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Sustainable Transportation within the framework of Green Deal Laboratory Manual



Tashkent state transport university



Laboratory Manual

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Introduction

The contemporary development of transport and traffic systems is increasingly guided by the principles of sustainable mobility. In the context of modernizing Uzbekistan's transport infrastructure, this approach demands a careful balance between the growing demand for passenger and freight transport and the critical requirements of environmental protection, road safety, energy efficiency, and digital transformation. Consequently, higher education institutions—especially Tashkent State Transport University as a leading hub—bear a profound responsibility in training high-caliber engineers capable of analyzing, planning, and designing transport systems in line with modern international benchmarks and the European Green Deal objectives. This laboratory manual was developed within the framework of the Erasmus+ international project SPHERE – Sustainable Transportation within the Framework of Green Deal (Project No. 101128065). The core objective of this initiative is to elevate the quality of higher education in the field of sustainable transport in Uzbekistan, modernizing study curricula to align directly with current labor market demands and industrial needs. Furthermore, the project focuses on adopting cutting-edge scientific methodologies, sharing European best practices, and enhancing the professional competencies of transport and traffic engineering specialists. The distinctive value of this manual lies in its seamless integration of theoretical knowledge in sustainable transportation with practical laboratory coursework. The state-of-the-art equipment and specialized software acquired through the SPHERE project empower students, academic staff, and young researchers to gain hands-on experience through real-world measurements, digital simulations, traffic flow analyses, and experimental activities. In this way, the university laboratory transcends being a mere classroom; it becomes an innovative hub for testing practical solutions aimed at creating safer, more efficient, and eco-friendly transport systems. This manual is primarily intended for undergraduate and master's students, PhD candidates, academic staff, and industry professionals specializing in transport systems, traffic organization, and logistics at TSTU. Its main purpose is to provide clear, standardized methodological guidelines for utilizing the new laboratory equipment and defining its practical applications in solving real-world engineering problems. The manual heavily promotes an interdisciplinary approach, recognizing that modern transport challenges cannot be solved in isolation, but require the convergence of urban planning, environmental science, information technology, and public policy. Ultimately, this methodological guide and the acquired technical assets serve as a strong foundation for boosting the university's institutional and research capacity. This technical infrastructure supports not only daily teaching activities but also facilitates joint applied research and contract-based projects with the Ministry of Transport, the Road Safety Service, and leading engineering firms to tackle urgent local challenges, such as urban congestion and environmental impacts in Tashkent. In summary, this laboratory

manual plays a dual role: it serves as a highly practical equipment guide and acts as a catalyst for educating a new generation of professionals ready to shape the future of mobility in Uzbekistan, ensuring the long-term sustainability of the project's outcomes in education and professional practice.

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1. Laboratory for Sustainable Transport

Managing traffic flows effectively across our capital and the wider republic remains one of the most critical challenges of our time. Amid growing concerns over noise, carbon emissions, and chronic urban congestion, modern transport engineering is shifting away from traditional models. Today, the priority is shifting toward smart infrastructure that places environmental balance and human safety at the absolute center of design. Driven by this urgency, Tashkent State Transport University has taken a strategic step forward by establishing a pioneering research and educational ecosystem under the auspices of the international Erasmus+ SPHERE initiative (Project No. 101128065). The launch of this new laboratory serves as a bridge to transform abstract textbook equations into dynamic, field-proven applications. Rather than focusing solely on theoretical models, our students and young researchers can now dissect real-world conditions on Tashkent's streets using digital twins, advanced computer simulations, and precise field-measurement instruments. Consequently, this facility acts as a key intersection where high-level academic instruction, scientific discovery, and industrial application converge. A Modern Research Hub for Next-Generation Engineers This methodological manual was specifically compiled to streamline laboratory protocols, standardize practical coursework, and maximize the efficiency of the newly deployed technical assets. The volume serves as an operational reference guide for undergraduate and postgraduate students, as well as for professionals collaborating with the Ministry of Transport and the Road Safety Service. The laboratory's core operations revolve around several interconnected pillars: Evidence-Based Analytics: Prior to proposing any urban intervention, empirical data regarding local traffic density, commuter behavior, and infrastructure capacity are systematically gathered and evaluated. Predictive Digital Modeling: Proposed interventions—such as deploying smart traffic signals, re-routing corridors, or designating Bus Rapid Transit (BRT) lanes—are simulated in micro- and macro-digital environments to forecast their impact before physical implementation. Safe and Active Mobility: Designing robust infrastructure that safeguards pedestrians and cyclists, pinpointing high-risk accident hotspots, and formulating proactive mitigation strategies. Environmental Mitigation: Investigating practical methods to minimize the transport network's footprint on air quality, urban noise levels, and the overall metropolitan microclimate. A Strategic Investment in the Future The catalog of hardware and software instruments detailed in the following sections represents an integrated suite of tools rather than a collection of isolated devices. Today's transport engineer must look beyond physical road construction to understand the interplay between urban planning, computer science, ecology, and public policy. This laboratory provides the exact interdisciplinary platform required to foster that broader view. In conclusion, this project at TSTU is far more than a routine upgrade of university equipment. It represents a long-term, sustainable investment in training a new generation of technical experts who are equipped to transform the transport infrastructure of

Uzbekistan and measurably improve the quality of life in Tashkent and our regional urban centers.

To bridge the gap between classroom learning and industrial demands, the laboratory operates as an active testing ground for urban mobility solutions. The technical architecture of the facility allows for the simultaneous execution of complex engineering tasks, ranging from localized intersection geometry improvements to macro-level regional transit planning. By establishing this operational framework, the university ensures that student research projects directly address the live problems reported by municipal authorities and transit operators. The practical modules detailed within this manual are specifically designed to foster advanced skills in the following applied domains: **Dynamic Network Optimization:** Utilizing real-time data streams to calibrate macroscopic traffic models, allowing researchers to evaluate how sudden changes in land use or population density affect the broader urban grid. **Vulnerable Road User Protection:** Analyzing pedestrian micro-mobility and cycling trajectories at complex roundabouts and uncontrolled crossings to design self-enforcing safety measures and traffic-calming zones. **Fleet Performance and Transit Reliability:** Assessing public bus corridors through spatial data analysis, focusing on travel-time variability, boarding delays, and the seamless integration of first-and-last-mile micro-mobility services. **Decarbonization and Energy Diagnostics:** Measuring vehicle emission signatures under diverse driving cycles and congestion scenarios to provide local environmental agencies with data-backed strategies for low-emission zones. **Institutional Collaboration and Long-Term Impact** Beyond its internal academic functions, the laboratory is strategically positioned to serve as an open-access consultancy and knowledge-sharing platform for external stakeholders across Uzbekistan. Through structured workshops, specialized certification courses, and joint public-private research initiatives, the facility directly supports the nation's broader transition toward intelligent transport systems and climate-resilient infrastructure. The continuous updates to the laboratory's data archives will provide a valuable repository for longitudinal studies on urban growth, infrastructure wear, and commuter behavior shifts over the next decade. Ultimately, the integration of these technological resources ensures that the SPHERE project delivers a lasting legacy.

2. Equipment in the Laboratory for Sustainable Transport

The equipment in the Laboratory for Sustainable Transport was acquired with the aim of supporting modern teaching processes, scientific research, and professional practice in the field of sustainable transportation and mobility. In accordance with the objectives of the Erasmus+ project SPHERE – Sustainable Transportation within the Framework of Green Deal, the equipment is intended to support the development of practical knowledge and skills of students, teachers, researchers, and professionals in the areas of transport infrastructure digitalization, traffic flow analysis, traffic safety, mobility management, environmental protection, and the application of modern technologies in the planning and improvement of transportation systems.

The development of modern transportation systems requires the use of precise measuring instruments, digital tools, analysis and simulation software, as well as devices that enable field data collection, processing, and visualization. For this reason, the equipment acquired within the SPHERE project was selected to facilitate the connection between theoretical knowledge and practical application. Its use enables the analysis of real transport and traffic-related problems based on relevant data, the development of sustainable mobility scenarios, and the acquisition of competencies necessary for applying modern methods in the planning, management, and improvement of transportation systems.

The particular importance of this equipment lies in its ability to support an integrated approach to transportation analysis. The concept of sustainable transportation is not limited solely to reducing negative environmental impacts, but also includes the development of a safer, more accessible, more efficient, and technologically advanced system for the movement of people and goods.

In this context, the laboratory equipment can be used for various types of activities, including:

- field measurements and data collection,
- digital recording and spatial analysis,
- transportation infrastructure analysis,
- reconstruction of traffic events,
- assessment of mobility and accessibility conditions,
- transport route planning and analysis,
- support for teaching activities and practical exercises,
- preparation of student and scientific research projects,
- implementation of professional analyses and projects.

Within the SPHERE Erasmus+ project, the following equipment were acquired:

- Bushnell radar gun: Used to measure the speed of moving vehicles from a distance and monitor speed limit compliance on roads.

- Gas Analyzer SKY2000: Used for real-time measurement of hazardous gas concentrations, detecting leaks, and ensuring workplace safety.
- ACEY Battery Tester: Used to test the charging and discharging cycles of batteries to evaluate their capacity and overall lifespan.
- Driving simulator: Designed to train drivers in a safe virtual environment, improve their driving skills, and simulate various road conditions.

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

In the context of the large-scale modernization of Uzbekistan's transport sector, this laboratory serves as a strategic practical hub for students at the Tashkent State Transport University. Rather than focusing solely on theoretical lectures, future engineers and analysts directly engage with intelligent transport systems, digital twins, and advanced software packages. Through practical assignments utilizing modern equipment like the Bushnell radar gun or the Gas Analyzer SKY2000, students gain hands-on experience in evaluating real-world traffic flows on Tashkent's avenues, measuring vehicle emissions, and interpreting data to make critical management decisions. This rigorous hands-on approach directly bridges the gap between academia and the evolving demands of the national job market. From a research perspective, the laboratory acts as an incubator for academic innovation, providing vital empirical data for undergraduate projects, master's theses, and doctoral dissertations. Researchers can utilize these facilities to digitize local transport corridors, study traffic conflict points at complex intersections in the capital, and evaluate the safety of rapidly expanding pedestrian and cycling infrastructures. By simulating various urban mobility scenarios, the university can spearhead scientific papers that propose viable solutions to current infrastructure challenges. In terms of real-world application, the laboratory is positioned to become a key consultant for the Ministry of Transport, the Tashkent City municipality, and other public transport authorities. The data collected and analyzed here will form the foundation for actionable recommendations aimed at easing urban congestion, optimizing public transit routes, and designing safe, active mobility zones.

3. Bushnell Radar Gun

The Bushnell Radar Gun (Figure 1) represents an advanced speed measurement and traffic analysis system intended for professional, educational, and research applications. This device integrates high-precision digital signal processing (DSP) technology, enabling accurate monitoring of vehicles' real-time speeds and acceleration patterns within urban and suburban environments. Thanks to its ergonomic design, ease of deployment, and consistency in data collection, the Bushnell Radar Gun provides a reliable empirical foundation for traffic flow analysis. Within the context of the Laboratory for Sustainable Transport at the Tashkent State Transport University (TSTU), this system has significant value because it enables the empirical study and monitoring of various traffic and

transportation scenarios in the real world. In this way, students, teachers, and researchers can analyze the actual behavior of traffic participants, evaluate speed compliance conditions, test the impact of infrastructure geometry, and examine the effects of different transport system elements without relying solely on theoretical models.



Figure 1. Bushnell Radar Gun

Speed measurement technology has particular importance in the field of sustainable transportation because it enables safe, controlled, and objective evaluation of different mobility dynamics. Using the Bushnell Radar Gun system, it is possible to monitor the movement of passenger cars, heavy vehicles, public transport units, and active mobility users under different infrastructure conditions, traffic volumes, lighting conditions, weather conditions, and traffic organization scenarios across Tashkent's street network.

A major advantage of this device lies in its integrated point-and-shoot radar technology, which enables real-time monitoring of vehicle approach speeds and critical deceleration zones. This is particularly important in research related to:

- traffic risk perception and speeding tendencies,
- analysis of drivers' speed adjustment near school zones and hospitals,
- investigation of vehicle behavior approaching pedestrian crossings,
- analysis of speed-related reactions in conflict-prone road sections,
- evaluation of speed limit sign visibility and driver compliance,
- safety research in intersection and roundabout approach areas,
- analysis of kinetic energy risks involving vulnerable traffic participants.

In the field of sustainable transportation, the Bushnell Radar Gun can be especially useful for:

- measurement of traffic speeds in real-world urban corridors,

- analysis of traffic participant behavior under changing speed limits,
- evaluation of infrastructure safety solutions like speed bumps and chicanes,
- testing the organization of vehicle flows near public transport stops,
- analysis of public space safety and calming measures in residential zones,
- investigation of interactions between speed and traffic density,
- education and training in the field of traffic enforcement and safety,
- calibration and verification of planned simulation and transport models,
- support for human factor research regarding speed choices,
- development of data-driven applications for urban mobility and policy making in Uzbekistan.

3.1. Importance for Teaching

One of the primary goals of the Laboratory for Sustainable Transport at the Tashkent State Transport University is to improve the educational process through the use of modern technologies and interactive learning methods. The Bushnell Radar Gun enables students to connect theoretical knowledge with realistic empirical experiences and analyze traffic situations in a controlled yet real-world environment. Instead of observing traffic situations, vehicle speeds, and congestion only through photographs, videos, or static diagrams, students can directly “enter” the urban street network of Tashkent and analyze movement conditions and speed dynamics from the perspective of field researchers. Such an approach significantly increases interactivity and improves the understanding of complex transportation problems, speed management, and traffic calming necessity.

Students can learn:

- how speed radar systems are used in transportation analysis and enforcement,
- how different traffic speed scenarios are measured and recorded in the field,
- how drivers’ speed compliance and attention are analyzed in high-risk zones,
- how infrastructure safety is assessed based on real-time vehicle velocity,
- how different traffic calming solutions are tested and verified using field data,
- how data obtained through digital radar technology are interpreted and processed,
- how speed measurement technology is applied in human factor, road safety, and mobility research.

A particular advantage of this system is that it encourages the development of analytical and research-oriented thinking among TDTU students. Students can independently conduct speed studies, observe driver behavior across various intersections in Uzbekistan, analyze results, and propose data-driven measures for improving the safety and sustainability of transportation systems.

3.2. Examples of Student Activities

In teaching and laboratory exercises, the Bushnell Radar Gun can be used for

a wide range of practical field activities.

Students can measure vehicle speeds across different urban corridors and analyze:

- which infrastructure elements affect vehicle acceleration and deceleration most frequently,
- how drivers react in potential conflict situations near pedestrian crossings,
- whether speed limit signs are sufficiently visible and generate high compliance rates,
- whether there are elements that hinder natural speed-calming and standard traffic flow.

It is also possible to conduct spot speed studies under real-world conditions and analyze:

- drivers' operational speeds along different road classifications in Tashkent,
- reactions to different traffic events and sudden bottlenecks,
- the impact of traffic signs and dynamic signal control on vehicle pacing,
- speed profiles and vehicle behaviors under reduced visibility or adverse weather conditions,
- the influence of infrastructure geometry on overall corridor safety and speed variance.

3.3. Importance for Scientific Research

The Bushnell Radar Gun can significantly improve scientific research in the fields of transportation engineering, urban mobility, and driver behavior. Precise speed-tracking technology enables the collection of objectives, empirical data related to vehicles' operational speeds and deceleration patterns, which is particularly important in traffic safety and crash prevention research.

The device can be useful in studies related to:

- driver behavior and speed choices in real-world urban environments,
- analysis of vehicle-pedestrian conflict dynamics at mid-block crossings,
- risk assessment and speed variance in conflict-prone bottleneck zones,
- operating speed profiles and geometric design analysis of urban corridors,
- testing the compliance rates and effectiveness of newly installed speed limit signs,
- analysis of transportation infrastructure safety via kinetic energy risk assessment,
- development of data-driven calibration models for macroscopic traffic simulation software,
- research in sustainable mobility, traffic calming, and speed management policy making.

An important advantage of this equipment is that it enables the cost-effective, rapid, and non-intrusive collection of real-world data across varying times of day

and traffic volumes. At the same time, gathering field-measured speed distributions enables the establishment of statistically sound baselines and accurate repeatability of empirical observations, which is essential for scientific validity and academic publications in Uzbekistan.

3.4. Importance for Sustainable Transportation and Intelligent Transport Systems

The Bushnell Radar Gun represents an important tool in the process of digitalization and development of intelligent transport systems in Uzbekistan. High-precision speed data collection enables the validation and tuning of different smart mobility concepts before their full-scale deployment in urban environments. In the field of sustainable transportation, field-measured radar technology can be useful for:

- testing urban mobility scenarios by assessing the baseline speed profiles of specific corridors,
- analyzing interactions between pedestrians, cyclists, and motor vehicles based on approach velocities,
- assessing public space safety and accessibility through the monitoring of speed-calmed residential zones,
- visualizing and validating planned infrastructure solutions by comparing before-and-after speed data,
- analyzing traffic safety metrics like 85th percentile speeds and critical pacing,
- education and awareness-raising regarding safe traffic behavior and enforcement standards,
- development of digital models and microscopic simulations using highly accurate field inputs.

In this way, the Bushnell Radar Gun is not only a speed enforcement instrument, but also a modern analytical tool that connects education, field research, digitalization, and sustainable transportation planning at the Tashkent State Transport University.

4. Gas Analyzer SKY2000

The Gas Analyzer SKY2000 (Figure 2) represents an advanced ambient air monitoring and emissions analysis system intended for professional, educational, and research applications. This device integrates high-precision electrochemical and infrared sensor technologies, enabling real-time monitoring of hazardous gas concentrations, vehicle exhaust emissions, and air quality parameters within urban and industrial environments. Thanks to its portable design, fast response time, and built-in data logging capabilities, the Gas Analyzer SKY2000 provides a reliable empirical foundation for environmental impact assessments. Within the context of the Laboratory for Sustainable Transport at the Tashkent State Transport University

(TSTU), this system has significant value because it enables the empirical study and monitoring of transport ecology scenarios in the real world. In this way, students, teachers, and researchers can analyze the actual environmental footprint of traffic flows, evaluate air pollution compliance, test the impact of green infrastructure, and examine the effects of different transport system elements on urban air quality without relying solely on theoretical estimates.



Figure 2. Gas Analyzer SKY2000

4.1. Importance for Teaching

One of the primary goals of the Laboratory for Sustainable Transport at the Tashkent State Transport University is to improve the educational process through the use of modern technologies and interactive learning methods. The Gas Analyzer SKY2000 enables students to connect theoretical knowledge of transport ecology with realistic empirical experiences and analyze environmental traffic impacts in a controlled yet real-world environment.

Instead of observing vehicle emissions, air pollution, and environmental degradation only through photographs, videos, or static charts, students can directly enter the urban street network of Tashkent and analyze air quality dynamics and gas concentration levels from the perspective of field researchers. Such an approach significantly increases interactivity and improves the understanding of complex transportation problems, eco-friendly transit management, and the necessity of low-emission zones.

Students can learn:

- how gas analyzer systems are used in transport-related environmental analysis and emission monitoring,
- how different vehicle exhaust concentrations are measured and recorded in

- the field,
- how urban air quality standards and public health risks are analyzed in high-density traffic zones,
- how transport infrastructure sustainability is assessed based on real-time ecological data,
- how different green mobility solutions are tested and verified using environmental field data,
- how data obtained through multi-gas sensor technology are interpreted and processed,
- how emission measurement technology is applied in human factor, public health, and sustainable mobility research.

A particular advantage of this system is that it encourages the development of analytical and research-oriented thinking among TSTU students. Students can independently conduct roadside air quality studies, observe the environmental impact of urban traffic across various intersections in Uzbekistan, analyze results, and propose data-driven measures for improving the safety, environmental health, and sustainability of transportation systems.

4.2. Examples of Student Activities

In teaching and laboratory exercises, the Gas Analyzer SKY2000 can be used for a wide range of practical field and roadside activities.

Students can measure air pollution levels across different urban corridors in Tashkent and analyze:

- which transportation elements affect hazardous gas concentrations and emission spikes most frequently,
- how emission levels change in potential traffic bottleneck situations near major intersections,
- whether local air quality standards are sufficiently met along high-density transit routes,
- whether there are structural elements that hinder natural air dispersion and ventilation in urban canyons.

It is also possible to conduct real-time emissions monitoring under real-world conditions and analyze:

- ambient air quality profiles along different road classifications and public transport corridors,
- environmental reactions to different traffic events and sudden gridlocks,
- the impact of heavy vehicle restrictions and green waves on roadside gas concentration levels,
- emission dispersal patterns and air quality dynamics under changing weather and atmospheric conditions,
- the influence of alternative fuel public transport (e.g., electric buses) on overall corridor environmental safety.

The portable multi-gas monitoring system can also be used to test and evaluate the environmental necessity of transport infrastructure solutions before finalizing structural redesigns. Students can analyze how different existing layouts—such as various types of intersections, bus terminals, pedestrian zones, or dedicated public transport corridors—influence localized air pollution and the health exposure of road users.

This empirical approach is especially important because it enables sustainable transportation and transport ecology to be studied not only theoretically, but also through hands-on field measurements and realistic environmental data analysis.

4.3. Importance for Scientific Research

The Gas Analyzer SKY2000 can significantly improve scientific research in the fields of transport ecology, urban environmental health, and sustainable mobility. Precise multi-gas detection technology enables the collection of objectives, empirical data related to vehicle-induced pollution, which is particularly important in environmental sustainability and urban public health research.

The device can be useful in studies related to:

- transport-related emission modeling in high-density real-world urban environments,
- analysis of vehicle exhaust exposure dynamics at pedestrian crossings and bus stops,
- risk assessment of toxic gases (such as (CO, NO_x, SO₂), and VOCs) in congested bottleneck zones,
- roadside air quality profiles and geometric street design analysis of urban corridors,
- testing the ecological efficiency and emission reduction rates of newly implemented traffic management policies,
- analysis of transportation infrastructure sustainability via carbon footprint and air quality assessments,
- development of data-driven calibration models for macroscopic environmental and dispersion simulation software,
- research in green mobility, low-emission zones, and environmental policy making in Uzbekistan.

An important advantage of this equipment is that it enables the cost-effective, rapid, and non-intrusive collection of real-world environmental data across varying times of day and traffic volumes. At the same time, gathering field-measured gas concentrations enables the establishment of statistically sound baselines and accurate repeatability of empirical observations, which is essential for scientific validity and academic publications in Uzbekistan.

4.4. Importance for Sustainable Transportation and Intelligent Transport Systems

The Gas Analyzer SKY2000 represents an important tool in the process of digitalization and development of intelligent transport systems and eco-friendly urban planning in Uzbekistan. High-precision emission data collection enables the validation and tuning of different smart and green mobility concepts before their full-scale deployment in urban environments. In the field of sustainable transportation, field-measured gas analysis technology can be useful for:

- testing urban mobility scenarios by assessing the environmental baselines of specific transport corridors,
- analyzing interactions between traffic volume, vehicle types, and air pollution based on real-time readings,
- assessing public space safety and health accessibility through the monitoring of low-emission residential zones,
- visualizing and validating planned eco-friendly infrastructure solutions by comparing before-and-after emission data,
- analyzing transport sustainability metrics like peak pollution hours and critical emission corridors,
- education and awareness-raising regarding vehicle emission standards and environmental enforcement targets,
- development of digital environmental models and micro-scale emission simulations using highly accurate field inputs.

In this way, the Gas Analyzer SKY2000 is not only an environmental monitoring instrument, but also a modern analytical tool that connects education, field research, digitalization, and sustainable transportation planning at the Tashkent State Transport University

5. ACEY Battery Tester

The ACEY Battery Charging Discharging Tester (Figure 3) represents an advanced energy storage testing and battery diagnostics system intended for professional, educational, and research applications. This device integrates high-precision current and voltage regulation technologies, enabling real-time monitoring of battery capacities, state-of-health (SoH), temperature variations, and cyclic degradation patterns. Thanks to its automated testing workflows, multi-channel data acquisition, and precision safety controls, the ACEY Battery Tester provides a reliable empirical foundation for electro-chemical and energy efficiency analysis. Within the context of the Laboratory for Sustainable Transport at the Tashkent State Transport University, this system has significant value because it enables the empirical study and monitoring of electric vehicle battery packs and renewable energy storage scenarios in a controlled environment. In this way, students, teachers, and researchers can analyze the actual performance degradation of power cells,

evaluate energy density metrics, test battery thermal safety, and examine the effects of different transport system elements on electric mobility without relying solely on theoretical simulator software.



Figure 3. ACEY Battery Tester

5.1. Importance for Teaching

One of the primary goals of the Laboratory for Sustainable Transport at TSTU is to improve the educational process through the use of modern technologies and interactive learning methods. The ACEY Battery Tester enables students to connect theoretical knowledge of electric propulsion and green energy with realistic empirical experiences and analyze electrochemical cell behavior in a controlled laboratory environment.

Instead of observing battery charging curves, power degradation, and thermal performance only through photographs, videos, or static charts, students can directly "enter" the laboratory workflow and analyze real-time power cycling and chemical aging profiles from the perspective of research engineers. Such an approach significantly increases interactivity and improves the understanding of complex green transportation problems, electric vehicle autonomy challenges, and the necessity of optimized energy management systems.

Students can learn:

- how battery testing systems are used in electric vehicle design and performance monitoring,
- how different charge-discharge cycles are measured and logged safely in a laboratory,
- how battery health degradation and public safety risks are analyzed in high-voltage transport systems,
- how transport infrastructure sustainability is assessed based on energy efficiency and lifecycle data,
- how different electric mobility solutions are tested and verified using hardware-in-the-loop energy data,
- how data obtained through multi-channel testing software are interpreted and processed,

- how battery management technology is applied in human factor, range anxiety, and sustainable mobility research.

5.2. Examples of Student Activities

In teaching and laboratory exercises, the ACEY Battery Tester can be used for a wide range of practical laboratory activities.

Students can measure cell degradation levels across different simulated transport duties and analyze:

- which operational cycles affect battery capacity retention and internal resistance surges most frequently,
- how battery temperatures change in potential high-drain acceleration or fast-charging scenarios,
- whether local electric vehicle energy standards are sufficiently met under varied load distributions,
- whether there are technical bottlenecks that hinder natural heat dissipation and cell balancing in modular battery packs.

It is also possible to conduct real-time energy efficiency monitoring under controlled laboratory conditions and analyze:

- battery state-of-charge (SoC) profiles matching various urban driving cycles of Tashkent,
- environmental and thermal reactions to different charging events and rapid discharge spikes,
- the impact of ambient temperature variations on roadside electric bus driving ranges,
- power delivery patterns and cell degradation dynamics under accelerated laboratory aging profiles,
- the influence of alternative regenerative braking strategies on overall battery pack safety and lifespan.

5.3. Importance for Scientific Research

The ACEY Battery Tester can significantly improve scientific research in the fields of electric mobility, clean energy storage, and transport electrification. Precise cell analysis technology enables the collection of objective, empirical data related to lithium-ion or solid-state battery degradation, which is particularly important in environmental sustainability and green vehicle engineering research.

The device can be useful in studies related to:

- electric vehicle battery pack degradation modeling for high-density real-world urban routes,
- analysis of thermal runaway dynamics during rapid-charging phases at municipal transport depots,

- risk assessment of secondhand EV batteries being repurposed for static grid storage,
- power delivery profiles and internal resistance analysis under heavy public transport duty cycles,
- testing the economic and chemical efficiency of newly developed local battery chemical formulations,
- analysis of transport infrastructure sustainability via carbon-footprint lifecycle assessments of EV batteries,
- development of data-driven calibration models for macroscopic energy and vehicle network simulations,
- research in green mobility, clean public transit networks, and eco-friendly policy making in Uzbekistan.

5.4. Importance for Sustainable Transportation and Intelligent Transport Systems

The ACEY Battery Tester represents an important tool in the process of digitalization and development of intelligent transport systems and electric vehicle infrastructure planning in Uzbekistan. High-precision battery data collection enables the validation and tuning of different smart grid and green mobility concepts before their full-scale deployment in urban environments. In the field of sustainable transportation, laboratory-measured battery testing technology can be useful for:

- testing urban mobility scenarios by assessing the electrical storage baselines of specific transit fleets,
- analyzing interactions between grid capacity, EV charging speed, and battery health based on real-time loads,
- assessing public fleet safety and cost accessibility through the monitoring of long-life battery operations,
- visualizing and validating planned eco-friendly transport solutions by comparing before-and-after cell efficiency data,
- analyzing transport sustainability metrics like peak charging grid stress and critical battery replacement cycles,
- education and awareness-raising regarding electric vehicle safety standards and smart-charging targets,
- development of digital energy models and micro-scale power simulations using highly accurate laboratory inputs.

In this way, the ACEY Battery Tester is not only a battery diagnostic instrument, but also a modern analytical tool that connects education, laboratory research, digitalization, and sustainable transportation planning at the Tashkent State Transport University.

6. Driving simulator

The Driving Simulator (Figure 4) represents an advanced interactive vehicle simulation and human-in-the-loop testing system intended for professional, educational, and research applications. This system integrates high-fidelity physics engines, multi-display visual projections, realistic force-feedback control interfaces, and telemetry logging software, enabling real-time monitoring of driver inputs, vehicle dynamics, and situational awareness metrics. Thanks to its customizable digital environments, automated scenario generation, and precise data tracking capabilities, the Driving Simulator provides a highly safe and reliable empirical foundation for human factors and traffic behavior analysis. Within the context of the Laboratory for Sustainable Transport at the Tashkent State Transport University, this system has significant value because it enables the empirical study and monitoring of complex driving scenarios, traffic conflicts, and infrastructure designs within a controlled virtual environment. In this way, students, teachers, and researchers can analyze the actual behavior of traffic participants, evaluate safety critical events, test innovative road designs, and examine the effects of different transport system elements without risking lives or causing disruptions in real-world traffic conditions.



Figure 4. Driving simulator

6.1. Importance for Teaching

One of the primary goals of the Laboratory for Sustainable Transport at TSTU is to improve the educational process through the use of modern technologies and interactive learning methods. The Driving Simulator enables students to connect

theoretical knowledge of traffic engineering and road safety with realistic behavioral experiences and analyze driver reactions in a completely controlled and safe environment.

Instead of observing traffic conflicts, hazardous road geometry, and vehicle maneuvering limitations only through photographs, videos, or static charts, students can directly enter the driver's seat and analyze micro-level vehicle dynamics and spatial awareness variables from the perspective of active road users. Such an approach significantly increases interactivity and improves the understanding of complex transportation problems, geometric design flaws, and the critical necessity of proactive traffic calming and crash prevention measures.

Students can learn:

- how driving simulation systems are used in modern transport planning, infrastructure auditing, and driver behavioral profiling,
- how complex urban traffic scenarios are designed, coded, and simulated safely in a laboratory,
- how driver distraction, fatigue, and public safety risks are analyzed under various high-stress road environments,
- how transport infrastructure safety is assessed based on real-time vehicle-to-infrastructure (V2I) digital telemetry,
- how different smart mobility and intersection layouts are tested and verified using human-in-the-loop validation,
- how data obtained through simulator telemetry logs are interpreted and processed using statistical analysis,
- how virtual reality and hardware simulation technologies are applied in human factors, ergonomics, and sustainable mobility research.

6.2. Examples of Student Activities

In teaching and laboratory exercises, the Driving Simulator can be used for a wide range of practical laboratory and software-based activities.

Students can simulate vehicle movements through hazardous corridors and analyze:

- which infrastructure elements and geometric configurations trigger sudden braking or irregular steering behaviors most frequently,
- how drivers react in potential conflict situations near unexpected mid-block pedestrian crossings or lane drops,
- whether newly proposed digital or physical traffic signs are sufficiently visible and generate rapid driver compliance under tight reaction windows,
- whether there are technical or environmental elements that hinder natural lane-keeping and clear visibility along major arterials.

It is also possible to conduct real-time behavioral monitoring under simulated experimental conditions and analyze:

- driver response profiles when encountering newly designed roundabouts or complex multi-lane junctions modeled from Tashkent,

- cognitive and motor reactions to sudden traffic events, unexpected obstacles, and mechanical system failures,
- the impact of nighttime driving, adverse weather conditions, and low visibility on critical stopping sight distances,
- speed selection and acceleration patterns under variable speed limit zones and dynamic tolling layouts,
- the influence of alternative advanced driver assistance systems (ADAS) on reducing human error and improving corridor safety.

6.3. Importance for Scientific Research

The Driving Simulator can significantly improve scientific research in the fields of human factors, traffic psychology, and safety-oriented transport engineering. High-frequency data tracking technology enables the collection of objective, empirical metrics related to driver reaction times, brake pedal force, steering wheel variance, and spatial trajectories, which is particularly important in proactive traffic safety and infrastructure risk mitigation research.

The device can be useful in studies related to:

- microscopic driver behavior and cognitive workload modeling for high-density, complex urban intersections,
- analysis of crash-avoidance dynamics during critical geometric design failures or unexpected pedestrian path intrusions,
- risk assessment of vulnerable road users (VRUs) interacting with vehicles in shared urban spaces or cycling corridors,
- speed adaptation profiles and visual scanning behavior across various highway and urban street configurations,
- testing the psychological efficiency and response rates toward newly deployed intelligent transportation signaling and warning systems,
- analysis of transportation infrastructure safety via surrogate safety measures (SSMs) extracted from simulated conflicts,
- development of data-driven calibration parameters for microscopic traffic simulation software platforms,
- research in active traffic management, eco-driving behaviors, and macro-level safety policy making in Uzbekistan.

6.4. Importance for Sustainable Transportation and Intelligent Transport Systems

The Driving Simulator represents an important tool in the process of digitalization and development of intelligent transport systems (ITS) and smart city planning in Uzbekistan. High-fidelity human-in-the-loop data collection enables the validation and tuning of connected and autonomous vehicle (CAV) protocols,

intelligent infrastructure concepts, and digital twins before their capital-intensive physical deployment in urban environments. In the field of sustainable transportation, simulator-derived behavioral technology can be useful for:

- testing innovative urban mobility scenarios by assessing driver adaptation to newly introduced Bus Rapid Transit (BRT) or dedicated bus lanes,
- analyzing micro-level interactions between human drivers, automated vehicles, and traffic infrastructure based on precise telemetry logs,
- assessing public space safety and accessibility design options by evaluating driver speed reduction compliance in pedestrian-oriented zones,
- visualizing and validating planned geometric and systemic transport solutions by evaluating before-and-after behavioral performance indexes,
- analyzing transport safety metrics such as time-to-collision (TTC) and post-encroachment time (PET) across a high quantity of repeatable trials,
- education and awareness-raising through immersive training modules focused on defensive driving and eco-friendly driving techniques,
- development of holistic digital transportation models and multi-modal simulations utilizing highly accurate empirical human behavior inputs.

In this way, the Driving Simulator is not only an educational training tool, but also a modern analytical platform that perfectly bridges the gap between classroom education, advanced laboratory research, end-to-end digitalization, and sustainable transportation infrastructure planning at the Tashkent State Transport University.

CONCLUSION

The laboratory manual represents a significant outcome of activities implemented within the Erasmus+ SPHERE project, with the primary objective of improving teaching, scientific research, and the practical application of knowledge in the field of sustainable transportation and mobility at the Tashkent State Transport University. Its main purpose is to provide users with a systematic overview of laboratory equipment—specifically the Bushnell Radar Gun, Gas Analyzer SKY2000, ACEY Battery Tester, and Driving Simulator—as well as the possibilities for their application in education, research, and professional practice. Through the description of modern technologies, methods of measurement, recording, simulation, spatial analysis, and digital data processing, the manual connects theoretical knowledge in the field of transportation and traffic engineering with practical approaches to transportation system analysis within the evolving infrastructure of Uzbekistan.

Modern transportation systems require an integrated, data-driven, and technology-supported approach to planning, management, and mobility improvement. For this reason, laboratory equipment and software represent important tools for understanding the complex relationships between infrastructure, traffic participants, vehicles, the environment, and traffic management measures. Instead of relying solely on theoretical assumptions, the application of modern technologies enables the collection of real-world data, analysis of spatial characteristics, simulation of different traffic scenarios, risk assessment, and visualization of the effects of various measures before their physical implementation in real environments like the Tashkent municipal grid.

The particular value of the laboratory infrastructure lies in its ability to support practice-oriented education. Through the use of modern equipment and specialized software, TSTU students acquire knowledge and skills that go beyond the scope of traditional classroom teaching. They have the opportunity to participate in field research, analyze spatial and traffic-related data, use digital tools, apply hardware-in-the-loop simulations, investigate human factors and traffic safety, and assess various aspects of green mobility and infrastructure. Such an approach contributes to the development of analytical thinking, critical problem-solving skills, and evidence-based decision-making abilities.

The application of equipment and software is of particular importance in the field of sustainable transportation, as it enables a comprehensive understanding of mobility, accessibility, safety, and environmental protection challenges. Walking, cycling, public transportation, and other forms of sustainable mobility can be analyzed through specific indicators and spatial conditions, while simulations and digital analyses enable the testing of different scenarios prior to their implementation. In this way, sustainable transportation does not remain merely a theoretical concept, but becomes a practical framework for developing safer, more efficient, and more accessible transportation systems across Uzbekistan.

In addition to its educational role, the laboratory also possesses considerable scientific and research potential. Equipment and software can be used to conduct various studies related to traffic safety, urban mobility, active transportation, infrastructure digitalization, spatial analysis, intelligent transport systems, and the behavior of traffic participants. The results obtained through the application of laboratory resources may serve as the basis for seminar papers, final and master's theses, doctoral dissertations, scientific publications, professional studies, and joint projects aimed at improving transportation systems and supporting local communities, Khokimiyats, and ministries.

An important aspect of this manual also lies in promoting an interdisciplinary approach, as sustainable transportation integrates transportation engineering, urban planning, traffic safety, information technologies, data analysis, environmental protection, and public policy. Working with laboratory equipment enables the integration of these disciplines through practical tasks and research activities, thereby creating conditions for a more comprehensive understanding of transportation systems and contemporary mobility challenges.

In essence, this laboratory manual represents more than a technical guide for the use of equipment. It provides a foundation for the development of a modern educational and research model in transportation, in which knowledge is acquired through practical work, analysis, experimentation, and the application of advanced technologies. Through the integration of equipment and software acquired within the Erasmus+ SPHERE project, conditions are created for strengthening institutional capacities at TSTU, modernizing national engineering education, and developing professionals capable of addressing the challenges of safe, smart, and sustainable mobility in the future.