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Sustainable Transportation within the framework of Green Deal Laboratory Manual



**JIZZAKH BRANCH OF NATIONAL UNIVERSITY OF
UZBEKISTAN NAMED AFTER MIRZO ULUGBEK**



**Laboratory
manual**

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Introduction

The role of road vehicles in the rapid development of the Republic of Uzbekistan is unparalleled. The introduction of sustainable transport is one of the main ways to address modern environmental, economic and social problems. With urbanisation expanding year on year and transport congestion on the rise, alongside the urgent need to reduce greenhouse gas emissions, The development and implementation of sustainable transport systems is becoming a priority for governments, institutions and professionals worldwide. This guide is aimed at enhancing the skills of professionals involved in the planning, management, and operation of sustainable transport solutions.

It is aimed at providing the essential knowledge, methodologies and best practices required to successfully implement sustainable mobility strategies. The guide covers key areas such as the fundamentals of sustainable transport policy, low-emission technologies, public transport planning, active mobility (walking and cycling) and the promotion of inclusivity in mobility. Sustainable transport is a multifaceted process that requires close coordination between sectors to ensure environmental protection, social equity, and economic efficiency simultaneously.

Therefore, this guide is also intended as a training manual to equip specialists and students with the necessary knowledge and tools to support the transition to sustainable transport systems.

This laboratory manual was developed within the framework of the Erasmus+ programme project SPHERE – Sustainable Transportation

within the Framework of Green Deal (Project No. 101128065). The main objective of the project is to enhance the quality of higher education in the field of sustainable transport, to modernise educational programmes and to strengthen their alignment with the needs of the labour market and society. Furthermore, the project is aimed at implementing modern scientific approaches, exchanging European best practices, and developing professional competencies in the field of transport and traffic engineering. ...aimed at introducing modern scientific approaches into practice, sharing Europe's best practices, and developing professional competencies in the field of transport and traffic engineering, serves to implement innovations and modernisation in sustainable transport by equipping students from the republic's higher education institutions with practical skills to work alongside state bodies and industry partners.

To date, the modern development of transport and road traffic systems is increasingly based on the principles of sustainable mobility. These principles address the growing need for the movement of people and goods while protecting the environment, balancing the demands of ensuring road traffic safety, increasing energy efficiency, accelerating digital transformation, and expanding social accessibility and usability, in line with the principles of the Green Deal. From this perspective, higher education institutions play a crucial role in preparing specialists capable of analysing, planning, and improving transport systems in accordance with modern European legislation and the principles of the Green Deal.

The particular significance of this guide is that it organically links

theoretical knowledge of sustainable transport with practical laboratory-based exercises. The modern equipment purchased under the SPHERE project enables students, academic staff, researchers and industry specialists to carry out measurements, modelling, analysis and conducting experimental research, thereby gaining practical experience. At the same time, they will gain a deeper understanding of the pressing issues in modern transport systems. As a result, the laboratory becomes a platform for applying theoretical knowledge in practice, developing scientific research skills, and testing innovative solutions aimed at creating safer, more efficient, and environmentally sustainable transport systems.

The guide is primarily intended for undergraduate and postgraduate students, academic staff, research scholars and specialists working in the field of transport and traffic engineering. It also serves as a useful resource for participants in professional development and continuing education programmes. The primary objective of the manual is to provide clear instructions for the use of laboratory equipment, to define their areas of application, and to ensure that practical sessions are organised on a unified and standardised basis. At the same time, the manual supports an interdisciplinary approach, as sustainable transport encompasses transport and traffic engineering, urban planning, environmental protection, road traffic safety, information technologies and public policy.

Through descriptions of laboratory equipment, practical exercise examples and various scenarios for their application, this guide serves to modernise the educational process and strengthen the practical

competencies of users. At the same time, it is one of the outcomes of the capacity-building and development activities carried out within the SPHERE project. The equipment procured under the project serves not only as a means of providing technical support for the teaching process, but also for future scientific research, professional analyses, and capacity-building activities, as well as for cooperation with industrial enterprises, ...serving as a solid foundation for developing cooperation with industrial enterprises, state institutions and other stakeholders.

Based on the above, this laboratory manual serves a dual purpose. On the one hand, it functions as a practical guide to the use of the laboratory equipment purchased under the SPHERE project. On the other hand, it highlights the importance of laboratory-based education in preparing specialists capable of effectively addressing contemporary challenges in sustainable transport, environmental mobility and road traffic safety. Thus, the manual contributes to ensuring the long-term sustainability of the project's results in education, scientific research, and professional practice, as well as their effective implementation.

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1. SUSTAINABLE TRANSPORT LABORATORY

SPHERE – Within the framework of the Green Deal, a Sustainable Transportation laboratory was established at the Jizzakh branch of the Mirzo Ulugbek Uzbekistan National University as part of the Erasmus+ project. This laboratory is a modern teaching and research centre that serves to develop education, scientific research and the application of knowledge in the field of sustainable transport and mobility.

The establishment of the laboratory is one of the important steps in strengthening the institutional capacity of the Jizzakh branch of the National University of Uzbekistan for the study of transport and road traffic systems using modern approaches. The laboratory was established to integrate theoretical knowledge with practical activities, conduct field research, carry out measurements, analyse data, perform modelling and utilise modern technical and software tools. In this way, the laboratory creates an environment that integrates the teaching process, professional practice and scientific research, serving to address pressing issues related to mobility, road traffic safety, and the efficiency and sustainability of transport systems.

The main aim of the laboratory is to create a working environment that meets the modern needs of the transport sector for students, academic staff, researchers and industry specialists. In such an environment, analysing the operation of transport systems, the behaviour of road users -behaviour, assessing the impact of infrastructure on mobility and safety,

analysing the environmental aspects of transport, and applying digital technologies in transport planning, modelling, and management processes.

One of the laboratory's most important tasks is to implement an evidence-based approach in practice. Modern transport planning requires the regular collection, processing and analysis of reliable data to support sound and effective decision-making. From this perspective, the equipment procured under the SPHERE project covers various aspects of transport, including the characteristics of traffic flows, enabling a deep analysis of indicators such as traffic flow characteristics, the behaviour of road users, the condition of the infrastructure, the environmental impact of transport, and the quality of life in urban areas.

The equipment purchased also plays an important role in developing practical competencies. They enable laboratory sessions, field measurements, demonstration exercises, student projects, professional analyses and scientific research. In particular, the equipment supports sustainable transport, urban mobility, active transport modes (pedestrian and cycling), public transport, road safety, transport analysis, the digitalisation of transport infrastructure, and the assessment of transport's environmental impact.

Within the laboratory, various practical and scientific research activities can be carried out. Students collect and analyse data on traffic flow, assess the conditions created for pedestrians and cyclists, and study the efficiency of public transport systems, identify hazardous situations

and safety threats in road traffic, as well as learn to model various scenarios for traffic organisation using modern software tools. In this way, the laboratory allows theoretical concepts to be transformed into practical experience, precise measurement results, and practical knowledge.

One of the laboratory's additional advantages is its interdisciplinary nature. Sustainable transport encompasses numerous interrelated fields, including transport and traffic engineering, urban planning, road traffic safety, environmental protection, energy efficiency, digitalisation and public policy. The laboratory therefore serves as a common platform for various educational and research activities, and enables students to understand the transport system as a complex system harmonised with safety requirements and the principles of sustainable development, as a complex system where technical solutions for transport systems are aligned with user needs, safety requirements and the principles of sustainable development.

The Sustainable Transport Laboratory serves to modernise the educational process by introducing modern teaching methods and practical learning approaches. Not limiting itself to theoretical lessons alone, students are enabled to identify problems, Students are encouraged to actively participate in the research process by identifying problems, collecting and analysing data, interpreting the results, and developing proposals for improvement. This approach fully meets the requirements for preparing specialists capable of solving modern mobility challenges, such as traffic congestion, environmental pollution, road traffic safety

issues, and the growing demand for sustainable modes of transport.

The importance of the laboratory is particularly evident in the field of sustainable urban mobility. Modern cities face numerous challenges, such as over-reliance on private cars, air pollution, noise, traffic congestion and inadequate safety conditions for pedestrians and cyclists. Through laboratory sessions, it is possible to analyse these problems, test various solutions, and develop recommendations aimed at creating a safer, more efficient, and environmentally friendly transport system.

The laboratory also plays an important role in promoting active mobility. Walking and cycling are among the most sustainable modes of transport, but their development depends on safe, comfortable and high-quality infrastructure. From this perspective, The laboratory enables the analysis of pedestrian and cyclist flows, the assessment of mobility conditions, the identification of spatial barriers and safety risks, and the development of measures aimed at improving mobility conditions.

Alongside active mobility, the laboratory also enables the analysis of public transport, a key component of a sustainable transport system. Through laboratory and field research, the comfort of stations, the quality of service, the reliability of transport operations, the capacity of routes and the potential for integrating public transport with walking, cycling and other modes of travel can be assessed.

The laboratory also serves to advance knowledge in the field of transport modelling and simulation. Using modern software tools, it is possible to create digital models of junctions, street networks, transport

corridors and urban areas, and to analyse the impact of various organisational and infrastructural measures. Simulations allow for the assessment of the expected outcomes of measures such as changing traffic patterns, prioritising public transport, optimising traffic light timings, or implementing traffic calming measures, before they are implemented in practice. One of the key areas of laboratory work is related to road traffic safety. Sustainable transport cannot be viewed separately from safety, because a transport system characterised by high levels of risk and road traffic incidents cannot be considered sustainable. The laboratory's equipment and methodologies enable the analysis of road users' behaviour, the identification of hazardous areas, the study of vehicle speeds, the analysis of traffic conflicts and the assessment of other safety indicators. This is of great importance for cooperation with educational institutions, scientific research organisations, and bodies responsible for enhancing road traffic safety.

The laboratory also plays an important role in the field of environmental protection. As transport is one of the main sources of greenhouse gas emissions, noise, energy consumption, and land use, future professionals must have a deep understanding of the environmental impact of different modes of mobility and transport systems. During practical sessions, it is possible to analyse the environmental aspects of transport, compare different mobility scenarios, and evaluate measures aimed at reducing its negative impact.

The laboratory serves as a platform for joint projects, professional

development courses, seminars, analytical work and consulting services, enabling the application of knowledge generated in an academic environment to practice and the resolution of real transport problems.

The laboratory equipment catalogue presented in the following sections of this manual comprises a range of technological tools selected in line with the objectives of the SPHERE project and the contemporary educational and research needs in the field of sustainable transport. The greatest advantage of these devices is the ability to apply them in a comprehensive manner. This facilitates a deeper understanding of the interrelationships between the operating principles of transport systems, infrastructure, users, vehicles, the environment, and management measures.

From this perspective, the Sustainable Transport Laboratory is not merely a building equipped with modern technical equipment. It forms the foundation of a modern teaching and research environment in which knowledge is acquired through practical sessions, experiments, analyses and the application of advanced methods and technologies. The development of the laboratory further strengthens the position of the Academy of Applied Sciences of Kosovo and Metohija in modernising education, developing scientific research, and promoting sustainable, safe, and efficient transport.

In conclusion, the establishment of the Sustainable Transport Laboratory within the SPHERE project demonstrates that we can view it as a significant investment in the future of education and scientific

research in the field of transport and traffic engineering. This laboratory allows the principles of sustainable mobility to be considered not just as theoretical concepts, but as the practical basis for the analysis, planning, and improvement of real transport systems. Through the laboratory's activities, developing new teaching materials, improving existing educational programmes, creating the necessary conditions to develop new teaching materials through laboratory work, improve existing educational programmes, and conduct high-quality scientific research, as well as to support the transition to more sustainable mobility in local and wider communities.

2. Equipment in the Sustainable Transport Laboratory

The equipment in the Sustainable Transport Laboratory was purchased to support modern teaching processes, scientific research and professional activities in the field of transport and sustainable mobility. SPHERE – Sustainable transport within the framework of the Green Deal (Sustainable Transportation within the Framework of Green Deal) in line with the objectives of the Erasmus+ project, this equipment has been procured to support modern teaching processes, scientific research, and professional activities in the field of transport and sustainable mobility. road traffic safety, mobility management, environmental protection, and the planning and improvement of transport systems.

The development of modern transport systems requires the use of high-precision measuring instruments, digital tools, analysis and modelling software, as well as data collection in the field, and visualisation of data in field conditions. For this reason, the equipment purchased under the SPHERE project was selected to ensure the integration of theoretical knowledge with practical activities. Their use enables the analysis of real-world problems related to transport and road traffic based on reliable data, the development of sustainable mobility scenarios, and the planning of transport systems, enabling the development of the necessary competencies to apply modern methods in the planning, management and improvement of transport systems.

The particular significance of these devices lies in the fact that they enable the comprehensive analysis of transport systems. The concept of

sustainable transport is not limited to merely reducing negative environmental impacts, but also encompasses the development of a transport system that is safer, more comfortable, more efficient and technologically advanced for transporting people and goods.

From this perspective, the laboratory equipment can be used for the following types of activities:

- Conducting measurements and data collection under road conditions;
- digital recording and performing spatial analyses;
- analysis of transport infrastructure;
- reconstruction of road traffic incidents;
- assessment of mobility and accessibility;
- planning and analysis of transport routes;
- technical support for teaching sessions and practical laboratory work;
- Preparation of student projects and research papers;
- Carrying out professional analyses and practical projects.

As part of the SPHERE Erasmus+ project, the following equipment and software tools were purchased:

- **Driving simulator (Light Vehicle Simulator);**
 - **Control Desk for Driving Simulator;**
 - **3-Shimmer3 GSR+ Unit**
-

- **Traffic safety radars, e.g. Falcon HR**
- **System for testing the driver's reaction time**

2.1 The role of equipment in education, scientific research and professional activity

The laboratory's equipment enables the organisation of practice-oriented education and the development of modern professional competencies in the sustainable transport sector. Through practical sessions, students will become familiar with the modern devices, digital tools and software used in professional and scientific activities, as well as, they will have the opportunity to learn about their application in the analysis and improvement of transport systems. This is particularly important, as modern education in the transport sector requires students not only to acquire theoretical knowledge but also to actively participate in processes such as conducting measurements, analysis, modelling, interpreting results, and decision-making.

From the standpoint of scientific research, laboratory equipment enables the conduct of various analyses, scientific investigations and research work. They enable the provision of road traffic safety in complex conditions for motor vehicles by taking into account the drivers' psychophysiological capabilities, the surrounding environment and the operational characteristics of the vehicles. Improved training and retraining methods can be developed to enhance the reliability of the “driver–vehicle–road” system, employing professional knowledge and skills and innovative technologies. as well as the study of the quality of

pedestrian and cycling infrastructure, and the analysis of conflicts and risk factors in traffic flow, visibility and safety conditions can be assessed, transport routes can be digitised, and various scenarios aimed at improving transport systems can be developed. Such activity serves as a solid foundation for preparing scientific articles, master's theses, student projects, applied research, and other scientific works.

In practical terms, the laboratory can assist local government bodies, state institutions and other interested organisations in resolving transport and mobility issues. Based on the data collected and analysed in the laboratory, improving transport infrastructure, enhancing road traffic safety, developing active mobility, optimising transport routes, Recommendations can be developed for improving areas designated for pedestrians and cyclists, as well as for planning measures aimed at reducing the negative environmental impact of transport

2.2 Interrelationship with equipment purchased under other Erasmus+ projects.

Although this manual primarily focuses on the equipment procured under the SPHERE Erasmus+ project, it should be emphasised that the Sustainable Transport Laboratory also includes additional equipment acquired under Islamic Development Bank projects. These devices also play a vital role in organising education, scientific research and practical activities in the field of sustainable transport and mobility.

In particular, equipment was purchased for studying drivers' behaviour and road traffic safety. These include training and

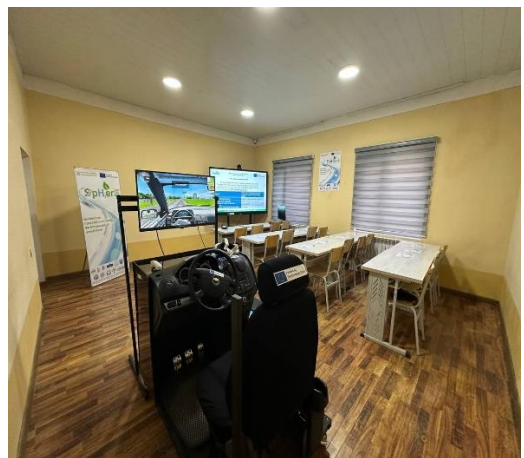
demonstration tools such as a driving simulator and special glasses that simulate the effects of alcohol. These devices effectively complement laboratory work in education and scientific research, particularly concerning the human factor, risk perception, reaction time, driver behaviour, and safe participation in road traffic. From the perspective of sustainable transport, the significance of such equipment is that it contributes to the development of a safer transport system and the enhancement of road traffic culture.

Thus, the integration and joint application of equipment procured under various Erasmus+ projects create extensive opportunities for developing modern education, conducting scientific research and enhancing practical activities in the field of sustainable transport.

The equipment purchased under the SPHERE Erasmus+ project constitutes the primary technical and scientific foundation of the Sustainable Transport Laboratory. Its use for digitising transport infrastructure, allowing for the analysis of road traffic safety, the planning and analysis of transport routes, data processing and visualisation, as well as the development of practical competences for students, academic staff and professionals. Furthermore, the ability to integrate equipment procured under other Erasmus+ projects further expands the laboratory's potential and facilitates a deeper, more comprehensive study of transport systems and sustainable mobility issues.

3. Car Driving Simulator. (Driving simulator, Light Vehicle Simulator)

The driving simulator is one of the most important technological tools for studying drivers' behaviour, analysing hazardous situations and providing education in the field of road traffic safety. Its application is directly linked to the concept of sustainable transport, as safety is one of the fundamental prerequisites of sustainable mobility. A transport system with a high level of risk and a high number of road traffic accidents and injuries cannot be considered a sustainable transport system, regardless of its environmental, economic or technological advantages.



2-picture. Driving simulator. (Driving simulator, Light Vehicle Simulator)

Driving simulator control desk (Control Desk for Driving Simulator)

Technical Capabilities

The driving simulator allows for the study of driver behaviour in a controlled laboratory setting, without putting participants at real risk. This approach is particularly important as it allows for the analysis of situations

that are dangerous, unpredictable, or ethically unacceptable to test in real-world traffic conditions. For example, pedestrians suddenly stepping onto the road, the vehicle in front braking sharply, driving in conditions with limited visibility, and adverse weather, driver fatigue, speeding, distracted driving, as well as traffic scenarios near schools, pedestrian crossings and junctions can be simulated.

Within the framework of the Sustainable Transport Laboratory, the driving simulator enables the analysis of drivers' attitudes towards various infrastructure solutions and traffic management measures. In particular, it is possible to study drivers' reactions to traffic calming measures, speed-limited zones, roundabouts, cycle lanes, pedestrian areas, public transport systems and various traffic management scenarios. This allows for the evaluation of the expected impact of specific measures before they are implemented in real-world conditions.

Another important advantage of the simulator is the ability to run the same scenario repeatedly with multiple participants. This allows young drivers, experienced drivers, professional drivers and drivers with varying propensities for risky driving to be compared. This approach is of great importance for scientific research, allowing for systematic data collection on indicators such as reaction time, speed of movement, braking intensity, trajectory of movement, and safe distance maintenance, such as indicators of reaction time, driving speed, braking intensity, driving trajectory, safe distance maintenance, compliance with traffic rules, and decision-making in critical situations.

3.1 The importance in the educational process

One of the main objectives of using a driving simulator is to enhance the quality of training in road traffic safety and the human factor through practical and interactive methods. The simulator enables students to link theoretical knowledge with realistic transport scenarios and to observe first-hand how various factors influence driver behaviour.

Instead of studying driver behaviour solely on the basis of scientific literature, statistical data and theoretical models, students actively participate in analysing specific road traffic situations. They can observe first-hand how factors such as speed, infrastructure, visibility, traffic density, weather conditions and the behaviour of other road users influence decision-making during the driving process.

Students will learn:

- methods for analysing driver behaviour under different conditions;
- the impact of infrastructure on road safety;
- how different traffic control regimes influence the behaviour of road users;
- assessing hazardous traffic situations;
- analysing reaction time and decision-making processes;
- Evaluating the effectiveness of traffic calming measures;
- Methods for analysing the human factor in transport systems.

One of the simulator's most important educational advantages is that it allows students to experiment with various scenarios and draw their own conclusions about the factors affecting transport safety and stability.

3.2. Examples of practical sessions for students

The driving simulator can be used for a wide range of practical activities in teaching and laboratory sessions.

Students can conduct research in the following areas:

- studying drivers' reaction times under different conditions;
- Analysing the behaviour of young and inexperienced drivers;
- Assessing the impact of speed on the prevention of road traffic accidents;
- Studying driver reaction times near schools, pedestrian crossings and junctions;
- analysing drivers' behaviour towards pedestrians and cyclists;
- evaluating the effectiveness of traffic calming measures;
- studying driving characteristics in night-time and low-visibility conditions;
- Analysing the effect of in-vehicle distraction on driving quality;
- Assessing driver responses in adverse weather conditions;
- Modelling various hazardous and conflictual traffic scenarios.

In addition to individual analyses, students can compare the results of different groups of participants, analyse the collected data, and develop proposals for improving road traffic safety. Such activity serves to integrate theoretical knowledge with practical experience and to develop an analytical approach to solving transport problems.

3.3. Significance for scientific research

Driving simulators are widely used in scientific research, particularly in studies of human factors, road traffic safety and driver

behaviour. The ability to fully control experimental conditions and replicate identical scenarios allows for the acquisition of objective, comparable, and measurable scientific results.

The simulator can be used in the following scientific research:

- analysing drivers' reaction times;
- assessing the impact of speed on safety;
- studying the effects of fatigue, stress and distraction factors;
- researching the behaviour of drivers from different age and risk groups;
- Analyse drivers' interactions with pedestrians and cyclists;
- Assess the effectiveness of various infrastructure solutions;
- Study safety in school zones and at pedestrian crossings;
- Analysing driving characteristics in conditions of restricted visibility;
- Testing various methods of traffic management;
- Conducting scientific research on sustainable and safe mobility.

One of the greatest advantages of the simulator is the ability to study hazardous situations without endangering participants' lives. At the same time, the controlled experimental environment allows experiments to be repeated multiple times. This is of particular importance for the reliability of scientific research and for comparing different scenarios.

3.4. The importance for sustainable and intelligent transport systems

The driving simulator plays a vital role in the development of sustainable and intelligent transport systems, as it allows various transport solutions to be tested and evaluated under real-world conditions before their implementation. In this way, potential risks can be identified, the impact of infrastructure changes assessed, and the effects of various traffic management strategies on safety and mobility can be determined in advance.

From a sustainable transport perspective, the simulator helps to understand how drivers react to new types of infrastructure, speed limits, pedestrian and cycling infrastructure, public transport systems, and traffic calming measures. This enables the design of safer, more comfortable and more efficient transport systems for all road users.

In a broader sense, the driving simulator supports a preventative approach to road traffic safety. In other words, rather than analysing road traffic incidents after they have occurred, potential risks are identified in advance, various measures are tested, and the likelihood of negative consequences is reduced. For this reason, the driving simulator is a key technological tool that links education, scientific research, and preventative work with the development of smart and sustainable mobility.

4. SHIMMER3 GSR+ Unit (SHIMMER3 GSR+ UNIT)



Optical pulse sensor
(finger)
Optical pulse sensors
(earlobe)
GSR+ Dry Electrodes
(x2)
Biophysical 9" leads (x2)
1x Wrist Strap
Weight: 0.6 kg
Dimensions: 45 × 33 × 1
cm

The Shimmer3
GSR+ unit is a wireless
wearable biosensor device
designed to monitor a
person's skin-galvanic

reaction (GSR/EDA) and heart rate in real time. It is primarily used in scientific research, neuromarketing, psychology and the study of cognitive load.

Key features and capabilities:

KGR (Cortical Galvanic Skin Response) measurement: Measures the skin's electrical conductivity using two finger-mounted electrodes. This helps to detect states of arousal, stress or emotional activation in a person;

PPG (Photoplethysmography) sensor: Records the blood

circulation (PPG) signal through a special earlobe or finger sensor and calculates the heart rate (HR);

MOTION TRACKING (9 DoF IMU): Using the built-in accelerometer, gyroscope and magnetometer, it can simultaneously record the user's movement activity;

Data transmission and storage: It can stream data to a computer in real time via Bluetooth, or record it independently to its internal SD card.

4.1. The importance in the educational process

The Shimmer3 GSR+ device is considered one of the most important tools in modern education for scientific research and the optimization of the learning process in the fields of neuromarketing, neuropedagogy, cognitive psychology, and medicine. Its main significance in education and its areas of application are as follows:

1. Students' Scientific Research Activities

Practical laboratories: It provides students in medicine, biology, psychology, and neuromarketing with the opportunity to study human physiology through practical laboratory activities.

Master's and doctoral research: Accurate quantitative data obtained through the sensor serve as a reliable source for master's theses, doctoral dissertations, and scientific publications.

2. Evaluation of the Effectiveness of Educational Materials

Measuring Interest and Attention: During the development of teaching materials, textbooks, or video lectures, it can identify the sections where students are more engaged or where their attention

declines by measuring their physiological stress levels.

EdTech and e-Learning Evaluation: The sensor can be used to evaluate the extent to which online learning platforms or gamified educational applications evoke positive emotional responses in students, providing valuable data for improving the platform.

3. Monitoring Cognitive Load and Stress

Examination and Test Analysis: It enables researchers to identify which types of examination or test questions induce the highest levels of stress and physiological arousal in students during assessments.

Fatigue Detection: It helps monitor the extent to which students' cognitive activity and emotional fatigue increase during prolonged classroom sessions.

Sample Practical Laboratory Exercises (Case Studies) for Using the Shimmer3 GSR+ Device in University Laboratories:

4.2. Sample Practical Laboratory Exercises for Students

1. Neuromarketing: "Evaluating the Emotional Impact of Different Advertisements"

Objective: To demonstrate how marketing visuals influence human emotions.

Procedure: Students attach the Shimmer3 GSR+ sensor to the participant and sequentially present three different types of video advertisements (humorous, fear-based, and socially oriented) while recording the participant's physiological responses.

Results Analysis: By analyzing the sensor recordings, particularly the

GSR peaks, students can identify which scenes evoke the highest levels of emotional arousal and which segments generate little or no physiological response, indicating lower engagement or interest.

2. Cognitive Psychology: "The Stroop Effect and Cognitive Load"

Objective: To measure stress levels when the brain processes conflicting information simultaneously.

Procedure: The participant is presented with color words (e.g., the word "RED" displayed in blue ink). Instead of reading the word, the participant is instructed **to identify the color** of the ink in which the word is written.

Results Analysis: Students observe that the GSR signal rises sharply and the PPG (photoplethysmography) pulse rate increases during moments when the participant hesitates or makes an error, indicating elevated cognitive load and physiological stress.

3. Occupational Hygiene: "Monotonous Work and Fatigue Dynamics"

Objective: To determine the effects of repetitive tasks on students' fatigue levels.

Procedure: The participant performs highly repetitive mathematical calculations or types text continuously for 15–20 minutes while physiological responses are recorded using the Shimmer3 GSR+ sensor.

Results Analysis: Students analyze how the baseline skin conductance (GSR) gradually changes over time, reflecting a decline in physiological arousal and sustained attention as fatigue develops.

4. Pedagogy and Design: "Usability of a Mobile Application or Website Interface (UX/UI)"

Objective: To identify usability challenges in digital products by analyzing users' physiological responses recorded with the sensor.

Procedure: The participant is asked to complete a task, such as registering on a complex website or locating a specific function within a digital interface.

Results Analysis: The GSR recordings reveal stress peaks at points where the user experiences difficulty, such as becoming confused or being unable to locate a button, thereby identifying usability issues within the interface.

Equipment Required for the Practical Laboratory Session:

Shimmer3 GSR+ unit with electrodes

A computer equipped with **Bluetooth** connectivity

ConsensysPRO (Shimmer rasmiy dasturi) yoki iMotions platformasi.

4.3. Significance for Scientific Research

The Shimmer3 GSR+ device enables researchers to investigate individuals' emotional, cognitive, and physiological states in both academic and applied research using objective physiological biomarkers and quantitative data, without relying solely on subjective self-reports or questionnaires.

The primary significance of this device in scientific research is demonstrated in the following areas:

1. Multi-sensorli integratsiya va Sinxronizatsiya (Multimodal Research)

Comprehensive Analysis: The Shimmer3 GSR+ is more than just a GSR

sensor. It also incorporates a 9-axis Inertial Measurement Unit (IMU) and a PPG (photoplethysmography) sensor for heart rate monitoring. This enables researchers to simultaneously analyze movement, cardiovascular activity, and physiological stress, providing a more comprehensive assessment of human responses.

Compatibility with Other Research Equipment: The Shimmer3 GSR+ can be synchronized with electroencephalography (EEG) systems, eye-tracking devices (e.g., Tobii Pro), and facial expression analysis systems with microsecond-level synchronization accuracy. This enables multimodal data collection and highly precise temporal alignment across multiple physiological and behavioral measurements.

2. Research in Naturalistic Environments (Ecological Validity)

Wireless and Compact Design: Its wireless and lightweight design allows researchers to collect physiological data outside the laboratory, enabling studies in real-world settings such as workplaces, while driving, or during shopping activities.

Autonomous Data Logging (SD Card): In environments where a Bluetooth connection may be unreliable or unavailable, data can be recorded directly to the device's internal SD card. The recorded data can then be transferred and analyzed after returning to the laboratory.

3. Neuromarketing and Consumer Behavior

Detecting Hidden Emotions: Consumers may report that they “liked” a product or advertisement in questionnaires, even if this is not true. However, their autonomic nervous system responses (GSR peaks) can

reveal their actual reactions, such as genuine interest or aversion toward the product.

Brand Visual Analysis: It enables quantitative assessment of which logo or packaging design generates a stronger emotional engagement and connection with consumers.

4. Cognitive Ergonomics and Psychophysiology

Cognitive Load: It serves as a fundamental basis for measuring stress resilience and mental workload in high-responsibility professions such as pilots, surgeons, dispatchers, and cybersecurity specialists, particularly under extreme or high-pressure conditions.

Clinical Psychology: It is used to monitor therapeutic effectiveness in the treatment of conditions such as phobias, post-traumatic stress disorder (PTSD), and depression.

Key Metrics Provided by Shimmer3 for Scientific Analysis:

SCL (Tonic Component): The overall (baseline) skin conductance level reflects general physiological arousal, fatigue, or background stress during learning or work activities.

SCR (Phasic Component): Rapid peaks triggered by sudden stimuli (such as sound, light, or images), reflecting momentary emotional reactions within a precise time window.

4.4. Relevance for Sustainable Transportation and Intelligent Transport Systems:

The Shimmer3 GSR+ sensor is a key research tool in the field of sustainable transport and intelligent transportation systems (ITS),

enabling the study of the psychophysiological interaction between humans (drivers or passengers) and transport infrastructure. The system does not rely on questionnaires but provides objective biomarker-based measurements of real-time driver stress and cognitive workload. Its significance in transportation research is reflected in the following strategic areas:

1. Intelligent Transportation Systems (ITS) and Driver Safety

Stress and Fatigue Monitoring: It measures driver fatigue, drowsiness, and stress caused by unexpected road situations (such as sudden braking or traffic congestion) in real time using GSR (skin conductance) and PPG (heart rate) sensors.

Driver Assistance Systems (ADAS): Data obtained from the Shimmer3 sensor can be integrated into the vehicle's intelligent onboard systems. If the driver exhibits excessively high stress peaks, the ITS can automatically adjust cabin lighting, play calming music, or suggest switching to autonomous driving mode.

2. Autonomous Vehicles (AV) and Human Integration

Measuring Trust and Safety Levels: It identifies how anxious a person becomes when transitioning from human-driven vehicles to full autopilot (driverless) systems, assessing their level of trust and perceived safety.

Control Transfer (Take-over Request): In critical situations where an autonomous vehicle must transfer control back to the human driver, the Shimmer3 system helps determine whether the driver is

cognitively ready or not by assessing their level of attention and readiness to respond. [8]

3. Digital Twins and Simulator Research

Simulator Validation: Researchers use the Shimmer3 GSR+ sensor to compare human reactions in driving simulators (VR environments) with real-world driving responses. This enables safe and accurate pre-deployment testing of transportation systems in laboratory conditions before implementing them on actual roads.

4. Sustainable and Eco-Friendly Transport Infrastructure Design

Attractiveness of Eco-Friendly Routes: It measures the stress levels experienced by cyclists and pedestrians along different urban routes (such as green areas versus noisy main roads). This provides urban planners and transport engineers with valuable insights for designing low-stress, environmentally friendly micro-mobility infrastructure, including bike lanes and pedestrian zones.

Public Transport Comfort: It contributes to improving service quality by studying passengers' emotional responses to comfort, microclimate conditions, and crowding levels in public transport systems such as metros and electric buses.

Technical Advantages in Scientific Transportation Research: The device's **9-DoF IMU (motion sensor)** and **Bluetooth technology** enable the simultaneous correlation of a driver's steering dynamics (such as sharp turns and acceleration patterns) with physiological stress peaks at microsecond-level precision (sensor fusion).

5. Road Traffic Safety Radars (e.g., Falcon HR Traffic Safety Radar)



Mobile Specification

10 to 205 mph (16 to 330 km/h)

Turi: 6 to 208 mph (9 to 334 km/h)

Target Opposite Direction

Target minimum (Patrol < 40 mph):

Specification: 10 mph (16 km/h)

Typical: 9mph (14 km/h)

Target minimum (Patrol > 40 mph):

Specification: 20 mph (32 km/h)

Target maximum:

(Combined patrol and target speeds):

Spec: 205 mph (330 km/h)

Same Direction:

Minimum difference speed:

Specification: 5 mph (8 km/h)

Typical: 3 mph (5 km/h)

Maximum difference: $0.65 \times \text{Patrol}$

Speed:

<https://kustomsignals.com/handheld-radar/falcon-hr>

Road Traffic Safety Radars (e.g., Falcon HR) are specialized Doppler radar systems designed to monitor vehicle speeds on roads, detect speeding violations, and help prevent traffic accidents.

Technical specifications and capabilities of the Falcon HR radar.

1. **K-Band frequency:** The device operates by emitting microwave signals at a frequency of 24.125 GHz, ensuring high accuracy.
2. **Directional detection (Directional DSP):** Using a powerful digital signal processor (DSP), the radar can separately measure vehicles that are approaching, receding, or moving in both directions.
3. **Fastest Vehicle Mode:** It is capable of accurately detecting the speed of a smaller passenger vehicle overtaking a large, slow-moving truck within traffic flow without errors.
4. **Operating modes:** The radar performs equally accurate measurements whether the patrol vehicle is stationary or moving.
5. **Driver behavior modeling:** In scientific research, the Falcon HR measures real traffic speed flow, while the Shimmer3 GSR+ records the driver's cognitive load and stress peaks (SCR) at those speeds.
6. **Speed and Stress Correlation:** Using these two technologies, researchers can identify road segments (such as curves or narrow roads) where increased speed causes strong physiological arousal and stress in drivers, enabling the redesign of road signs and traffic infrastructure.

5.1. Significance in the Educational Process

The significance of **Falcon HR** and similar traffic safety radars in the educational process lies in enabling students in fields such as **physics, engineering, intelligent transportation systems (ITS)**, and road safety

to connect theoretical knowledge with practical applications.

The main significance of these devices in the educational system is demonstrated in the following areas:

- Traffic flow data collection:** Students of the transport program learn to measure the average speed of vehicle flow (Spot Speed Study) on the roadside using Falcon HR.

- Speed regime design:** Based on the collected statistical data, students develop projects such as setting a maximum safe speed for a specific road section, adjusting the cycle of “smart” traffic lights, or installing artificial road calming measures (speed-reducing barriers).

- Metrology and legislation:** In academies of internal affairs and law programs, students study radar error rates, their proper calibration, and the rules for ensuring that recorded measurements serve as legal evidence in court or fine issuance processes.

- Effectiveness of prevention:** Students conduct practical research to examine how warning signs about radar presence influence driver psychology and contribute to speed reduction.

5.2. Importance for scientific research

- **Practical task:** One group of students drives a vehicle (with a Shimmer3 GSR+ sensor attached), while another group measures their speed at an unexpected location using a Falcon HR radar.

- **Research objective:** Students analyze how much the driver’s stress level (GSR peaks) increases when they see a radar-equipped inspector or hear a radar signal, and how this relates to speed reduction and the

correlation between stress and driving behavior.

5.3. Barqaror transport va intellektual transport tizimlari uchun ahamiyati

The importance of Falcon HR and similar traffic safety radars in the field of Sustainable Transport and Intelligent Transport Systems (ITS) is directly connected to the digitalization of road traffic, ensuring safety, and reducing environmental impact.

1. Smart City and ITS sensor network

Real-time traffic monitoring: Radars such as Falcon HR not only measure vehicle speed but also provide data on the number of vehicles passing a road section within a specific time interval (traffic flow density) [Kustom Signals Falcon HR]. This information is transmitted to the central ITS server, enabling adaptive traffic control systems to automatically adjust the green-light duration of “smart” traffic signals based on congestion levels.

V2X (Vehicle-to-Everything) integration: Speed and traffic flow data collected from radars form the foundation for sending early hazard warnings to autonomous or intelligent vehicles via wireless networks (V2I – Vehicle-to-Infrastructure communication), enabling safer and more predictive driving by informing vehicles in advance about road risks.

2. Sustainable transport and environmental impact reduction (Eco-Driving): Ecological speed control: When vehicles travel at excessively high speeds or engage in frequent sudden braking and acceleration (stop-and-go conditions), they emit the highest levels of harmful

gases into the atmosphere, such as CO₂ and NO_x. By using radar systems to maintain a smooth and consistent traffic flow, fuel consumption can be reduced by up to 15–20%, while also decreasing air pollution and overall environmental impact.

Green Wave efficiency: In cities, coordinated traffic signal systems are implemented based on radar data to enable vehicles to move at a stable speed (for example, 50 km/h) without stopping. This “green wave” approach allows vehicles to pass through consecutive intersections without unnecessary halts, improving traffic flow efficiency, reducing congestion, and lowering fuel consumption and emissions.

3. Protection of micro-mobility and sustainable infrastructure. Safety of vulnerable road users: Strict speed control using Falcon HR radars near bicycle lanes, pedestrian crossings, and schools makes sustainable transport modes such as cycling, scooters, and walking more attractive and safer for people by significantly reducing the risk of accidents in these sensitive areas. **Speed corridor design:** Based on radar statistics, urban planners modify the geo-architecture of roads and create sustainable infrastructure that naturally reduces vehicle speed, such as roundabouts and narrowed streets. This approach helps calm traffic flow, improve safety, and support more sustainable urban mobility patterns.

4. Combined research: Falcon HR + Shimmer3 GSR+

In ITS laboratories and scientific studies, the integration of these two devices enables a comprehensive analysis of the “**human–vehicle–road**” triad within transport systems:

The Falcon HR measures the objective external conditions of the road environment, including vehicle speed, traffic flow dynamics, and potential risk levels.

The Shimmer3 GSR+ records the driver's internal psychophysiological state under these speed conditions or when approaching a radar-controlled zone, including stress peaks, emotional arousal, and changes in attention and concentration levels.

Result: When these two systems are synchronized, intelligent transport engineers are able not only to ensure road safety but also to model optimal sustainable transport routes with minimal stress levels, which are most favorable for human health and the nervous system.

6.SYSTEM FOR TESTING THE DRIVER'S REACTION TIME



A driver reaction time testing system is a hardware–software complex that measures the driver's response speed to visual or acoustic warning signals in microseconds.

This system is used to ensure road traffic safety, detect driver fatigue levels, and assess their professional fitness and suitability for driving.

System structure and operating principle

The system usually consists of the following three main components:

1. **Stimulus:** A visual signal suddenly presented to the driver (a red light on the screen, a simulated road obstacle) or an auditory signal.
2. **Input device (Response unit):** A special brake pedal, steering wheel button, or touchscreen panel that the driver must press as soon as they see or hear the signal.
3. **Software:** An analytical module that calculates the difference between the moment the signal is given and the moment the button is pressed (reaction time) in milliseconds.

Integration of Intelligent Transport Systems (ITS) with existing devices

This system forms a perfectly unified safety chain in Intelligent Transport Systems (ITS) together with the previously discussed Shimmer3 GSR+ and Falcon HR devices.

1. Comprehensive driver monitoring: If the reaction time testing system indicates a slowdown in the driver's responses, the Shimmer3 GSR+ sensor reveals how much fatigue or cognitive stress (mental strain) is behind this slowdown.
2. Safe distance algorithms: Using Falcon HR radar, traffic flow speed is measured. This speed is compared with the driver's individual reaction time (for example, 0.5 seconds), and the ITS system automatically calculates the safe distance (braking distance) between vehicles and alerts the driver.

6.1. Importance in the educational process

The driver reaction time testing system is considered one of the most effective laboratory tools in the educational process (especially in automotive engineering, intelligent transport systems, medicine, psychophysiology, and driver training schools) for understanding theoretical knowledge through practical experiments. The main importance of this system in education is demonstrated in the following areas:

1. In Automotive Engineering and Road Design: Understanding the “Braking Distance” Formula

Visualising the Theory: Students get a hands-on feel for the human factor in determining braking distance, a concept they often see in

textbooks.

Mathematical Calculations: In the laboratory, students measure their own reaction time (e.g., 450 milliseconds). They then use this figure to calculate, in precise numerical terms, the distance the car will travel in metres before the driver can press the brake pedal when travelling at 60 km/h or 100 km/h.

2. **Transport Psychology and Medicine: Studying the factors of fatigue and distraction**

Assessing the impact of factors: Students will conduct an experiment to see by how many times fatigue, drowsiness and distraction (for example, talking on the phone or texting while driving) slow a driver's reaction time during a lesson.

Testing Hypotheses: Students conduct practical mini-research on topics such as “Does listening to music affect reaction time?” or “Do energy drinks really boost concentration?”.

3. **Innovative Laboratory Projects (3-device integration)**

An ideal scientific laboratory scenario can be created for university students, integrating all three devices (Falcon HR, Shimmer3 GSR+, and the Reaction System):

Students' task: As the subject's speed (indicated by the Falcon HR sensor) increases, they learn to conduct a correlational analysis of how their reaction time changes as the subject's speed (as indicated by the Falcon HR sensor) increases, and how strongly the autonomic nervous

system signals stress (arousal) during this process via the Shimmer3 GSR+.

4. Improving the quality of training for prospective drivers

Professional fitness: In driving schools and specialised military/extreme driving academies, this system is used to test prospective drivers' readiness for emergency situations and to develop their reflexes.

6.2. Importance for scientific research

The driver reaction time testing system serves as a fundamental biomarker in academic and applied scientific research in the fields of Human Factors, transport psychophysiology, and artificial intelligence safety.

The primary significance of this system in scientific research is manifested in the following areas:

1. The development of cognitive load and fatigue models

Time-brain activity correlation: Scientists determine a model of human brain fatigue or vigilance decrement by observing changes in reaction time in milliseconds.

Analysis of external factors: This serves as a primary tool for quantitatively demonstrating how various drugs, sleep deprivation, monotony, or driving duration affect an individual's Information Processing Rate.

2. Designing and Optimising Human-Machine Interfaces (HMI)

Warning system effectiveness: Hazard warning sensors in modern intelligent vehicles (visual lights, acoustic signals or steering-wheel

vibration) are tested. Researchers scientifically study which type of warning elicits the shortest reaction time in humans.

Perception-Reaction Time: The latent delays between a driver perceiving signals via their visual sensors and making a decision in complex road situations (e.g., sudden fog, a pedestrian stepping out) are measured.

3. Autonomous Vehicles (AV) and Take-over Research

Critical transition period: The time taken for a human to press a button on the steering wheel or react by braking, when a Level 3 or 4 autonomous vehicle is required to hand back control to the driver in an emergency (take-over request), is measured.

Setting safety margins: The data obtained from this system is fed into artificial intelligence algorithms to calculate the minimum distance and time reserves (Time-to-Collision) for the autonomous vehicle to safely hand over the steering to a human.

Integration of Three Systems: The Culmination of Scientific Research

In research laboratories, this reaction system, in conjunction with the previously discussed Shimmer3 GSR+ and Falcon HR, forms a multimodal scientific platform:

Data Synchronisation (Sensor Fusion): While the Falcon HR radar measures the vehicle's speed in the simulator, the reaction system records the speed at which the driver applies the brakes, and the Shimmer3 GSR+

shows the driver's emotional outburst (SCR peak) in the autonomic nervous system at that exact millisecond.

Scientific conclusion: This three-way analysis allows scientists to determine not only ‘How many seconds did it take the driver to brake?’ This 3-way analysis allows scientists to find precise and reliable answers not only to the question, ‘How many seconds did it take the driver to brake?’, but also to fundamental scientific questions such as, ‘How much stress was the driver under at the time of braking, and how was this related to the vehicle's speed?’

6.3. Barqaror transport va intellektual transport tizimlari uchun ahamiyati

The driver reaction time testing system ensures road traffic safety in the field of Sustainable Transport and Intelligent Transport Systems (ITS), It is of strategic importance for designing smart city infrastructure and developing driverless (autonomous) transport technologies.

The key role of this system in transport systems is manifested in the following areas:

1. V2X (Vehicle-to-Everything) and Smart Infrastructure Design
Variable Message Signs (VMS): ITS control centres automatically lower the speed limits on electronic road signs when weather conditions (rain, snow, fog) change or a hazard appears on the road. These limits are calculated based on human average reaction time and braking distance safety models.

Traffic light and junction optimisation: The duration of the amber light at pedestrian crossings and junctions, and the activation times of smart sensors, are programmed to account for the average reaction time of drivers from seeing the visual signal to braking.

2. Autonomous Vehicle (AV) Safety and Control Transfer

Managing the “take-over” process: In Level 3 autonomous vehicles (systems transitioning from driverless to driver-driven mode), the driver's reaction time is the most critical parameter. The scientific data gathered through the feedback system precisely determines how many seconds before a hazardous situation arises that the autonomous vehicle should alert the human.

Driver Monitoring System (DMS): In modern ITS-enabled vehicles, in-car cameras and sensors detect if the driver's reaction time has slowed due to drowsiness or a head movement (e.g., blinking), and the system automatically activates autopilot mode.

3. Sustainable Micro-mobility Infrastructure and Pedestrian Safety

Mixed transport environment: To ensure safe movement between cyclists, scooters, and pedestrians in cities, the speed at which drivers react to a sudden obstacle is studied. This data will enable urban planners to design sustainable and safe micro-mobility routes.

Eco-Driving: Quick reactions and accurate anticipation of situations help the driver avoid sudden braking and rapid acceleration. This reduces fuel consumption and supports the environmental objectives of sustainable transport.

In research and practical transport systems, Falcon HR, Shimmer3 GSR+, and the Reaction Time Measurement System together form a perfect intelligent chain:

Falcon HR: Monitors the external environment and the vehicle's real-time speed dynamics.

Reaction Time System: Measures in milliseconds how quickly a person can physically respond to this external dynamic (e.g., an unexpected radar or obstacle).

Shimmer3 GSR+: Analyses the internal stress, arousal, and cognitive load of the human body during this reaction and decision-making process.

This three-way integration enables transport engineers to maximise safety in the “Human - Vehicle - Road” system.

To date, we have provided a detailed examination of the significance of all three main devices and systems (Shimmer3 GSR+, Falcon HR and the Reaksiya system) in the fields of education, scientific research and transport.

Comparative and integrative analysis of three systems

Comparison criteria	Shimmer3 GSR+ Unit	Falcon HR Radar	Driver reaction time testing system
Main type of device	Wearable wireless biosensor (Human sensor)	Portable Doppler radar (Infrastructure sensor)	Hardware-software complex (Reflex sensor)

Key performance indicators	Skin electrical conductivity (GSR), heart rate (PPG), movement kinematics (IMU).	The precise speed of an approaching or receding vehicle.	The time (in milliseconds) from the warning signal being given until the brake/button is pressed.
The place in the Human-Machine-Road chain	The human factor: the driver's internal emotional and psychophysiological state, stress and fatigue.	The "Road" and "Vehicle" factors: External kinetics, traffic flow rate, and traffic dynamics.	"Transition (Integration)" factor: The speed at which the human brain physically responds to external stimuli.
The main importance in the educational process	He teaches neuromarketing, cognitive psychology, and working with biomarkers in student research.	In physics, it demonstrates the Doppler effect, and in urban planning and transportation engineering, it teaches flow analysis.	In automotive engineering, it proves the formulas for braking distance and the effects of distracting factors in practice.
The role of sustainable transport and ITS	Measures passenger comfort and driver cognitive load (fatigue) in eco-friendly routes.	The "smart city" provides information for dynamic adjustment of traffic lights and safe environmental speed control (Eco-driving).	Smart traffic lights calculate the time to program the yellow light and the time to hand over control to humans in autonomous vehicles..
The main drawback or limitation of the study	Physical movements (such as turning the steering wheel sharply) can create artificial	It only works in a straight line, cannot see objects behind sharp turns	Results in a laboratory setting may differ slightly from

	noise (artifacts) in the signal.	and obstacles. olmaydi.	unexpected, extreme stress situations in real life.
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The most important scientific result of the laboratory work is that traffic safety cannot be fully assessed with just one sensor. To perfectly design the safety chain in the "Human – Vehicle – Road" system, the integration of all three systems is necessary. While the Falcon HR radar measures external speed hazards on the road, the Reaction system calculates the driver's physical reaction time in milliseconds, and the Shimmer3 GSR+ shows the level of internal emotional stress in those same seconds.

This methodology will serve as an important foundation for shaping our skills in the future as an intellectual transport engineer in the transfer of driverless (autonomous) transport management and the design of safe urban infrastructure.

CONCLUSION

This laboratory manual is one of the important results of the activities carried out within the framework of the Erasmus+ SPHERE project, the main objective of which is to improve the educational process, develop scientific research and expand the practical application of knowledge in the field of sustainable transport and mobility. The main task of the manual is to provide users with systematic information about laboratory equipment, software and technical devices, as well as their application in educational, scientific research and professional activities. Through the description of modern technologies, measurement, data recording, simulation, spatial analysis, and digital data processing methods, the manual combines theoretical knowledge in the field of transportation and traffic engineering with practical approaches to the analysis of transport systems.

Modern transport systems require an integrated, data-driven, and technology-enabled approach to planning, management, and mobility improvement. Therefore, laboratory equipment and software are important tools that allow for a deep understanding of the complex interdependence of the transport infrastructure, road users, vehicles, the environment, and traffic management measures. Instead of relying solely on theoretical assumptions, modern technologies make it possible to collect data from real conditions, analyze spatial characteristics, model different traffic scenarios, assess risks and visualize their impact before the introduction of various measures in the real environment.

The use of laboratory equipment and software tools is of particular importance in the field of sustainable transport, as they allow for a comprehensive study of issues related to mobility, ease of use, safety, and environmental protection. Pedestrian traffic, cycling, public transport and other forms of sustainable mobility can be analysed based on specific indicators and spatial conditions, while simulations and digital analyses allow different scenarios to be tested before they are implemented in practice. Thus, sustainable transport emerges not only as a theoretical concept, but also as a practical approach that serves to create safer, more efficient, and more accessible transport systems.

In addition to its educational functions, the laboratory also has great research potential. Laboratory equipment and software tools can be used in various scientific studies aimed at studying road safety, urban mobility, active mobility, digitalization of transport infrastructure, spatial analysis, intelligent transport systems, and the behavior of road users. The results obtained based on laboratory capabilities can serve as a scientific basis for coursework, graduation theses, master's theses, scientific articles, applied research, and projects aimed at improving transport systems and supporting local communities.

Another important aspect of this manual is its contribution to the development of an interdisciplinary approach. Sustainable transportation brings together various fields, including transportation engineering, urban planning, traffic safety, information technology, geographic information systems, data analysis, ecology, and public policy. Working with

laboratory equipment allows these subjects to be integrated through practical assignments and scientific research. This will create the necessary conditions for a deeper and more comprehensive understanding of transport systems and modern mobility issues.

In general, this laboratory manual is not just a guide to the use of technical equipment, but an important methodological resource that serves to form a modern model of education and scientific research in the field of transport. In it, knowledge is acquired through practical activities, analysis, experiments, and the application of advanced technologies. Through the integration of modern equipment and software tools purchased under Erasmus+ projects into educational and scientific processes, the institutional capacity of the educational institution will be strengthened, the educational system will be modernized and a solid ground for training highly qualified specialists who will be able to effectively solve problems in the field of safe, intelligent and sustainable mobility in the future.
