



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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DESIGN AND TOPOLOGY OPTIMIZATION OF A LIGHTWEIGHT CHAIN SPROCKET FOR ELECTRIC MOTORCYCLE APPLICATIONS

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Abstract

Lightweight and efficient drivetrain components are of critical importance for electric vehicles, where mass reduction directly influences energy consumption, vehicle range, and dynamic performance. This is particularly relevant in electric motorcycle racing, such as the MotoStudent Electric competition, where strict performance constraints and sustainability goals coexist. Chain sprockets, as rotating drivetrain components, contribute significantly to rotational inertia and overall system efficiency. Therefore, their structural optimization represents a valuable opportunity for performance improvement and sustainable design. This paper presents the design, structural analysis, and topology optimization of a secondary chain sprocket developed for an electric MotoStudent motorcycle. Two sprocket configurations with 53 and 65 teeth were designed in accordance with DIN 8196 standards. Static loading conditions were derived from electric motor torque and chain dynamics, including impact and centrifugal forces. Analytical force calculations were combined with finite element analysis conducted in SolidWorks and ANSYS to evaluate stress distribution at the tooth face and root. A high-strength titanium alloy (Ti-6Al-4V, Grade 5) was selected to achieve an optimal balance between structural integrity and mass reduction. Topology optimization was performed using ANSYS and followed by parametric optimization with modeFrontier, employing a multi-objective genetic algorithm to minimize mass while constraining maximum von Mises stress. The topology-optimized sprocket designs achieved approximately 50% mass reduction compared to the initial baseline models, while maintaining acceptable stress levels under the applied loading conditions. Stress concentrations were successfully reduced in critical regions, and material was removed from low-load areas without compromising mechanical safety. The optimized geometries demonstrated improved stiffness-to-weight ratios and reduced rotational

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inertia, which are essential for high-performance electric motorcycle applications. The results confirm that this optimization workflow is an effective approach for the development of lightweight drivetrain components in electric MotoStudent and motorsport applications. By reducing material usage and improving efficiency, the proposed design methodology supports sustainable mobility objectives while enhancing vehicle performance. The presented approach is transferable to other electric vehicle drivetrain components and demonstrates the potential of advanced engineering tools in sustainable motorsport development.

Keywords: electric vehicles, MotoStudent, topology optimization, chain sprocket, sustainable mobility

I. INTRODUCTION

The transition toward sustainable mobility necessitates a paradigm shift in automotive design, where energy efficiency is paramount. Lightweighting strategies are of critical importance for electric vehicles (EVs), as mass reduction directly correlates with reduced energy consumption, extended range, and improved environmental performance [1]. This relationship is particularly acute in electric motorsport competitions, such as MotoStudent Electric, which serve as essential testbeds for future mobility technologies. These competitions challenge engineering students to reconcile stringent performance constraints with sustainability goals, fostering the development of innovative solutions that can be transferred to commercial applications.

Within an electric motorcycle drivetrain, the chain sprocket acts as a critical power transmission element. While often overlooked, rotating components like sprockets contribute significantly to the vehicle's rotational inertia. Reducing the mass of these components not only lowers the overall vehicle weight but also decreases the gyroscopic effect and energy required for angular acceleration, thereby enhancing the vehicle's responsiveness and handling characteristics [2]. Traditional sprocket manufacturing, however, often relies on standardized geometries with substantial material redundancy. This results in unnecessary weight that adversely affects the performance metrics of electric powertrains, which is counterproductive to the goals of sustainable engineering.

The specific operating conditions of electric motorcycles – characterized by high instantaneous torque at low rotational speeds – differ significantly from internal combustion engines, necessitating a reevaluation of conventional design approaches. This study addresses these challenges by applying advanced Computer-Aided Engineering (CAE) tools to optimize secondary chain sprockets for an electric MotoStudent motorcycle. The research builds upon preliminary chain drive simulations documented in earlier technical reports [3, 4], expanding the workflow to include topology optimization and parametric refinement. Furthermore, the rigorous demands of

creasing necessitate a shift from standard aluminum alloys to high-strength materials like Ti-6Al-4V to ensure high fatigue resistance under dynamic loads [5].

Current literature on structural optimization emphasizes the potential of topology optimization algorithms to achieve substantial mass reductions without compromising structural integrity [6]. These methods have been successfully applied in high-stakes fields such as aerospace to maximize stiffness-to-weight ratios [7]. However, there is limited research connecting these advanced computational techniques specifically to the cost and manufacturing constraints of student motorsport competitions. This paper aims to bridge that gap by presenting a comprehensive workflow that integrates analytical calculation, Finite Element Analysis (FEA), and Multi-Objective Genetic Algorithms (MOGA).

By demonstrating that lightweight components can be designed using accessible engineering tools, this research contributes to the broader objective of advancing technological innovation and fostering sustainable engineering skills.

II. METHODS

The research methodology followed a structured, multi-stage workflow integrating analytical calculations, computer-aided design (CAD), finite element analysis (FEA), topology optimization and numerical parametric optimization. This integrated approach ensured that the final optimized sprocket designs maintained structural integrity under operational loads while achieving maximum mass reduction. The complete workflow is illustrated in Figure 1, showing the progression from initial design through optimization to final validation.

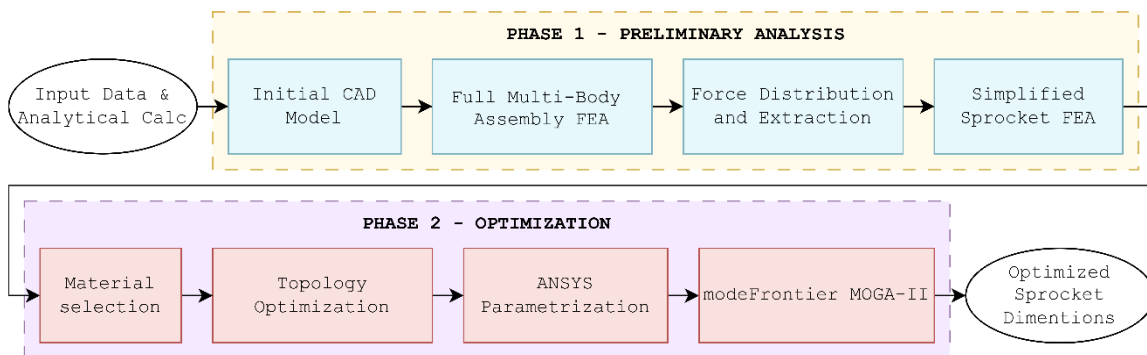


Figure 1. Optimization workflow.

1. Sprocket design and analytical force calculations

Two secondary sprocket configurations were designed according to DIN 8196 standards [5], with 53 and 65 teeth to accommodate different performance requirements—53 teeth for maximum speed testing and 65 teeth for acceleration testing. The primary design parameters included the chain. These calculations formed the basis for the initial CAD models created in SolidWorks, with dimensional specifications summarized in Table 1 and shown in Figure 2.

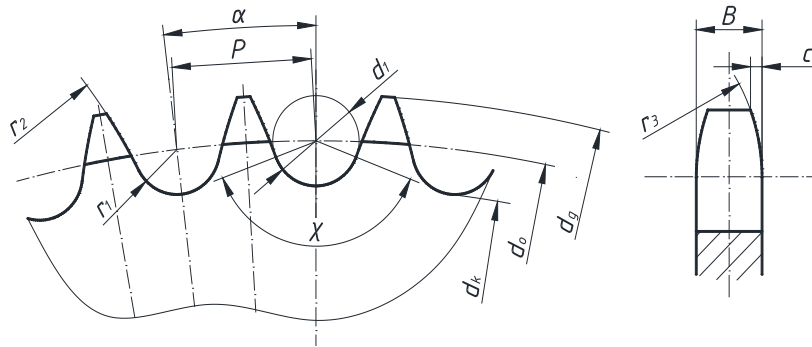


Figure 2. Sprocket geometry dimensions given by DIN 8196 [5]

Table 1. Sprocket dimensions calculated following the DIN 8196 [5]

Specification of the tooth profile - DIN 8196				
Dimintions	Sym.	Tol.	53 Tooth	65 Tooth
Roller diameter	d1		7.75	7.75
Pitch diameter	do		214.38	262.86
Root diameter	dk		206.62	255.12
Tip diameter	dg	max	222.5	270.98
		min.	218.94	267.49
Roller sitting radius	r1	max	4.05	4.05
		min.	3.91	3.91
Tooth flank radius	r2	max	185.318	273.11
		min.	51.15	62.31
Tooth side radius	r3		12.7	12.7
Tooth side relief	c	max	1.905	1.905
		min.	1.27	1.27
Angular pitch	tau		6.7924°	5.5384°
Roller sitting angle	X	max	138.31°	138.615°
		min.	118.301°	118.615°
Tooth count	z		53	65
Sprocket width	B		4.5	4.5

2. Finite element analysis in SolidWorks

Initial FEA simulations were conducted in SolidWorks to validate the analytical force calculations and establish baseline stress distributions. The simulation methodology evolved through two phases, as documented in Report MP201201 [3].

2.1 Phase 1: Complete chain-sprocket assembly simulation

A detailed assembly was created consisting of the secondary sprocket and 14-16 chain links positioned along the sprocket circumference Figure 3. This approach required around 100 components in the simulation with objective of maintaining simulation accuracy. Global "No Penetration" contact setting between chain rollers and sprocket teeth. Fixed constraints applied to sprocket bolt holes and shaft interface, roller fixtures applied to chain links to prevent outward movement. Tension force of 16466.12 N applied to a designated chain link. Local mesh refinement on sprocket tooth contact faces and chain roller surfaces with element sizes of 1.1 mm in critical regions.

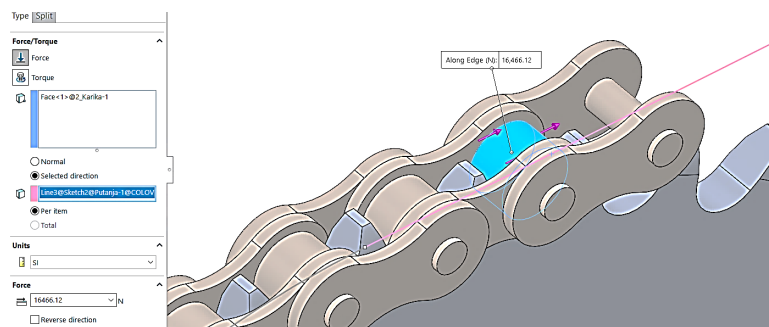


Figure 3. Sprocket with chain links (a zoom of the part of the assembly).

Results included stress analysis with maximum at 630.7 MPa, displacement analysis maximum displacement: 0.136 mm and factor of safety evaluation minimum: 1.1 at tooth roots. Most critically, reaction forces at each tooth contact interface were extracted, forming the basis for simplified subsequent analyses.

2.2 Phase 2: Simplified sprocket-only simulation

The complex chain-sprocket assembly was replaced with a simplified model where extracted reaction forces were directly applied to sprocket tooth faces and roots shown in the following figure. This approach reduced simulation time from ~40 minutes to 2-3 minutes while maintaining result accuracy.

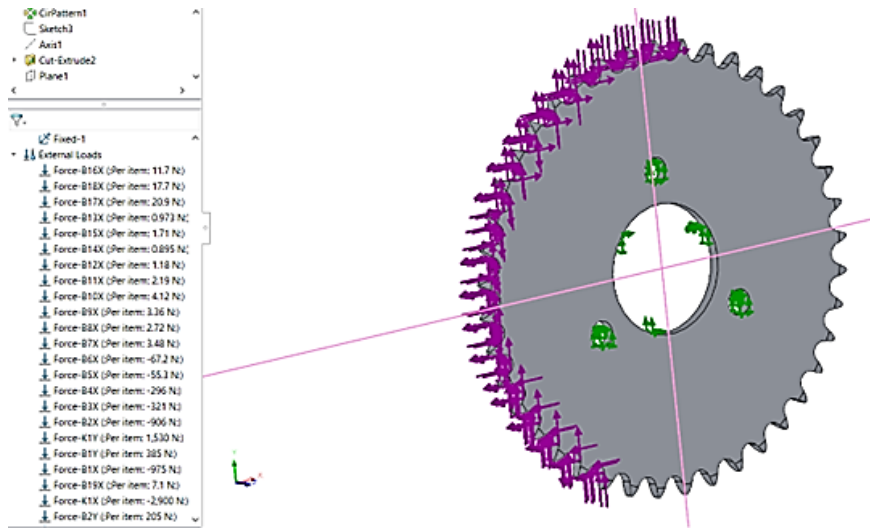


Figure 4. Forces and constraints applied on the sprocket.

The force application required careful consideration of directionality, with 76 force components precisely positioned according to the contact geometry. A finer mesh with global element size of 1.1 mm was applied to the sprocket model, resulting in improved result resolution without significantly increasing computation time.

3. Topology optimization and parametric refinement

The optimization process employed a two-stage approach:

3.1 Stage 1: Preliminary topology optimization

An initial pure topology optimization was performed in ANSYS to identify optimal material distribution patterns (Figure 4.1 from MP210102.pdf). This provided conceptual guidance for manual design refinement, revealing that approximately half of the sprocket teeth experienced minimal loading and could potentially be lightened.

3.2 Stage 2: Parametric optimization with modeFrontier

A parametric optimization workflow was implemented using modeFrontier software with the following configuration: Algorithm - MOGA-II (Multi-Objective Genetic Algorithm) selected for efficient Pareto frontier convergence, Design Evaluations - 100 iterations with 40 initial random

designs for design space exploration, Objective Functions - Minimization of both mass and maximum von Mises stress.

The optimization process generated Pareto frontiers illustrating trade-offs between mass reduction and stress increase as shown in Figure 7b). Optimal design points were selected based on engineering judgment, considering both performance objectives and manufacturability constraints. Selected optimal designs were re-modeled in SolidWorks, incorporating the optimized parameters, and subjected to final FEA validation in both SolidWorks and ANSYS. Final stress distributions for 53-tooth and 65-tooth sprockets confirmed that stress levels remained within acceptable limits while achieving substantial mass reduction.

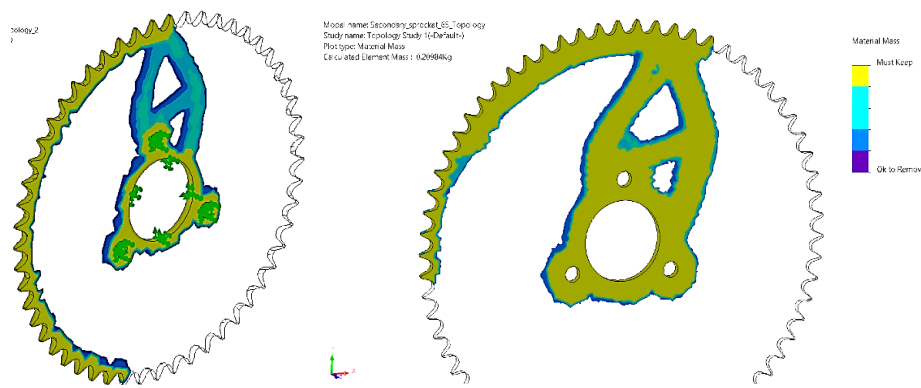


Figure 5. Topology optimization.

4. ANSYS simulation and parametrization

The optimization workflow transitioned to ANSYS for advanced FEA capabilities and seamless integration with modeFrontier. The process involved:

4.1 Geometry import and parametrization

Sprocket geometry was imported as .STEP files from SolidWorks into ANSYS Design Modeler. Key dimensions were parametrized to create a design space for optimization, focusing on six critical parameters defining relief cutouts and structural features as seen in the Figure 6. These parameters included: D20 - Inner relief diameter, D1 - Intermediate relief diameter, D2 - Outer relief diameter, R24 - Inner fillet radius, R6 - Intermediate fillet radius, L17 - Relief depth.

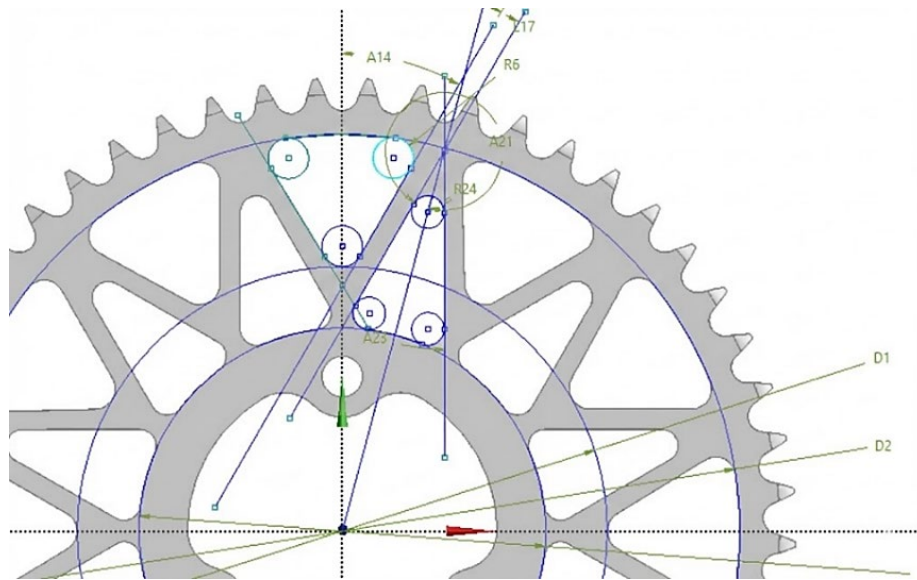


Figure 6. Parametric optimization variables for 53 Teeth.

Two critical response parameters were defined for optimization objectives: mass extracted from geometry properties and maximum von Mises stress extracted from solution results. The sprocket material was upgraded from aluminum alloy 7075-T6 (used in initial simulations) to titanium alloy Ti-6Al-4V (Grade 5) in annealed condition.

III. RESULTS

The optimization workflow yielded significant improvements in both mass reduction and structural efficiency for the two sprocket configurations. Quantitative results are presented for mass, stress, and geometric parameters, with comparative analysis between baseline and optimized designs.

In modeFrontier a calculator preset is the closest preset to final workflow, so we alter it in the following. The dimensions parametrized in the relief sketch are in this case our input variables so we have to add 6 input variable data nodes, as for the parametrized mass and max stress we add 2 output variable data nodes and set their goals to minimize. Because we have a static analysis in Ansys the center node must be replaced with a Ansys CAE Node and itself must connect with every node as shown in Figure 7a).

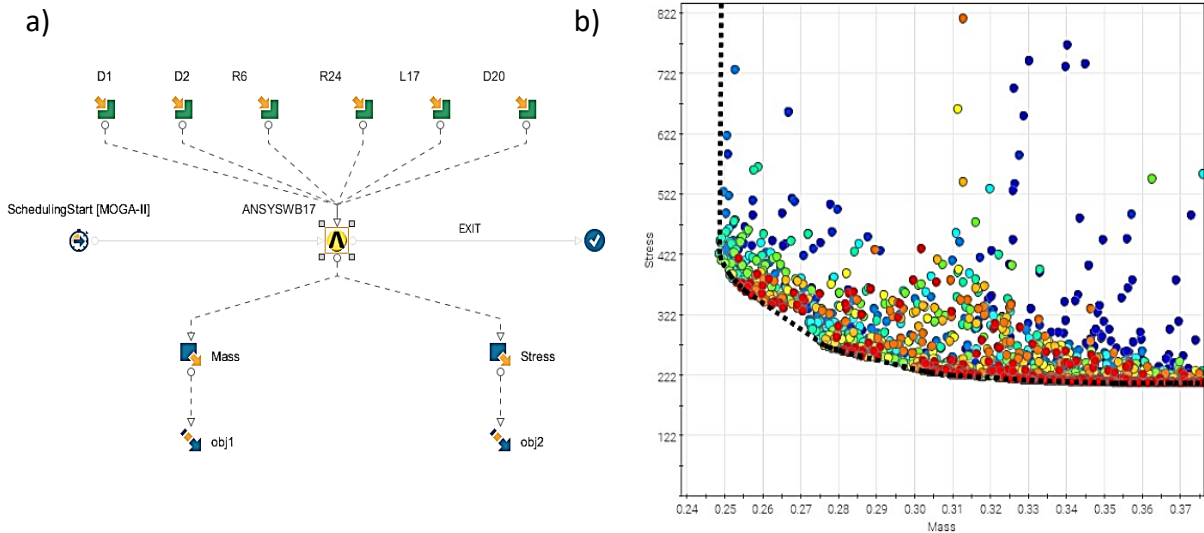


Figure 7. a) Modefrontier workflow and b) Pareto solutions of the multi-objective optimization.

The overall optimization yielded a rough 50% weight reduction in both cases, this can possibly be more optimized if the initial simulation is done dynamically and with the proper topology optimization. But at the end the topology optimization is more of a suggestion for the engineer that can be taken further into final design. The solutions generated in this way enable selection of a compromise between the factor of safety and mass as shown in Figure 7b).

IV. CONCLUSIONS

This study successfully demonstrates an integrated design and optimization workflow for developing lightweight chain sprockets for high-performance electric motorcycle applications. The methodology, combining analytical calculations, finite element analysis, and multi-objective parametric optimization, achieved a 50% mass reduction for both 53-tooth and 65-tooth sprocket configurations while maintaining structural integrity under operational loading conditions. The optimized titanium alloy (Ti-6Al-4V) sprockets exhibited maximum von Mises stresses of 623 MPa and 587 MPa respectively, corresponding to safety factors of 1.41 and 1.50 relative to yield strength – values deemed acceptable for the dynamic loading environment of motorsport applications.

The research confirms several key engineering principles for lightweight component design. First, the transition from aluminum to titanium alloy proved essential for achieving both strength and weight objectives, demonstrating that material selection must be integrated with geometric optimization. Second, the parametric optimization approach using modeFrontier's MOGA-II algorithm provided superior manufacturable solutions compared to pure topology optimization,

highlighting the importance of balancing computational suggestions with practical manufacturing constraints. Third, the force extraction and application methodology—transitioning from complex chain-sprocket assemblies to simplified force models—reduced simulation times from 40 minutes to 2-3 minutes while maintaining accuracy, establishing an efficient workflow for iterative design processes.

This study presents a replicable framework for developing high-performance, lightweight components that address the dual imperatives of competitive motorsport and sustainable engineering. By achieving significant mass reduction without compromising structural safety, the research advances both technical capabilities and ecological responsibility in electric vehicle development.

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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	Community 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)

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

	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 Ognjanović	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 Motaleb 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

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

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	Community 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

	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

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	