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UNIVERSITETI POLIS

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
Project Reference: 101081873-ERASMUS-EDU-2022-CBHE-STRAND-2

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Project Partners:

FH JOANNEUM University of Applied Sciences · FRANKFURT UNIVERSITY OF APPLIED SCIENCES · UPT · UCG · UDG · AVL · GAMA-AUTO · ALFA Centar

ISBN 9789928347268

DOI: 10.37199/c41001000

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TABLE OF CONTENTS

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. Project ref.: 101081873-ERASMUS-EDU-2022-CBHE-STRAND-2

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15

THE ROLE OF INTERMODAL TRANSPORTATION FOR THE SUSTAINABLE MOBILITY

DOI: 10.37199/c41001015

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Abstract

This paper refers to the challenges faced in Europe regarding energy consumption in the transport sector. Based on statistics from the European Union and the United Nations, the transport sector contributes up to one-quarter of global greenhouse gas emissions, and this share is increasing. Intermodal transportation is the combined use of different vehicles within a trip, in most cases with a notable railway share, hence it has a high potential in terms of energy efficiency. In accordance with the EU emission goals (Fit for 55, EU 2040), it is a reasonable approach, to have an insight into the transportation modal change possibilities that can move European urban transportation towards sustainability. This paper provides an overview of the major factors that make railway transport competitive and attractive. The paper contains an enumeration of transportation modes in the Budapest metropolitan area and their environmental impact of the urban transport. The analysis considers required traction power, the efficiency of the drivetrains, electricity mixes and potential ridership. Focusing on the railway share of the intermodal transportation, energy demand calculations were performed by a numerical traction power estimation. The calculations show that by increasing the share of rail transportation, a significant decrease can be achieved in the overall energy demand of the urban transportation. Intermodal transportation is presented as an energy-saving possibility in the mobility sector by describing a current transportation route and schedules in Hungary. Intermodal transportation is compared to the individual passenger car transportation. The full intermodal transport and increased guided transport share are discussed. The goal is to show a comparison in energy demand between an increased share of intermodal railway transportation and individual commute in Europe, based on the example of the Budapest metropolitan area. Besides the technical advantages, possible drawbacks and side effects are discussed, focusing on life quality, excessive investment demands and the cost-benefit approach.

Keywords: railway, intermodal, energy consumption, sustainability, metropolitan area

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I. INTRODUCTION

A quarter of European greenhouse gas emissions are linked to transportation. This is the major reason why transportation is a notable sector in terms of sustainability goals. Significant improvements can be achieved in accordance with the greenhouse gas reduction goals set by the European Union (Fit for 55, EU 2040). Apart from the climate impact, European metropolitan areas face other environmental problems that are rooted in insufficient transport solutions. Highway expansions represent an inefficient use of urban space, resulting in elevated noise and dust pollution, as well as the reduction of green areas.

Moreover, the excessive energy consumption of individual road transport is not only an environmental aspect but also raises concerns about the EU's energy independence and the vulnerability of fossil fuel supply. While this goes hand in hand with the greenhouse gas reduction goals, it is also an important aspect of railway transportation that significantly lower energy consumption results in not only less climate impact but also decreases the import volume of crude oil products, thereby improving the trade balance of the EU.

II. METHODS

In the following, an energy calculation is presented for three transport modes that are common in an urban area. The energy consumed is linked to the CO2 emissions, hence this will provide a basis for the comparison of individual transportation with intermodal transportation in typical urban areas.

1. Transportation possibilities in the Budapest metropolitan area

The first option uses an internal-combustion passenger car, while the second uses an electric car on the same route. For both fossil fuel and battery-powered vehicles, indirect emissions from the petrochemical industry, battery production and the electricity storage losses must be added to direct emissions. (Magyar Tudomány, 2021)

The third option uses intermodal transportation with multiple vehicles in a single trip. In this example, 75% of the route is covered by suburban railway, with the remaining segments consisting of rural road access to the train station and urban railway travel.

The above-listed transport modes are summarized and presented in Figure 1.

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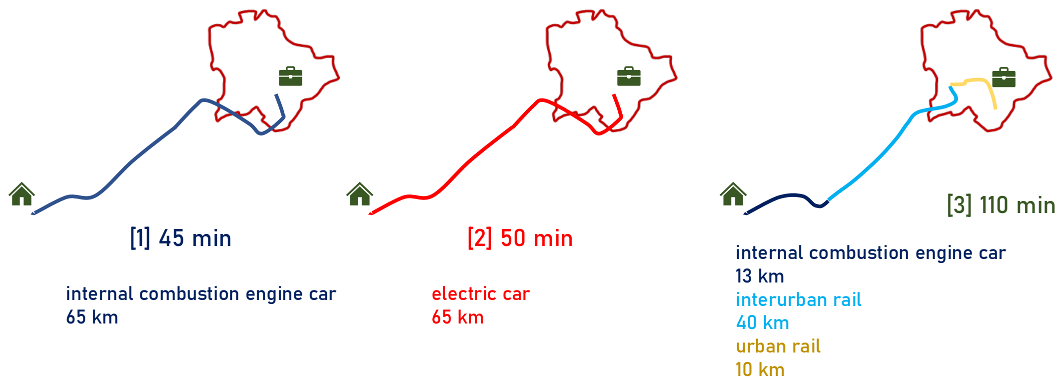

Figure 1. Transportation possibilities for a chosen itinerary in the Budapest metropolitan area.

2. Calculations

In this section, CO2 emission calculations for each transportation possibility are presented. Data retrieved from the European Union represent the CO2-equivalent values, which account for all greenhouse gases weighted by their climate impact (EEA, 2025).

3. Individual transportation

[1] Internal combustion car

Data on fuel consumption of a conventional car can be seen in Table 1.

Table 1. Internal combustion engine car fuel consumption (Magyar Tudomány, 2021).

	values
CO2 emissions (m’)	202 g/km
route length (s)	65 km

Total CO2 emission over the 65-km-long route:

$$m = m' \cdot s = 202 \cdot 65 = 13130\ g$$

The carbon emissions of the passenger car share of the intermodal transportation are estimated in the same way.

[2] Electric car

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The energy consumption of an electric car can be seen in Table 2. The value is based on the Spritmonitor online database of various passenger cars. The electricity consumption of five widespread models (VW ID.3, Renault Zoe, Hyndai Kona, Kia e-Niro, Nissan Leaf) was averaged, 1583 vehicles in total.

Table 2. Electric car energy consumption (Spritmonitor, 2026).

	values
consumption (b)	0.1709 kWh/km
route length (s)	65 km

Total energy consumption over the 65-km-long route:

$$W = b \cdot s = 0.1709 \cdot 65 = 11.1085 \; kWh$$

As mentioned above, CO2 emissions depend on the electricity mix. The second value for the European Union in Table 3 includes an additional 175 g/kWh from battery production and storage losses based on a UNECE report from 2022.

Table 3. Electricity mix data (EEA 2024, UNECE 2022 p36 Fig. 23).

	CO_2 emissions
European Union (m’)	187 g/kWh
European Union (m’’) (included battery production)	362 g/kWh
Hungary (mH) (included battery production)	312 g/kWh

CO2 emissions of an electric car over the 65-km route with respect to electricity mixes

$$m_1 = W \cdot m' = 11.1085 \cdot 187 = 2077 \; g$$

$$m_2 = W \cdot m'' = 11.1085 \cdot 362 = 4021 g$$

$$m_H = W \cdot m^H = 11.1085 \cdot 312 = 3465 \; g$$

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4. Public transportation

The Hungarian State Railways have 123 Stadler FLIRT multiple unit trains, whose technical data are shown in Table 4. A large proportion of the commuter service in the Budapest metropolitan area is covered by these trains; therefore, this type was taken into consideration.

Table 4. Multiple unit train specifications (Stadler, Andersson et.al 2018)

	values
total mass (m)	130 t
track length (s)	40 km
air resistance coefficient (k)	0.001
front wall area (A)	12 m2
rotating mass factor (γ)	0.08
Acceleration (a)	0.8 m/s2

The following calculations for the energy consumption are based on Newton's laws and the railway dynamics principles.

The dynamics of the movement of an accelerating railway vehicle can be described as follows (Zobory, 2017)

$$(1+\gamma)\cdot m\cdot\frac{dv}{dt}=F_t-F_{res}$$

where the total resistance is the sum of all resistances:

$$F_{res}=F_{roll}+F_{air}+F_{acc}$$

where the rolling resistance for commuter trains is:

$$F_{roll}=e\cdot G=e\cdot m\cdot g$$

where e is the specific resistance, that is an experimentally determined ratio (Csanádi, 1954) unit: $\left[\frac{N}{kN}\right]$

for multiple unit commuter trains:

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$$e = \left(2 + 0.022\frac{v^2}{100}\right)$$

The air resistance for railway vehicles is (Andersson et.al 2018):

$$F_{air} = k \cdot A \cdot v^3$$

The acceleration resistance, where γ=0,08 is the relative mass addition to consider the rotating masses (Wende, 2003)

$$F_{acc} = m \cdot (1 + \gamma) \cdot a$$

The equations above were implemented in a Microsoft Excel model. This numerical model calculates the work performed over 20-meter sections of the railway track in accordance with the equations for acceleration, deceleration, and constant-speed traction. By summing the computed energy demand for each 20-meter section, the model estimates the total energy consumption of the railway vehicle.

$$W = \sum_{0km}^{40km} F_v \cdot s = 864.8\ MJ$$

The results of the tractive work calculation on the Hungarian Railways Line 30a is summarized and presented in Figure 2. It can be seen, that the increasing utility factor let the energy consumption per passenger decrease, and stabilized at 1.2 kWh for this 40 km section.

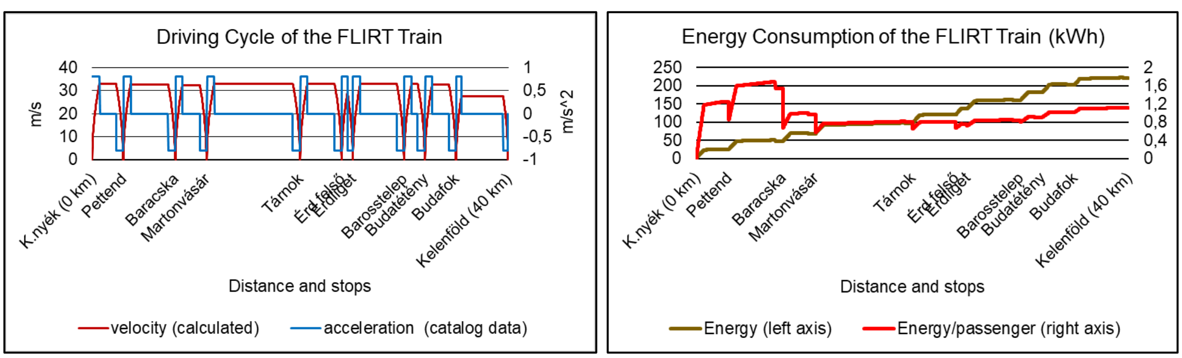

Figure 2. Left: Driving cycle of an interurban train in the Budapest metropolitan area. Right: Energy consumption in accordance with travelled distance and utilization.

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5. Estimation for urban railway lines

According to the Umweltbundesamt (German Federal Environment Agency), the emissions per passenger kilometer of urban rail public transport in 2024 were 42 g; therefore travelling 10 km by tram and metro produces 420 g of emissions.

III. RESULTS

The following section presents an exemplary CO2 emission analysis for the Budapest metropolitan area based on the energy consumption calculations above. Three transportation modes were compared on a 65-km commute route: conventional car, electric car, and intermodal transport (combining road access, interurban railway, and urban rail). Table 5 below shows the total CO2 emissions for this specific itinerary.

Table 5. Greenhouse gas emissions from the different transport modes presented in Figure 1.

Transport mode	Total CO2 emissions
Internal combustion engine car [1]	13130 g
Battery electric car [2]	3465 g
Intermodal transportation [3]	3210 g

1. Extended results

Although the analysis of the Budapest Metropolitan Area may appear to be a specific case, most urban areas of the European Union are similar in terms of road and railroad networks, intermodal possibilities, urban structure and commuter behaviour. Therefore, the Budapest example can be considered representative of urban areas across Europe.

The Excel model was extended with a more detailed approach for electricity carbon footprint estimation in order to provide a comparison between different European grids. As shown in Table 6, significant differences can be observed depending on the fossil fuel and nuclear share of the electricity mix, with Poland having the worst value and France having the best.

Table 6. CO2 equivalent GHG emissions from selected European grids (EEA).

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Country	GHG emissions CO2 eq.
EU average	187 g/kWh
Germany	298 g/kWh
France	43 g/kWh
Poland	554 g/kWh
Hungary	137 g/kWh

The extended comparison presented in Table 7 includes the full public transport possibility, by replacing the passenger car by a diesel bus. The emissions of local bus transport was calculated the same way as the urban rail, and the data was also retrieved from the Umweltbundesamt, estimated 94 g per passenger kilometers.

Table 7 below summarises the emission values of different transport modes based on the electricity mixes presented in Table 6 above.

Table 7. Greenhouse gas emissions from different transport modes (EEA, Umweltbundeasamt).

Transport Mode	EU	Germany	France	Poland	Hungary
ICE car	13130 g	13130 g	13130 g	13130 g	13130 g
Electric car	4000 g	5226g	2408 g	8055 g	3465g
P+R	3270 g	3403 g	3097 g	3710 g	3210 g
Full public transport	1866 g	1999 g	1693 g	2306 g	1806 g

It can be observed that the railway transportation significantly decreases the CO2 emissions, regardless the large differences in the electricity grids. The reason is that the overall energy consumption is more crucial in terms of sustainability than the electricity provided to an efficient transport mode. As it can be seen in Table 7, public transportation enables a notable CO2 emission reduction even with the worst electricity grid (Poland) while emissions in countries with an already clean grid (France) can still be improved.

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IV. DISCUSSIONS AND CONCLUSION

1. Greenhouse gas emission reduction

The analysis shows that without any improvements in the electricity infrastructure, the total emission reduction can be 80-85%, dependent on the passenger car consumption and the utilization of the public transport lines. This is a significant difference even compared to the best case of electromobility, because electric cars can only provide up to ~70% greenhouse gas emission reduction, and only in case of low-carbon electricity.

From a cost-benefit perspective, the widespread adoption of electric vehicles requires substantial investment in electricity grid infrastructure to achieve meaningful emission reductions. In contrast, railway-based intermodal transport delivers significant CO_2 reductions because of its inherent energy efficiency, even without electricity grid improvements. This makes rail transport a more economically viable pathway to immediate emission reductions, particularly when infrastructure investment resources are limited.

2. Further benefits of guided transportation

Railway transport is nearly free of local emissions, apart from noise or dust, although modern railway technologies can address these issues to an acceptable level.

The larger capacity of the vehicles has an additional advantage, their tare weight is lower compared to the payload. Furthermore, the larger the vehicle, the better the utilization tends to be. According to a report by BKK Centre for Budapest Transport (2024), the average number of people in a passenger car is 1.3, while public transport operates at considerably higher utilization, reaching even over 100% during rush hours. This results in lower space requirements for transportation infrastructure.

3. Possible drawbacks

Besides the beneficial effects of the increased railway share, the possible drawbacks have to be mentioned as well. The major concern is the excessive investment demand of the infrastructure. Furthermore, the large scale of improvements, such as track and railway station renovations, new connections, and even park and ride facilities, can raise opposition in local communities.

Park and ride solutions are already common in many major cities and agglomerations, yet users still face the disadvantage of their inflexibility and in some cases, poor coverage. Only a considerably cheaper, faster, and more convenient public transport network can balance the comfort offered by passenger car transportation.

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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

Work package	
WP11	**International conference**
TASK	
11.4	Coummunity Building Events

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

05.03.2026	
Entrance Hall, POLIS University	
8:30 – 9:00	**Registration**
9:00 – 9:30	**Opening Performance**
Welcome session – Auditorium A5 (Ground floor)	
9:30 – 10:00	**Opening Remarks** **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)
Auditorium A5 (Ground floor)	
10:00 –11:00	**Keynote speakers** **DI Horst Pflügl AVL** Collaborative Research for sustainable Mobility **DPSHTRR Representative** – (General Directorate of Road Transport Services in Albania)
11:15 – 11:30	**Coffee break (Moving into parallel sessions)**

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

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

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

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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

Work package	
WP11	**International conference**
TASK	
11.4	Cocmmunity Building Events

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

06.03.2026		
First Floor Hall, POLIS University		
8:30 – 9:00	Registration	
9:00– 9:15	SESSION 4: SOCIAL AND ENVIRONMENTAL IMPACT AULA B1	SESSION 5: FUTURE SCENARIOS AULA B4
9:00 – 9:15	Opening Session: Prof. Dr. Bhavin Kapadia (FHF)	Opening Session: 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

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

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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 Opening Session: Prof. Kristofor Lapa (UV)	**Use of AI in the Process of Green Transformation and Impact on Public Health** - Esmeralda Hamiti, Federika Alliaj, Kristi Metushi
12:15-12:30	**The Adoption of Electric Vehicles in Albania: A Comparative Study with Other Western Balkan Countries** - Doklejda 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	

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