application of GIS tools in mobility planning;
- development of quality indicators for pedestrian and bicycle infrastructure;
- preparation of data for simulation models;
- comparison of the existing and designed state of infrastructure.

A particular advantage of this device is that it enables a high level of objectivity in analysis. Instead of describing infrastructure problems only qualitatively, it is possible to measure, document and visually present them. This is important for scientific papers, professional studies, projects and cooperation with local self-governments.

#### 4.5. Significance for Traffic Safety

Sustainable transport and traffic safety are inseparable. A transport system that is not safe cannot be sustainable, as it produces significant social, economic and health-related consequences. The Geosun GS-260X can be extremely useful in analysing the safety characteristics of infrastructure.

Using this device, it is possible to analyse:

- intersection geometry;
- curve radii;
- sight distance at access points;
- the position of pedestrian crossings;
- the relationship between pedestrian areas and the carriageway;
- the position of bicycle paths;
- zones where different road users interact;
- the presence of physical obstacles;
- the visibility of traffic signs;
- spatial conditions for the movement of vulnerable road users;
- risks in the zones of schools, stops, intersections and pedestrian flows.

Such analyses can help identify infrastructural risk factors. For example, if a pedestrian crossing is located where sight distance is limited, the LiDAR model can clearly show which elements obstruct pedestrians or drivers. If a sidewalk is too narrow or interrupted, 3D data can show where pedestrians are forced to step onto the carriageway. If the turning radius is too large, the analysis can indicate conditions that encourage higher vehicle speeds in areas with pedestrian flows.

#### 4.6. Significance for Active Mobility Planning

Active mobility, which includes walking and cycling, represents one of the basic pillars of sustainable transport. However, its development depends on the quality of infrastructure. The Geosun GS-260X enables pedestrian and bicycle infrastructure to be analysed in a precise and systematic manner.

In practice, students can use LiDAR data to assess:

- whether sidewalks are sufficiently wide;
- whether there are obstacles on pedestrian areas;

- whether pedestrian crossings are logically positioned;
- whether ramps are accessible;
- whether there is continuity of the pedestrian network;
- whether the bicycle path has sufficient width;
- whether bicycle infrastructure is physically protected;
- whether there are conflict points between pedestrians, cyclists and motor vehicles;
- whether public transport stops are well connected to the pedestrian and bicycle network.

This type of analysis enables sustainable transport to be viewed not only as a strategic goal, but also as a specific spatial task: how to arrange a street, intersection or corridor so that they are safer, more accessible and more suitable for sustainable modes of movement.

#### 4.7. Connection with Digitalisation and Smart Transport Systems

Digitalisation is one of the key directions in the development of modern transport. The Geosun GS-260X enables the creation of a digital database of transport infrastructure, which can serve as a basis for the development of smart transport systems, GIS analyses, digital twins of infrastructure and advanced mobility models.

Digital models created through LiDAR scanning can be used for:

- creating 3D representations of the existing state;
- developing digital archives of traffic infrastructure;
- comparing the state of infrastructure across different time periods;
- monitoring changes in the road and street network;
- supporting the infrastructure maintenance process;
- preparing data for simulations;
- visualising planning solutions;
- communicating with decision-makers and the public.

This approach is particularly important in teaching, because students acquire knowledge that is aligned with contemporary trends in Europe and worldwide. They learn that the transport system is not only physical infrastructure, but also a system of data, models, analyses and management decisions.

## 5. SOFTWARE FOR TRAFFIC SIMULATIONS

PC Crash 15.0 Expert (3D) is a specialised software tool for the analysis, reconstruction and 3D simulation of traffic accidents and other traffic events. Within the Laboratory for Traffic and Transport, established through the Erasmus+ SPHERE project, this software has particular significance because it enables traffic safety to be analysed in a modern, visual, measurable and scientifically based manner.

Although sustainable transport is often associated with the reduction of emissions, the development of public transport, walking, cycling and energy efficiency, its essence is much broader. A transport system cannot be sustainable if it is not safe. Every traffic accident, especially one involving injured or killed persons, produces serious social, economic, health-related and spatial consequences. Therefore, traffic safety is one of the fundamental pillars of sustainable transport.

PC Crash 15.0 Expert (3D) enables students, teachers, researchers and professionals to become familiar with methods used in modern traffic accident analysis. According to official data, PC-Crash is a 3D tool for simulating collisions and movement trajectories, intended for the analysis of different types of traffic accidents, while the results can be presented through 3D animations, reports, tables and graphs.

### 5.1. Main Purpose of the Software

The main purpose of PC Crash 15.0 Expert (3D) software is the reconstruction of traffic accidents and the analysis of the movement of participants before, during and after a collision. The software enables the user to create a traffic accident scene in a digital environment, enter relevant parameters, define vehicles and participants, model their movement and examine different scenarios that may explain how the accident occurred.

Within laboratory work, this software can be used for:

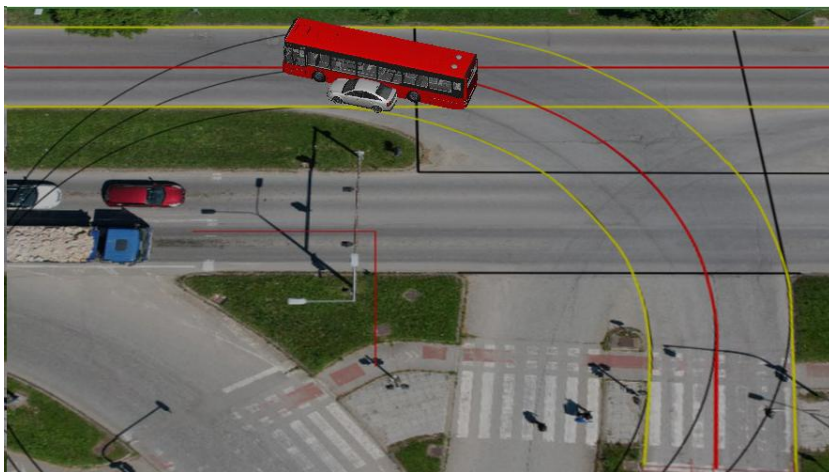
- simulation of vehicle movement;
- reconstruction of traffic accidents;
- analysis of vehicle-to-vehicle collisions;
- analysis of vehicle–pedestrian collisions;
- analysis of vehicle–motorcycle collisions;
- analysis of vehicles running off the carriageway;
- analysis of vehicle rollovers;
- analysis of braking and stopping distances;
- examination of the impact of speed on the severity of consequences;

- assessment of the possibility of accident avoidance;
- creation of 3D visualisations and animations;
- preparation of graphs, tables and reports.

According to the manufacturer's description, PC-Crash enables the simulation of collisions involving up to 32 vehicles in a 2D and 3D environment, including vehicle-to-vehicle, vehicle-to-motorcycle and vehicle-to-pedestrian collisions, occupant movement and vehicle rollover.

## 5.2. Significance of PC Crash 15.0 for Sustainable Transport

In the context of the SPHERE project, PC Crash 15.0 Expert (3D) plays an important role because it connects traffic safety with the concept of sustainable mobility. Sustainable transport should enable the movement of people and goods in a way that is safe, efficient, accessible, environmentally friendly and socially responsible. Safety is a prerequisite in this system, because no mode of transport can be acceptable if it produces a high level of risk for users.



**Figure 7.** Simulation of crashes

This software enables traffic safety to be analysed through specific situations. For example, students can examine how a change in speed affects stopping distance, how reaction time affects the possibility of avoiding an accident, how the position of a

pedestrian crossing affects vehicle–pedestrian conflict, or how different carriageway conditions change vehicle movement dynamics. Such analyses are particularly important in planning measures aimed at reducing risk and increasing the safety of all road users.

PC Crash 15.0 can help in understanding the relationship between infrastructure, vehicles, road user behaviour and the consequences of traffic accidents. This is fully aligned with the modern approach to traffic safety management, in which accidents are not viewed as random events, but as the result of a combination of multiple factors: speed, road, vehicle, human factor, environment and traffic organisation.

### 5.3. Role in Teaching and the Development of Practical Competencies

One of the most important functions of PC Crash 15.0 Expert (3D) software in the laboratory is the improvement of the teaching process. Traffic and transport students often learn about traffic accidents, speed, braking, sight distance, conflicts and collisions through theoretical formulas and descriptions. PC Crash enables these concepts to be transformed into visual, dynamic and interactive models.

Through working with the software, students can understand:

- how a traffic accident scene is created;
- how geometric road data are entered;
- how vehicles and their characteristics are defined;
- how movement trajectories are entered;
- how speeds are analysed;
- how braking marks and vehicle positions are interpreted;
- how the possibility of accident avoidance is examined;
- how a 3D animation of the event is created;
- how results are presented through graphs and reports;
- how conclusions are drawn based on several possible scenarios.

This type of teaching has great pedagogical value. Students do not observe a traffic accident only as a final outcome, but learn to analyse the process that led to it. They can change individual parameters, such as speed, reaction time, coefficient of friction, vehicle position or the moment braking begins, and observe how the simulation outcome changes. In this way, they develop the ability for engineering thinking and understanding cause-and-effect relationships in traffic.

#### 5.4. Application in Traffic Accident Analysis

PC Crash 15.0 Expert (3D) enables detailed analysis of different types of traffic accidents. Its application is particularly significant in situations where it is necessary to examine several possible scenarios and determine the most likely sequence of events.



**Figure 8.** Simulation crashes

In laboratory conditions, typical types of accidents can be analysed, such as:

- vehicle–pedestrian collision;
- side-impact collision at an intersection;
- collision during a left-turn manoeuvre;
- rear-end collision;
- vehicle–cyclist collision;
- accident in the area of a pedestrian crossing;
- vehicle running off the carriageway;
- vehicle rollover;
- collisions in the area of roundabouts;
- accidents in conditions of reduced visibility.

For each of these situations, it is possible to define the initial conditions, analyse the movement of the participants, examine the influence of speed and assess whether the accident could have been avoided under certain conditions. This is particularly important for understanding prevention, because students can see how small changes in speed, reaction time or the position of participants can lead to significantly different outcomes.

## 5.5. 3D Visualisation as a Teaching and Research Tool

One of the greatest advantages of PC Crash 15.0 Expert (3D) is the possibility of visualising results. Instead of presenting accident analysis only through text, formulas and numbers, the software enables the creation of 3D displays and animations. The official description of the PC-Crash software highlights the possibility of presenting results through 3D animations, detailed reports, tables and graphs.

3D visualisation has several advantages:

- it facilitates the understanding of complex traffic situations;
- it enables a clearer presentation of the movement of participants;
- it helps in comparing different scenarios;
- it is useful for teaching and training;
- it enables better communication of results;
- it can be used in presentations, reports and professional analyses.

In the educational process, 3D visualisation is of particular importance because it enables students to see the dynamics of a traffic event. For example, in the analysis of a vehicle striking a pedestrian, students can follow the movement of the vehicle, the position of the pedestrian, the moment the danger is perceived, the beginning of braking and the point of impact. Such visual analysis contributes to a better understanding of risks and the importance of preventive measures.

## 5.6. Speed Analysis and the Possibility of Accident Avoidance

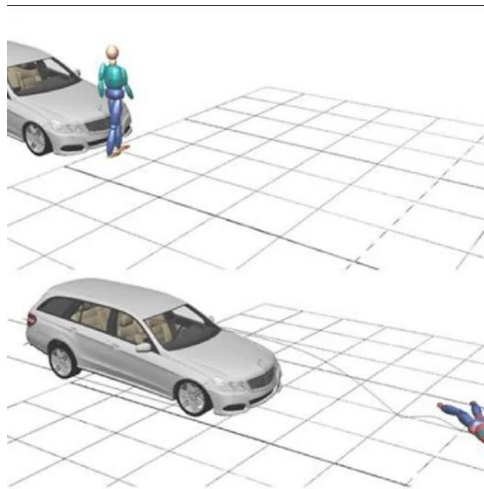
One of the most important applications of PC Crash 15.0 software relates to speed analysis. Speed is one of the key factors that influence the occurrence of an accident, the possibility of avoiding a collision and the severity of consequences. Within laboratory

exercises, students can examine how different speeds affect stopping distance, time to collision, impact force and the space required to avoid an accident.

This aspect is very important for sustainable transport, because a system that encourages high speeds in urban areas is usually neither safe, nor pleasant, nor suitable for pedestrians and cyclists. PC Crash enables the effects of speed to be presented concretely and visually. For example, students can simulate the same situation at speeds of 30 km/h, 50 km/h and 60 km/h and analyse how the outcome changes. Such exercises can strongly demonstrate the importance of speed limits, 30 km/h zones, traffic calming and the protection of vulnerable road users.

## 5.7. Application in the Analysis of Vulnerable Road Users

PC Crash 15.0 Expert (3D) is particularly useful for the analysis of accidents involving pedestrians, cyclists and motorcyclists. These categories of road users are especially important in the concept of sustainable transport, because walking and cycling represent desirable modes of mobility, but their development depends on the level of safety.



**Figure 9.** Simulation of pedestrian crashes

If pedestrians and cyclists are not safe, citizens will use active modes of movement less, which increases dependence on cars. Therefore, the analysis of accidents involving vulnerable road users is of great importance for planning a sustainable transport system.

Through PC Crash, students can analyse:

- vehicle–pedestrian collisions at pedestrian crossings;
- vehicle–pedestrian collisions outside pedestrian crossings;
- vehicle–cyclist collisions at intersections;
- vehicle–cyclist conflicts during turning manoeuvres;
- motorcycle–passenger car collisions;
- the impact of vehicle speed on the accident outcome;
- the impact of driver reaction time;
- the impact of visibility and the position of participants.

Such analyses can be used as a basis for proposing measures such as speed reduction, improved lighting, better positioning of pedestrian crossings, physical protection of bicycle paths, arrangement of school zones and the application of traffic calming measures.

## 5.8. Use of Video Recordings and Modern Data Sources

Version PC Crash 15.0 introduced important capabilities for working with video recordings. According to the official description of its features, PC-Crash 15.0 enables direct work with video recordings, lens distortion correction, the use of video frames as new 3D cameras, automatic vehicle tracking in video recordings and calculation of 2D movement.

This functionality is very important for modern traffic analysis. Today, video recordings from cameras, drones, vehicles or other devices are increasingly common sources of data. In laboratory work, students can learn how video recordings are used for movement analysis, marking vehicle positions, tracking trajectories and estimating speed.

In the context of sustainable transport, this capability is significant because video analysis can be used not only for accident reconstruction, but also for research into road user behaviour, conflicts, pedestrian and cyclist movement, as well as the effects of different traffic measures.

## 6. THERMAL CAMERA FOR TRAFFIC RECORDING

The InfiRay AL25 Thermal Imaging Monocular is a thermal imaging monocular that enables the detection of objects, vehicles, pedestrians, cyclists, animals and other elements in space based on thermal radiation. Unlike conventional optical devices, thermal imaging devices do not depend solely on visible light, but enable observation even in conditions of reduced visibility, such as night, fog, smoke, rain, poorly lit zones or parts of infrastructure without public lighting.



**Figure 10.** InfiRay AL25 Thermal Imaging Monocular

In the context of sustainable transport, this device has a significant role because it contributes to the analysis of safety, accessibility and the quality of the transport environment. Sustainable transport does not only imply environmentally friendly modes of movement, but also a safe system in which pedestrians, cyclists, public transport users and drivers can move with the lowest possible risk. It is particularly significant for analysing conditions at night and under reduced visibility, when the risk for vulnerable road users is increased.

The application of the InfiRay AL25 in the Laboratory for Traffic and Transport can be directed towards assessing the visibility and detectability of pedestrians and cyclists, analysing unlit or insufficiently lit pedestrian crossings, public transport stops, bicycle corridors, school zones and other high-risk locations. The device makes it possible to check in the field whether road users are sufficiently visible, where “dark zones” exist,

and whether it is necessary to improve public lighting, traffic signs or spatial organisation.

For students, this device is useful because it enables a practical understanding of the relationship between visibility, infrastructure and traffic safety. Through laboratory and field exercises, students can analyse how lighting conditions affect the safety of pedestrians, cyclists and drivers, how the detectability of persons differs depending on clothing or equipment, and how the position of lighting poles, pedestrian crossings and stops affects the quality of the traffic environment.

The device can be used in the following activities:

- assessment of the detectability of pedestrians and cyclists in night-time conditions;
- safety analysis of pedestrian crossings without adequate lighting;
- identification of poorly lit zones in urban space;
- analysis of conditions at public transport stops during evening hours;
- safety assessment of bicycle and pedestrian corridors;
- observation of road user movement under reduced visibility conditions;
- support for field research in school zones, intersections and suburban roads;
- documentation of high-risk locations and preparation of recommendations for infrastructure improvement.

The particular value of the InfiRay AL25 lies in the fact that it enables safety analysis from the perspective of real movement conditions. Many traffic locations may appear acceptable during the day, but at night they may become risky due to insufficient lighting, poor detectability of pedestrians, improper positioning of traffic signs or visual obstacles. The thermal imaging monocular enables such problems to be observed and documented.

In a broader sense, the use of this device contributes to the development of a safer and more sustainable transport system. Its application can help in planning measures such as improving public lighting, better marking of pedestrian crossings, improving conditions for cyclists, arranging public transport stops and reducing risks for vulnerable road users. Therefore, the InfiRay AL25 represents a useful tool for teaching, field research and professional analyses in the field of sustainable and safe mobility.

## 7. ADDITIONAL EQUIPMENT IN THE FUNCTION OF SUSTAINABLE TRANSPORT

In addition to the equipment procured within the Erasmus+ SPHERE project, the Laboratory for Traffic and Transport also possesses equipment provided through other international Erasmus+ projects, primarily TRAFSAF and DGTRANS. Although these projects had specific thematic focuses, the procured equipment also has significant application in the broader context of sustainable transport.

Sustainable transport does not only imply environmentally friendly movement, but also includes traffic safety, risk reduction, rational use of resources, reduction of negative environmental impacts, improvement of road user behaviour, application of digital technologies and development of the competencies of future professionals. Therefore, the equipment procured through previous projects represents an important supplementary resource for laboratory, teaching, research and professional work.

This equipment enables sustainable transport topics to be viewed interdisciplinarily — through the analysis of the human factor, vehicle roadworthiness, noise, air quality, route tracking, recording of field conditions, driver education and risk assessment. In this way, a broader laboratory basis is created for understanding the transport system as a complex system in which the human, vehicle, road, environment and management are interconnected.

The following section presents individual devices and equipment from other Erasmus+ projects that can be used to support activities in the field of sustainable transport.

### 7.1. Driving simulator

The driving simulator, procured within the Erasmus+ TRAFSAF project, represents one of the most important devices for researching driver behaviour, analysing risky situations and providing education in the field of traffic safety. Its application is directly connected with the concept of sustainable transport, because safety represents one of the fundamental prerequisites of sustainable mobility. A transport system that produces a high level of risk, traffic accidents and injuries cannot be considered sustainable, regardless of its environmental or economic characteristics.



**Figure 11.** Driving simulator

The simulator enables driver behaviour to be examined in different traffic scenarios under controlled laboratory conditions, without exposing participants to real risk. This is particularly important for the analysis of situations that would be dangerous or ethically unacceptable to test in real traffic. For example, it is possible to simulate the sudden appearance of a pedestrian, sudden braking of the vehicle ahead, driving in conditions of reduced visibility, adverse weather conditions, driver fatigue, increased speed, distraction, or driving near schools, pedestrian crossings and intersections.

In the context of sustainable transport, the simulator can be used to analyse how drivers respond to traffic calming measures, speed-restricted zones, new infrastructure solutions, bicycle paths, pedestrian zones, roundabouts, public transport and different traffic management regimes. In this way, it enables the assessment of how a certain measure may affect driver behaviour before it is implemented in real space.

A particular advantage of the simulator is the possibility of repeating the same scenarios for a larger number of respondents. This enables the comparison of reactions among different groups of drivers, such as young drivers, experienced drivers, professional drivers or drivers with different levels of risk exposure. This approach is significant for

scientific research, as it enables the systematic collection of data on reaction time, travel speed, route choice, braking intensity, distance keeping, compliance with traffic signs and decision-making in critical situations.

For students, the driving simulator has exceptional educational value. Through work on the simulator, students can understand how the human factor affects traffic safety and how driver behaviour changes depending on environmental conditions, infrastructure, speed, visibility and the presence of other road users. They can analyse specific results, compare scenarios and draw conclusions about which measures contribute to a safer and more sustainable transport system.

The simulator can be used in the following activities:

- examination of driver reaction time;
- analysis of young drivers' behaviour;
- simulation of risky traffic situations;
- analysis of the impact of speed on the possibility of avoiding an accident;
- examination of driver behaviour in school zones;
- analysis of drivers' attitudes towards pedestrians and cyclists;
- assessment of the effects of traffic calming measures;
- simulation of driving at night or in conditions of reduced visibility;
- analysis of the impact of distraction on vehicle control;
- education of students and professionals about traffic risks.

In a broader sense, the driving simulator contributes to the development of a preventive approach to traffic safety. Instead of analysing traffic accidents only after they occur, the simulator enables potential risks to be examined in advance. This is in line with the modern approach to sustainable transport, which aims to identify, measure and reduce risks before they lead to negative consequences.

Therefore, the driving simulator represents an important supplementary resource of the Laboratory for Traffic and Transport. Although it was not procured within the SPHERE project, its application is fully compatible with the objectives of sustainable transport, as it contributes to improving safety, educating future professionals, developing research and promoting responsible behaviour in traffic.

## 7.2. Multifunctional Diagnostic Device

The MaxiIM IM608 Pro multifunctional diagnostic device, procured within the Erasmus+ DGTRANS project, represents a significant resource for analysing the technical condition

of vehicles, diagnosing electronic systems and checking the functionality of various transport vehicle components. Although the device was procured primarily to support activities in the field of dangerous goods transport, its application is much broader and can be directly connected with the concept of sustainable transport.



**Figure 12.** Multifunctional Diagnostic Device

Sustainable transport implies that vehicles participating in traffic should be roadworthy, safe, energy-efficient and as environmentally friendly as possible. Modern vehicles contain a large number of electronic systems that affect safety, fuel consumption, harmful gas emissions, vehicle stability, braking, steering, engine operation and vehicle behaviour in critical situations. Therefore, vehicle diagnostics is an important part of the modern approach to transport management.

In teaching and laboratory work, this device enables students to understand the importance of vehicle roadworthiness for the safety and sustainability of the transport system. Through practical exercises, it is possible to analyse basic vehicle operating parameters, read faults from electronic control units, become familiar with the operating principles of OBD systems and understand how technical failures can affect traffic risk, increased fuel consumption or the emission of pollutants.

In the context of sustainable transport, the MaxiIM IM608 Pro can be used for:

- diagnostics of transport vehicles;
- checking vehicle electronic systems;
- analysis of faults that may affect safety;
- checking systems that affect harmful gas emissions;
- educating students about the importance of vehicle roadworthiness;
- analysis of the condition of the vehicle fleet;

- support for practical exercises in the field of vehicle maintenance;
- understanding the relationship between the technical condition of vehicles, safety and environmental protection.

The particular value of this device lies in the fact that it enables the vehicle to be viewed as an active element of a sustainable transport system. It is not enough only to plan high-quality infrastructure and promote sustainable modes of movement; it is also necessary to ensure that the vehicles being used are roadworthy, reliable and compliant with safety and environmental requirements. Therefore, this device represents an important supplementary tool in laboratory work.

### 7.3. Noise Level Meter

The Lutron SL 4036SD noise level meter is a device for measuring noise intensity in traffic and urban environments. Traffic noise is one of the most significant negative impacts of transport on quality of life, especially in urban areas, residential zones, schools, healthcare institutions and along main roads. Therefore, noise measurement is an important part of analysing the sustainability of the transport system.



**Figure 13.** Lutron SL 4036SD noise level meter

In the context of sustainable transport, noise is not viewed only as a nuisance, but as a factor that can affect health, comfort, the attractiveness of public space and the quality of life of the population. A high level of traffic noise may indicate excessive motor traffic load on a street, high speeds, a high share of heavy vehicles, inadequate traffic organisation or an unfavourable relationship between the road and the surrounding space.

In laboratory and field work, the Lutron SL 4036SD can be used for:

- measuring noise alongside roads and streets;
- analysing the impact of traffic on the environment;

- comparing noise levels in different time periods;
- analysing noise in school zones, hospital areas and residential areas;
- assessing the impact of heavy vehicles and public transport;
- examining the effects of traffic calming measures;
- preparing student and research papers;
- preparing recommendations for reducing the negative impacts of transport.

For students, this device is particularly useful because it enables the impact of traffic on the environment to be measured in a simple and practical way. Students can compare different locations, different traffic regimes and different time periods, as well as connect the measured noise values with traffic flow composition, travel speeds and infrastructure characteristics.

In a broader sense, noise measurement contributes to understanding that sustainable transport is not only a matter of movement, but also a matter of quality of life in urban space. Noise reduction can be achieved through the development of public transport, the promotion of walking and cycling, speed reduction, restrictions on heavy vehicle movement, the use of quieter vehicles and better urban planning.

#### 7.4. Particle Counter and Air Quality Analyser

The Particle Counter PC220 is a device for analysing air quality, measuring particle concentration and monitoring parameters such as temperature, humidity and the presence of certain harmful gases. In the field of sustainable transport, air quality is one of the key indicators of the impact of traffic on the environment and public health.



**Figure 14.** The Particle Counter PC220

Road transport, especially in urban areas, can be a significant source of air pollution. Exhaust emissions, particles generated by the wear of tyres, brakes and road surfaces, as well as the resuspension of dust, can negatively affect air quality. Therefore, measuring particles and other parameters is important for understanding the real impact of transport on the environment.

In laboratory and field work, the Particle Counter PC220 can be used for:

- measuring air quality near roads;
- analysing the impact of traffic intensity on particle concentration;
- comparing air quality in different urban zones;
- examining the impact of heavy vehicles and traffic congestion;
- analysing conditions near schools, kindergartens and residential areas;
- monitoring air quality in transport facilities;
- educating students about the environmental aspects of transport;
- preparing recommendations for reducing the negative impacts of traffic.

For students, this device enables them to practically connect traffic flows with environmental consequences. For example, they can measure air quality alongside a street with high traffic intensity, in an area with a higher share of pedestrians and cyclists, or near an intersection with frequent vehicle stopping and starting. Based on the results, they can consider measures such as reducing motor traffic, promoting public transport, arranging green belts, developing bicycle infrastructure and improving traffic management.

This device is particularly important because it enables transport sustainability to be measured through specific environmental parameters, and not only through theoretical assumptions.

## 7.5. Protective Coating Thickness Gauge

The EC-900 protective coating thickness gauge is a device for measuring coating thickness on metal and other surfaces. In the field of transport, protective coatings play an important role in preserving the durability of vehicles, equipment, structures, tanks, containers, barriers, supports and other elements of transport infrastructure.

Although this device can primarily be associated with the transport of dangerous goods, its application is also significant in the context of sustainable transport. Sustainability also implies a longer service life of equipment, rational maintenance, corrosion prevention, reduction of repair costs and prevention of technical failures. Properly maintained transport vehicles and infrastructure elements contribute to the safety, reliability and efficiency of the transport system.



**Figure 15.** Protective Coating Thickness Gauge

In teaching and research, the EC-900 protective coating thickness gauge can be used as a practical tool for understanding the importance of maintenance, technical control and durability of transport equipment and infrastructure. Its application enables students to move beyond theoretical explanations and to examine real surfaces, components and structural elements that are exposed to wear, corrosion and external environmental influences.

The EC-900 can be used for checking the thickness of protective coatings on different types of transport equipment, including vehicle parts, metal structures, containers, tanks, barriers, supports, road equipment and other infrastructure elements. By measuring the coating thickness, it is possible to assess whether the protective layer is adequate, uniform and capable of providing the expected level of protection. This is particularly important in transport systems where equipment and infrastructure are exposed to moisture, temperature changes, mechanical impacts, chemicals, road salt and other factors that may accelerate degradation.

In laboratory exercises, students can analyse the condition of vehicle components and infrastructure elements by comparing measured values with expected or recommended coating thicknesses. In this way, they can understand how insufficient or uneven protective coating may increase the risk of corrosion, reduce the service life of

equipment and lead to additional maintenance costs. Such exercises can also help students understand the connection between preventive maintenance and the safe functioning of transport systems.

The device can also be used for quality control of protective layers. This is important when evaluating whether a coating has been properly applied, whether the surface is sufficiently protected and whether additional maintenance or repair work is required. Through this type of practical work, students become familiar with procedures that are commonly applied in technical inspection, maintenance planning and quality assurance.

In the context of sustainable transport, the EC-900 has particular importance because sustainability is not related only to mobility planning, public transport, walking, cycling or environmental protection. It also includes the rational use of resources, longer service life of vehicles and infrastructure, reduction of unnecessary repairs and prevention of technical failures. Properly maintained equipment reduces the need for frequent replacement of components, lowers maintenance costs and contributes to a more reliable and safer transport system.

This device is also useful for understanding the relationship between maintenance, safety and environmental protection. If transport vehicles, equipment and infrastructure are not properly maintained, the risk of failures, accidents, corrosion, material damage and environmental pollution increases. For example, corrosion on certain transport components may weaken their structural integrity, while inadequate protection of tanks, containers or supporting structures may create additional operational and safety risks.

Therefore, the EC-900 represents a valuable supplementary tool in laboratory work. It enables students to understand that sustainable transport is not only a matter of planning movement, but also a matter of preserving resources, extending the life cycle of equipment and ensuring the safe and efficient operation of the transport system. Through practical exercises with this device, students develop technical awareness, measurement skills and a better understanding of the role of maintenance in modern transport systems.

## 8. CONCLUSION

The Laboratory Manual represents an important result of the activities implemented within the Erasmus+ SPHERE project, with the main objective of improving the practical application of knowledge in the field of sustainable transport. Its purpose is to provide users with a clear overview of the equipment, the methods of its application and the opportunities it offers in teaching, research and professional work. Through the description of modern laboratory equipment, the manual connects theoretical knowledge in the field of traffic and transport with specific methods of measurement, recording, analysis, simulation and data visualisation. In this way, a basis is created for a better understanding of transport processes and the development of competencies necessary for planning a safer, more efficient and more environmentally friendly transport system.

The equipment procured within the SPHERE project is of particular importance because it enables sustainable transport to be studied through a practical and data-based approach. Modern transport systems can no longer be analysed only on the basis of general assessments and theoretical assumptions, but require precise data on infrastructure, user movement, safety risks, accessibility, visibility, spatial organisation and the impact of traffic on the environment. This is precisely why laboratory equipment represents a key instrument for the transition from the traditional way of studying transport to a modern, digitalised and research-oriented model of work.

The manual has a significant educational role because it enables students to acquire practical knowledge that cannot be fully developed through traditional teaching. Through working with the equipment, students learn how to plan field research, how to collect data, how to process them and how to interpret the results in the context of real transport problems. Such an approach develops analytical thinking, independence in work, the ability to draw conclusions based on data and an understanding of the complex relationships between infrastructure, users, vehicles, the environment and management measures.

The application of laboratory equipment is particularly important for the development of active mobility. Walking and cycling represent the most sustainable forms of movement, but their use in everyday life depends on the quality, safety and accessibility of infrastructure. With the help of modern devices, it is possible to analyse the width and continuity of sidewalks, the position of pedestrian crossings, the existence of obstacles, conditions for the movement of persons with reduced mobility, the possibility of introducing bicycle paths and the safety of intersections between different flows. In this way, students can understand that sustainable mobility is not only a strategic goal, but also a specific spatial and engineering task.

The Laboratory Manual also contributes to understanding the importance of public transport in the sustainable transport system. Public transport is one of the most important elements of sustainable mobility, as it enables the transport of a larger number of passengers with lower consumption of space, energy and resources per user. Modern equipment can be used to analyse access to stops, pedestrian connectivity, spatial conditions for users, the safety of public transport zones and the possibilities of integrating public transport with walking, cycling and other modes of movement. Such analyses have practical value for improving the quality of transport services and increasing the attractiveness of sustainable modes of movement.

In addition to its teaching role, the equipment procured through the SPHERE project has great research potential. It enables the implementation of scientific and professional analyses in the fields of traffic safety, urban mobility, digitalisation of infrastructure, accessibility, active transport and the planning of sustainable transport systems. The results obtained through the application of the equipment can serve as a basis for seminar papers, final papers, master's theses and doctoral dissertations, as well as for the preparation of scientific papers, professional studies and projects aimed at improving traffic in the local community.

An important contribution of this manual is also reflected in encouraging an interdisciplinary approach. Sustainable transport includes several interconnected areas: traffic engineering, urban planning, traffic safety, environmental protection, digitalisation, data management and public policies. Working with laboratory equipment enables these areas to be connected through specific tasks and practical examples. In this way, users of the manual develop a broader understanding of the transport system and acquire knowledge that they can apply in different professional situations.



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