



# BOOK OF PROCEEDINGS

# INTERNATIONAL CONFERENCE SUSTAINABLE MOBILITY

**5-6 MARCH**

# 2026

The INTEC International Conference brings together academics, researchers, policymakers and industry experts to discuss innovative approaches and collaborative solutions for a sustainable future in engineering and mobility. The conference will be hosted by POLIS University in Tirana, Albania, and co-organized by partners from across the EU as part of the Erasmus+ CBHE Project 101081873-ERASMUS-EDU-2022-CBHE-STRAND-2.



INTEC International Engineering Competence Centres to push sustainable mobility development in Albania and Montenegro  
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Project Partners:



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## ANALYSIS OF BATTERY CHARGING AND DISCHARGING BEHAVIOR FOR ELECTRIC VEHICLE APPLICATIONS

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### Abstract

*The increasing adoption of electric vehicles highlights the need for accurate analysis of battery charging and discharging behavior. This paper presents a prototype software solution for analyzing, visualizing, and predicting battery energy behavior using an open experimental dataset. The study is based on the NASA Battery Dataset, which provides detailed measurements from real lithium-ion battery cycles. Representative cycles from early, mid-life, and late stages of battery operation are analyzed to examine voltage, current, power, and energy evolution over time. The energy delivered during discharge is calculated to estimate the battery State of Charge (SOC). Furthermore, cycle characteristics such as discharge duration, voltage, and current are used to develop a simplified predictive formulation (proof-of-concept) of delivered energy. The results are presented through clear visualizations that support intuitive interpretation of battery dynamics and degradation. The proposed approach establishes a foundation for future extensions toward intelligent energy management and charging strategies in electric vehicles.*

**Keywords:** Electric vehicles (EVs), lithium-ion battery analysis, State of Charge (SOC) Estimation, data-driven battery estimation

## **I. INTRODUCTION**

The ultimate growth of electric vehicles (EVs) has confirmed the importance and the need for reliable battery analysis and energy management strategies. The popular lithium – ion batteries offer high efficiency because they offer power delivery and retain charge well. By using their main characteristics and efficiency, they directly influence vehicle range, safety, and long–term sustainability. Monitoring charge and discharge cycles of lithium–ion batteries is critical for safety. Overcharging or deep discharging can lead to battery damage. That is why it is very important to understand battery behavior during this process for system–level optimization and the development of intelligent applications in electric mobility.

During the research on the process of charge and discharge cycles, lithium–ion batteries show gradient changes in voltage, current, capacity, and delivered energy. In practical EV applications, the main problem is represented by the question: “How long does the device have until it stops working?” State of charge (SOC) becomes the most important factor in repairing the issues of the applications, including batteries. This factor shows the key characteristics for battery management systems, enabling operations that are safe and also effective in managing battery capacity. Methods representing estimation techniques that have been proposed in the literature can achieve high accuracy, and it requires large datasets, complex implementation, etc. So, as a result, there can be a simplified analysis that can show meaningful battery behavior from experimental data.

## **II. METHODS**

The following section expresses the main methods that made this analysis possible, including the experimental dataset, the charge and discharge behavior, the energy, the SOC calculation of the battery, and data-driven energy estimation analysis

### **1. Experimental dataset**

The main factor that made this analysis of this case study is the NASA Dataset. This original dataset shows detailed measurements recorded during the process of charging and discharging cycles under laboratory conditions. The dataset was obtained from the NASA Ames Prognostics Data Repository and accessed via the Kaggle platform.

Each cycle includes time–series data of voltage(V), current(I), and time(s), making it possible to analyze the battery’s electrical behavior. Most importantly, a large number of battery cycles is captured (from early – life operation to ageing stages). Therefore, the idea of this project is to

make the cycles from three different operational stages interpretable: early-life, mid-life, and late-life. The analyzed cycles were randomly selected, with one representative cycle chosen from the early-life, mid-life, and late-life stages of the battery.

Li-ion batteries represent complex electrochemical–mechanical systems in which various degradation mechanisms are present. So, by this analysis with the chosen dataset, it can be controlled the battery usage in real – time to optimize battery life – cycle performance.

## 2. Charge and discharge behavior analysis

The analysis focuses on the examination of charging and discharging through voltage and current profiles.

The constant-current (CC) and constant-voltage (CV) regions were examined for charging cycles, as functions of time, in order to identify characteristics of charging phases. So, by this charging analysis, it is shown that the battery response at different stages of operation is observed in lithium-ion batteries. Particular attention was given to discharge behavior, which provides direct information about usable energy and battery performance (as voltage and current trends during discharge).

These parameters are related to the usable energy delivered by the battery and serve for state-of-charge calculations.

## 3. Energy and state of the charge calculation

The determination of the state of charge (SoC) of a battery may be a problem of more or less, depending on the type of battery and the application in which the battery is used. To evaluate battery performance, the electrical power during operation was calculated using the measured voltage and current signals. SOC, for each discharge cycle, was normalized between full charge and complete discharge, enabling representation of a battery charge depletion while avoiding the need for complex electrochemical or equivalent circuit modes.

The energy estimated was performed using a simple linear regression model of the form:

$$\hat{E} = a \cdot T_d + b,$$

where  $\hat{E}$  denotes the estimated discharged energy,  $T_d$  the discharge duration, and  $a$  and  $b$  the regression coefficients. Due to the limited number of representative cycles, the model is intended as a **proof-of-concept** demonstration.

The discharged energy used for regression was obtained from experimentally measured voltage

and current signals, as described below.

$$P(t) = V(t) * I(t)$$

where  $t_0$  and  $t_f$  represent the start and the end of the discharge process, and by this metric, the usable energy delivered by the battery during the operation.

$$E = \int_{t_0}^{t_f} P(t) dt$$

Finally, the state of charge has been estimated by using and normalized between full charge and complete discharge:

$$SOC(t) = 1 - \frac{E(t)}{E_{total}}$$

where  $E(t)$  is the cumulative discharge energy at time  $t$ , and  $E_{total}$  is the total discharged energy of the cycle.

### III. RESULTS

This section presents the main results, analyzing battery charge and discharge behavior in terms of voltage, current, energy, and state of charge across different operating stages.

#### 1. Charge behavior analysis

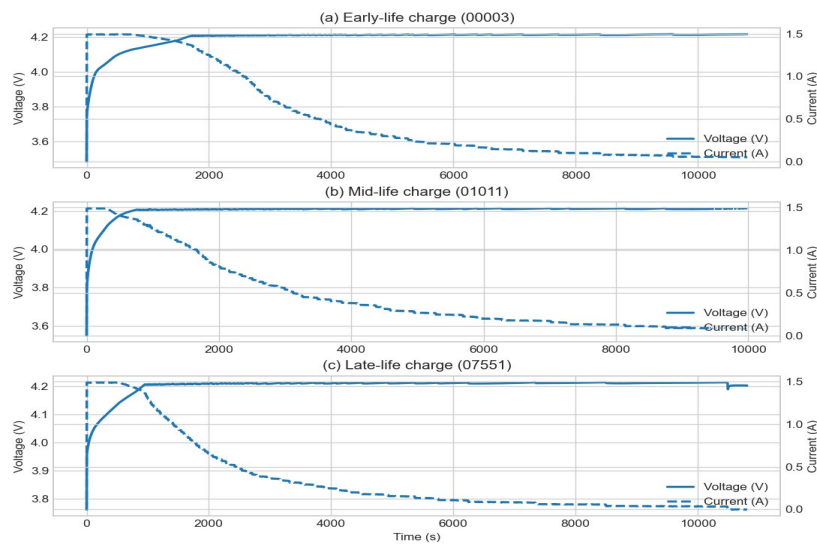


Figure 1. Voltage and current profiles during charging for (a) early-life (00003), (b) mid-life (01011), and (c) late-life (07551) battery cycles.

In Figure 1, voltage and current represent the (a)early-life (00003), (b)mid-life (01011), and (c)late-life (07551) charge cycles. From early to late-life, it can be seen that the battery is charged using a constant-current and voltage (CC-CV) strategy.

It has resulted, during the CC phase, in the charging current remaining approximately 1.5 A, while the voltage increases from about 3.5V to 4.2V over 1500-2000 s.

Minor variations are observed between early-life and late-life cycles, in which the fundamental charging behavior remains consistent across different stages of battery operation.

## 2. Discharge behavior analysis

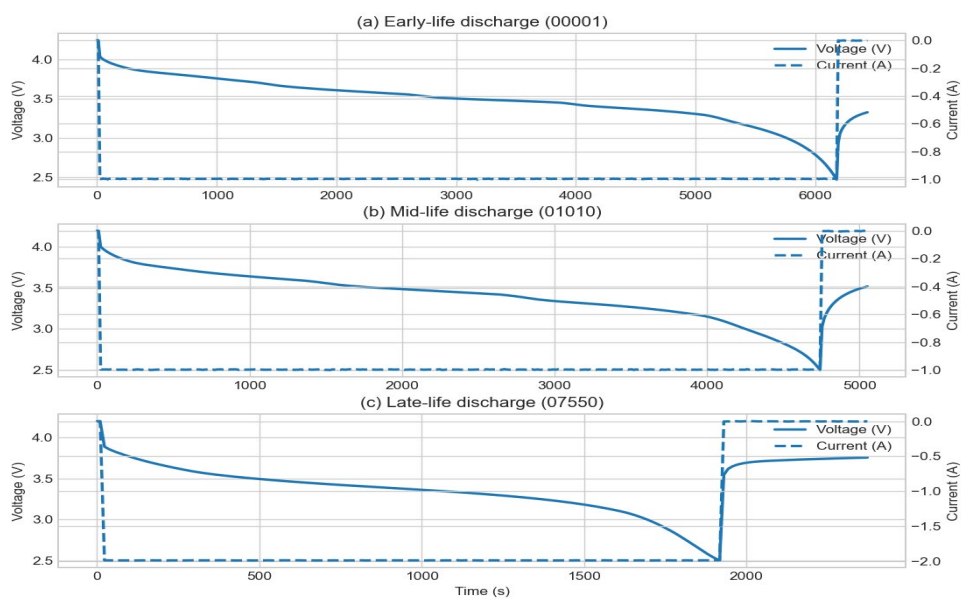


Figure 2. Voltage and current profiles during discharging for (a) early-life (00001), (b) mid-life (01010), and (c) late-life (07550) battery cycles.

Figure 2 has the same concept of presenting voltage and current profiles as Figure 1; the main differences are in the discharged cycles, corresponding to (a)early-life (00001), (b)mid-life (01010), and (c)late-life (07550) battery operation. During these cycles, in Figure 2, it can be seen that during discharge the battery has a constant current of -1A.

The battery voltage decreases from 4.2V during the discharging process. The early-life cycle exhibits the longest discharge duration (about 6000 s), while the mid-life and late-life shorter (4800 s and 2000 s).

As the battery ages, the discharge process becomes shorter, and the voltage drop becomes steeper. These discharge characteristics are the highlights that affect the further analysis of SOC and the energy.

### 3. Energy analysis and SOC estimation

The results summarized in Table 1 show, from early-life, mid-life, and late-life, the discharged energy through the selected discharge cycles. Step by step, starting from early-life, which delivers 5.94Wh, making it possible to decrease the energy to 4.45Wh for the mid-life cycle and further to 3.51Wh for the late-life cycle. Furthermore, this clear reduction indicates progressive battery degradation with ageing.

*Table 1. Discharged energy for representative early-life, mid-life, and late-life cycles.*

Cycle stage	Cycle ID	Discharged energy (Wh)
Early-life	00001	5.94
Mid-life	01010	4.45
Late-life	07550	3.51

State of charge (SOC) was implemented by using an energy-based formulation (based on the discharge energy).

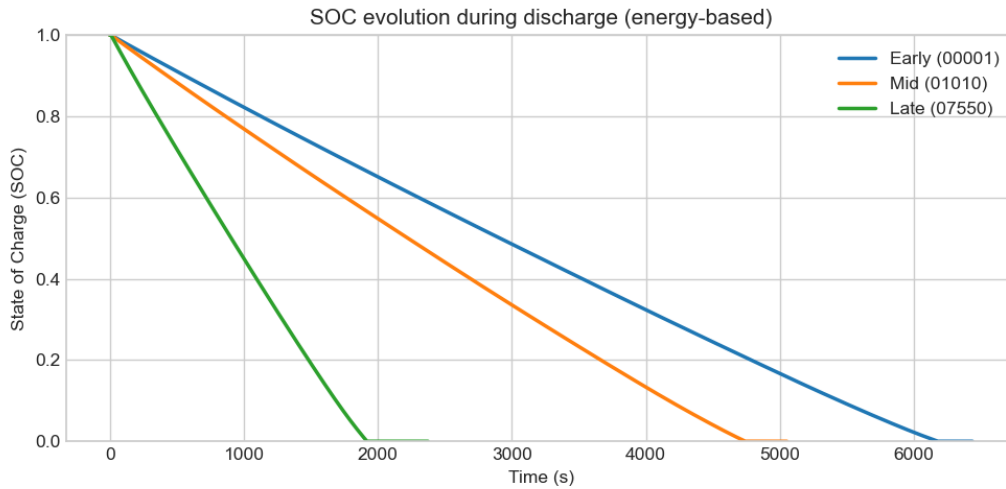


Figure 3. State of charge (SOC) evolution during discharge for early-life, mid-life, and late-life battery cycles.

The presented SOC trajectories are obtained using the proposed energy-based formulation and represent a simplified predictive estimation of SOC evolution during discharge. For the analyzed cycles, the estimated SOC reaches zero at approximately 6000 s (early-life), 4800 s (mid-life), and 2000 s (late-life), clearly illustrating the impact of battery aging on usable discharge duration.

While advanced SOC estimation approaches such as electrochemical models, Kalman filter-based methods, and data-driven techniques have been widely studied, this work deliberately adopts an energy-based formulation to maintain interpretability and low computational complexity. This choice makes the proposed approach suitable for rapid analysis, educational purposes, and early-stage prototyping.

The presented results support qualitative trend estimation rather than quantitative prediction accuracy. This work focuses on qualitative trend analysis and proof-of-concept demonstration, while explicit error analysis, signal filtering, and quantitative validation are left for future investigation

#### IV. CONCLUSION

This paper enables an understanding of key differences in battery behavior across early-life, mid-life, and late-life operation. As a result, the charging of consistent phases, which have opposite characteristics (discharge characteristics), showed a reduction in duration, delivered energy, and usable state of charge as the battery ages. The final results confirm that discharge-related indicators reflect a reflection of battery degradation rather than charging behavior. The progress of the

decrease in discharged energy and faster SOC depletion observed in the final life cycles highlights the direct impact of ageing of the battery. In this study, we propose a hybrid approach. In the future, a combination of linear regression will accomplish early-stage estimation of SOC operation. While similar datasets have been widely used, the contribution of this work lies in a compact and interpretable SOC estimation framework suitable for rapid analysis and educational or prototyping purposes. The interpreted results show the importance of battery-aware analysis for the future electric vehicle energy management and decision-support applications.

Error analysis, filtering methods, and quantitative model validation were not included, since the primary goal of this study is qualitative trend analysis and proof-of-concept demonstration. Future work will address the influence of temperature, as well as systematic cycle selection, signal filtering, and quantitative validation of the proposed approach.

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**International conference on sustainable mobility**

**Agenda**

**Project title:** International Engineering Competence Centres to push Sustainable  
 Mobility Development in Albania and Montenegro  
**Acronym:** INTEC

<b>Work package</b>	
<b>WP11</b>	<b>International conference</b>
<b>TASK</b>	
11.4	Community Building Events

<b>Dates</b>	05.03.-06.03.2026
<b>City</b>	Tirana
<b>Meeting venue</b>	POLIS University Entrance Hall
<b>Address</b>	Rr. Bylis 12, Kodi Postar 1051, Kutia Postare 2995, Tirana, Albania

<b>05.03.2026</b>	
Entrance Hall, POLIS University	
<b>8:30 - 9:00</b>	<b>Registration</b>
<b>9:00 - 9:30</b>	<b>Opening Performance</b>
<b>Welcome session - Auditorium A5 (Ground floor)</b>	
<b>9:30 - 10:00</b>	<b>Opening Remarks</b> Dr. Elona Karafili (Vice Rector, POLIS University) Dr. Flora Krasniqi (Head of Office of Projects and Internationalization, POLIS University) DI Daniela Wenzl (INTEC Project Coordinator)
<b>Auditorium A5 (Ground floor)</b>	
<b>10:00 - 11:00</b>	<b>Keynote speakers</b> DI Horst Pflügl AVL Collaborative Research for sustainable Mobility DPSHTRR Representative - (General Directorate of Road Transport Services in Albania)
<b>11:15 - 11:30</b>	<b>Coffee break (Moving into parallel sessions)</b>

11:30	SESSION 1: POLITICAL AND REGULATORY FRAMEWORK AULA B1	SESSION 2: TECHNOLOGICAL INNOVATION AULA B4
11:30 - 11:45	<b>Opening Session:</b> Prof. Emeritus dr Nataša Gospić (FSKL)	<b>Opening Session:</b> Associate Prof. Ivan Tolj (US)
11:45 - 12:00	<b>Integrating Event Data Recorder (EDR) Technology into Sustainable Road Safety Frameworks within the European Green Deal</b> Eriselda Alimeti, Parid Milo, Mentor Çejku, Anis Sulejmani, Odhisea Koça	<b>Empirical Comparative Study of Structural CFRP Sandwich Structure Inserts for Out-of-Plane loads</b> Imre Kovács
12:00 - 12:15	<b>Infrastructure Readiness for Sustainable Mobility: EU Frameworks and the Case of Albania</b> Ervin Kalemaj, Parid Milo, Mentor Çejku, Anis Sulejmani, Odhisea Koça	<b>The Role of Intermodal Transportation for the Sustainable Mobility</b> Márton Kovács
12:15 - 12:30	<b>Review of the Evolution of International Ship Energy Efficiency Regulations and the Albanian context</b> Dr. Blenard Xhaferaj, Doklejda Hodaj	<b>Impact of Heat Pump Systems on Winter Energy Use and Driving Range in Battery Electric Vehicles</b> Luis Henrique Pereira Martins
12:30 - 12:45	<b>Renewable Energy Procurement (CPPA) and Transport Electrification: European Perspectives and Albanian Challenge</b> Antonio Ndoci, Anis Sulejmani, Odhisea Koça, Mentor Çejku, Parid Milo	<b>Liquid Cooling Systems for Electric Vehicle Batteries: Improving Safety, Performance and Sustainability</b> João Miguel de Almeida Ribeiro Silva
12:45 - 13:00	<b>The Current Status of Autonomous Vehicle</b>	<b>Analysis of Battery Charging and Discharging Behavior for Electric Vehicle Applications</b> Leona Markic, Luka Filipović

	<b>Technology Adoption in the Balkan Region</b> Darjana Lopičić, Oliver Popović, Miloš Ilić, Bojan Kocić	
<b>13:00 - 14:00</b>	<b>Lunch</b>	
<b>14:00 - 14:15</b>	<b>Reviewing the European Green Deal in Energy, Mobility and Industry</b> Veselinka Calasan, Ivana Ognjanović	<b>Automotive Cooling Systems Sustainability: A Focus on the Expansion Tank</b> Ana Inês Barbeiro Casimiro
<b>14:15 - 14:30</b>	<b>The European Green Deal and its National Implementation: From Strategy to Practice</b> Blerina Bektashi, Andi Bektashi	<b>Design and Development of a Constant-Volume Combustion Chamber for Optical Investigation of Hydrogen and Water Injection Under Engine-like Conditions</b> Julius Hollerith, Prof. Dr. Bhavin Kapadia
<b>14:30 - 14:45</b>	<b>From Prediction to Regulation: Evidence Production Approaches in Autonomous Mobility Research and Their Policy Implications</b> Sadmira Malaj	<b>Emission Reduction of Marine Propulsion Systems in SECA Zones Through the Integration of Hydrogen Technologies</b> Motaleb Miri, Ivan Radaš, Marija Mandić, Ivan Tolj
<b>14:45 - 15:00</b>	<b>Questions and Discussion</b>	<b>A Comprehensive Analysis of Ventilation System for Enhanced Energy Efficiency in Marine Propulsion Applications</b> Sara Blašković, Gojmir Radica, Jakov Šimunović

15:00 - 15:15		<p><b>Design and Topology Optimization of a Lightweight Chain Sprocket for Electric Motorcycle Applications</b></p> <p>Teo Čolović, Ivo Marinić-Kragić</p>
15:15 - 15:30	<p><b>SESSION 3: ECONOMIC AND BUSINESS PRESPECTIVES + CASE STUDIES AND GOOD PRACTICES</b></p> <p>Aula B1</p> <p><b>Opening Session:</b> Dr. Anis Sulejmani (PUT)</p>	<p><b>Questions and Discussion</b></p>
15:30 - 15:45	<p><b>Managing Renewable Energy Resources as a Foundation for Sustainable Mobility Transitions</b></p> <p>Deivi Sinanaliaj, Martin Bektashi</p>	
15:45 - 16:00	<p><b>Feasibility of Electric Bus deployment in Montenegro: A Case Study of Budva (Erasmus+ INTEC / IECC Context)</b></p> <p>Anastasija Mrkajic, Vinko Nikic.</p>	
16:00 -16:15	<p><b>Children Paths as an Urban Regeneration Strategy: Naim Frasheri Study Case</b></p> <p>Dejvi Dauti</p>	
16:15 - 16:45	<p><b>Questions and Discussion</b></p>	

## International conference on sustainable mobility

# Agenda

**Project title:** International Engineering Competence Centres to push Sustainable Mobility Development in Albania and Montenegro  
**Acronym:** INTEC

<b>Work package</b>	
WP11	International conference
<b>TASK</b>	
11.4	Community Building Events

<b>Dates</b>	05.03.-06.03.2026
<b>City</b>	Tirana
<b>Meeting venue</b>	POLIS University Entrance Hall
<b>Address</b>	Rr. Bylis 12, Kodi Postar 1051, Kutia Postare 2995, Tirana, Albania

06.03.2026		
First Floor Hall, POLIS University		
8:30 – 9:00	<b>Registration</b>	
9:00– 9:15	<b>SESSION 4: SOCIAL AND ENVIRONMENTAL IMPACT</b> AULA B1	<b>SESSION 5: FUTURE SCENARIOS</b> AULA B4
9:00 – 9:15	<b>Opening Session:</b> Prof. Dr. Bhavin Kapadia (FHF)	<b>Opening Session:</b> MA Adrian Millward-Sadler (FHJ)
9:15 – 9:30	Comparison of Lifecycle Emissions of a SUV with Fuel Cell and Battery Electric Powertrains - Bhavin Kapadia, Alper Sayin, Sandra Eisenträger	GENAI Literacy as a Transversal Skill for Emerging Professionals: Implications for Sustainability- Critical Knowledge Work - Adrian Millward-Sadler
9:30 – 9:45	Smart Mobility Technologies and their Impact on Urban Sustainability: Insights from	Effects of Technical Traffic Calming Measures – Filip Perović

	<b>European and Western Balkan Cities –</b> Alma Gjonaj, Vjola Ziu	
<b>9:45 – 10:00</b>	<b>The Disappearing Squares: Social and Environmental Impacts of Urban Mobility Planning in Durres –</b> Arjola Sava	<b>Cybersecurity Vulnerabilities in Electric Vehicle Operating Systems: A Global Awareness Analysis -</b> Aleksa Radević
<b>10:00 – 10:15</b>	<b>The City that Demands Continuous Movement: The Disappearance of the Right not to Move within the Framework of Sustainable Mobility –</b> Avrili Meshi	<b>Development of a risk assessment model for the transport of hazardous materials using ALOHA and GIS software tools –</b> Marko Radetić
<b>10:15 – 10:30</b>	<b>Between Rhetoric and Reality: Discursive Framings, Greenwashing and Outcomes in Sustainable Mobility –</b> Kejsi Veselagu	<b>Mapping Distance and Time Leveraging Isochrone Intelligence in Emerging Cities -</b> Andia Vllamasi, Erjon Cobani
<b>10:30 – 10:45</b>	<b>Reimagining the City Through Green Mobility Strategies: The Case of Tirana -</b> Vjola Ziu, Alma Gjonaj	<b>Can AI develop its Own “Taste” Automotive Design? -</b> Gregor Andoni, Kristjana Meço
<b>Coffee Break</b>		
<b>11:00 – 11:15</b>	<b>Linking Morphology, Perceived Safety, and Sustainable Mobility in Post-Socialist Urban Contexts-</b> Sindi Doce	<b>Optimizing Public Transport Corridors Using AI-Based Scenario Modelling: A case Study on Tirana’s Ring Road -</b> Erjon Çobani, Julian Beqiri, Merita Guri
<b>11:15 – 11:30</b>	<b>Towards Sustainable Transport: A Comparative Analysis of Electric Vehicle Adoption in Montenegro and Albania -</b> Radmila Milić	<b>Threat Landscape and Multi-Layered Protection Mechanisms for Autonomous and Electric Vehicle Systems -</b> Marko Asanovic, Oliver Popović, Zoran Avramović, Nataša Gospić

11:30 - 11:45	Questions and Discussion	Cybersecurity Challenges in Modern Vehicular Communication Networks - Aleksandar Grgurević, Nataša Gospić, Oliver Popović
11:45 - 12:00		Green Transition in Albania: Challenges and Future Actions - Erik Kushta, Andi Hyka, Enea Nasto
12:00 - 12:15	SESSION 6: CONTROVERSIES AND CHALLENGES Aula B1	Use of AI in the Process of Green Transformation and Impact on Public Health - Esmeralda Hamiti, Federika Alliaj, Kristi Metushi
	Opening Session: Prof. Kristofor Lapa (UV)	
12:15-12:30	The Adoption of Electric Vehicles in Albania: A Comparative Study with Other Western Balkan Countries - Doklelda Hodaj, Andrea Lapa	Development of an Automatic Traffic Sign Detection System Using YOLOv8 - Valentina Vojinović, Luka Filipović
12:30-12:45	Application of Quality Tools in the Analysis of Factors Influencing the Development of Electromobility in Montenegro - Jelena Šaković Jovanović, Draško Jovanović, Mirjana Grdinić Rakonjac, Marko Lučić, Miloš Perović, Aleksandar Vujović, Gordana Radulović	The Historical Development of Artificial Intelligence and Its Influence on the job market in Automotive Engineering - David Josef Pilgram
12:45 - 13:45	Questions and Discussion	Questions and Discussion
13:45	Lunch	