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The HADRIAN Novel Human-Machine Interface Prototype for Automated Driving: Safety and Impact Assessment

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National
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The HADRIAN project

➤ HADRIAN:



“Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs”

hadrianproject.eu

➤ HADRIAN Partners:

16 partners from 9 EU countries involving [National Technical University of Athens](#)

➤ Duration of the project:

42 months (December 2019 - May 2023)

➤ Framework Program:

Horizon 2020 - The EU Union Framework Programme for Research and Innovation - Mobility for Growth

HADRIAN

Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs

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Introduction

- The **human factor** is responsible for up to 94% of all traffic crashes.
- The introduction of **Automated Driving (AD)** is anticipated to improve road safety by reducing human error.
- Up to SAE automation level 4 (high automation), the driving task will still require **human interventions and interactions** with the vehicle.
- **Human-Machine Interfaces (HMIs)** are anticipated to play a major role in cooperation between user and Autonomous Vehicle (AV).
- The EU H2020 **HADRIAN project** aimed to investigate and provide seamless and fluid interactions between the driver and AV.



Objectives

- The present study aims at assessing and provide insights into the **impacts of HADRIAN HMI prototypes** on safety, driving performance and drivers' perceptions.
- An "HADRIAN-tailored" **safety and impact assessment** methodology was developed using special **Key Performance Indicators (KPIs)** as a basis.
- The driver's role in automated vehicles is also investigated using this **holistic user-centered assessment**, which evaluates safety and perceived impact effects.
- Special focus is given to **Take-Over Requests (TORs)** and transitions between Automated Driving (AD) levels.

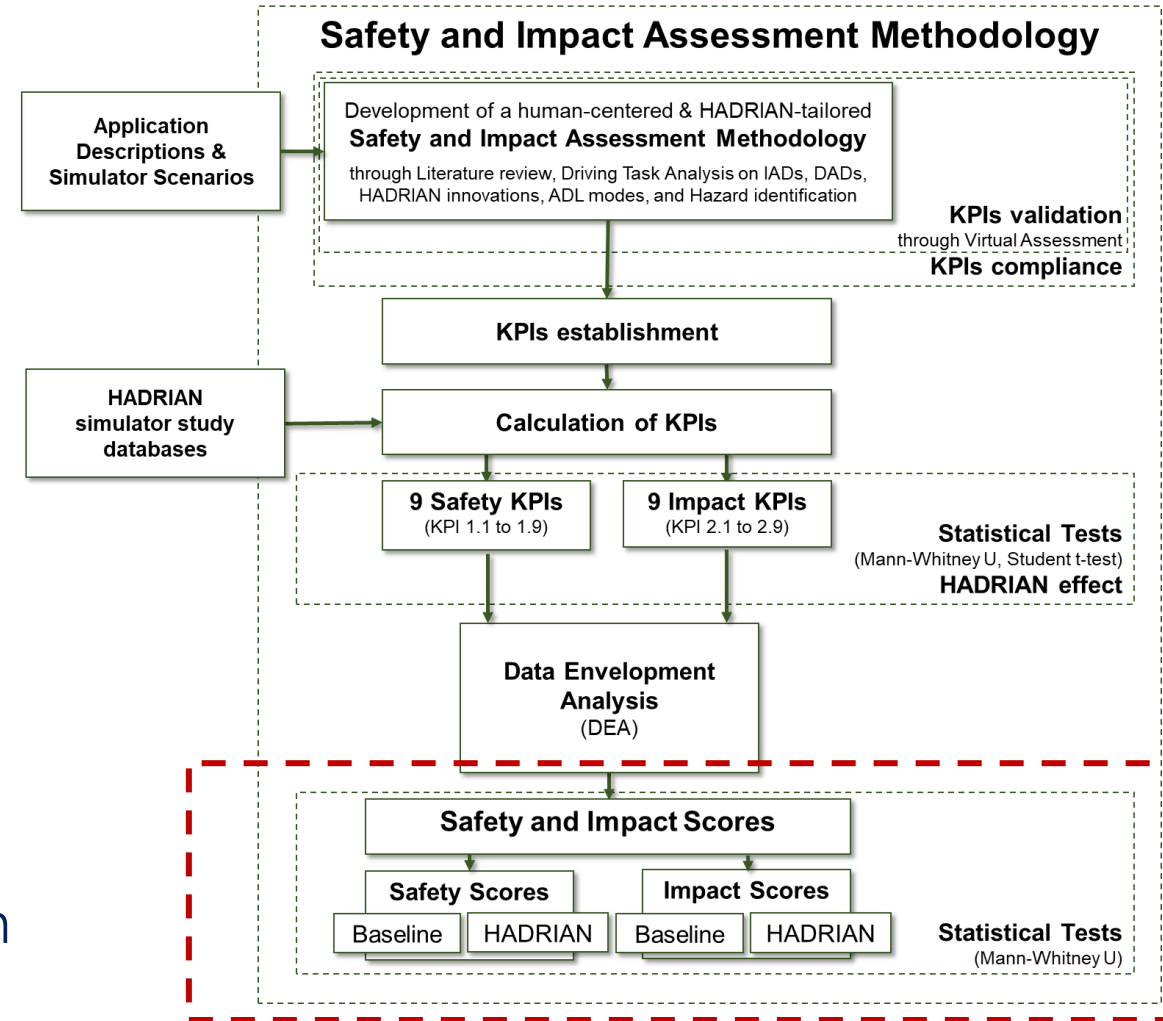


KEY
KPI
PERFORMANCE
INDICATORS



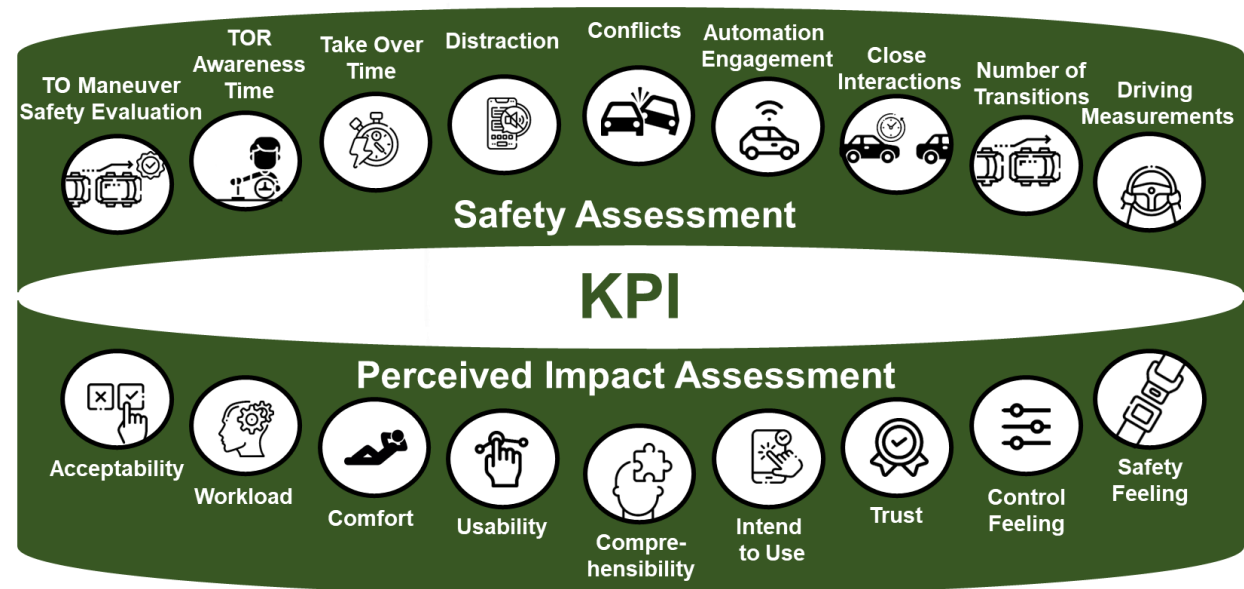
Assessment Development

- The development of the **Safety and Impact Assessment Methodology** was based on:
 - Literature Review
 - Driving Task Analysis
 - Hazard Identification Procedureas described in previous publications and HADRIAN documentation.
- **KPIs** were estimated through driving, eye-tracking metrics, and subjective measurements obtained during HADRIAN simulator studies.
- At the final stage, a total score was calculated using **Data Envelopment Analysis (DEA)** to obtain scores for both the "baseline" and HADRIAN innovations for comparison purposes.



KPIs overview

- This **KPI-based assessment** consists of:
 - 9 KPIs related to **safety** and driving performance
 - 9 KPIs related to the **impact on the drivers' perspectives**
- The detailed **mathematical equations** for calculating the KPIs are fully reported in the HADRIAN documentation.



Integrated fluid HMI

- For one of the **driving simulator experiments**, 20 participants drove with a baseline HMI and 19 used a HADRIAN HMI titled "Integrated fluid HMI".
- The HADRIAN HMIs were compared with state-of-the-art in-vehicle systems, serving as the "**baseline**" HMIs.
- HADRIAN innovations aimed to provide better automated driving **predictability, availability, and continuity.**



Component	Baseline System	HADRIAN System
SAE 2 takeover time	No preparation time	5 seconds
SAE 3 takeover time	5 seconds	15 seconds
SAE predictability	None	Displayed time left of SAE 3 driving on HMI tablet
Driver monitoring	Hands off steering wheel warning via sound	Hands off steering wheel & eyes of road warning via sound, LED, HUD and HMI tablet
Tutoring	None	Interactive audiovisual tutoring system on HMI tablet; corrective feedback for first few takeovers
LED cues	None	Front mounted LED stripe for status information and warnings
Haptic cues	None	Steering wheel vibrations for status changes
HUD	None	Driving speed, speed limit upcoming obstacles, takeover countdown

KPIs

- KPIs derived from the experiment, and the **percentage change** was analyzed to assess the initial impact of the HADRIAN HMI.
- **Positive effects** on safety were observed in several KPIs, including increased safety scores for takeover maneuvers, decreased takeover request awareness time, increased takeover time, and limited distraction.
- Higher differences indicating a **positive perceived impact** were observed in KPIs such as reduced subjective workload and increased comfort, usability, trust, and control feeling, reflecting a positive effect of the HADRIAN system.
- However, the remaining KPIs showed either **negative or neutral impacts** on the drivers.

Safety KPIs

KPI	Title	HADRIAN HMI Trend*	Average Percentage Change	p-value	
1.1	Take Over Maneuver Safety Evaluation	+	-0.25%	0.306 ²	
1.2	Take Over Request Awareness Time	+	-5.81%	0.373 ¹	
1.3	Take Over Time	+	27.74%	0.009 ¹	
1.4	Distraction	+	-92.25%	0.000 ¹	
1.5	Conflicts	Neutral	1.63%	0.937 ²	
1.6	Automation Engagement	Level 2	Neutral	-0.17%	0.465 ¹
		Level 3	Neutral	-0.16%	0.448 ¹
1.7	Time-to-Collision	Neutral	-0.75%	0.877 ¹	
1.8	Number of Transitions	AD → Manual	-	4.64%	0.064 ¹
		Manual → AD	-	-2.99%	0.633 ¹
1.9	Driving Measurements	Speeding Duration	-	2.18%	0.736 ¹
		Speed Over the Limit	-	0.61%	0.448 ¹
		Harsh Cornerings	Neutral	40.35%	0.747 ¹
		Harsh Brakings	-	29.15%	0.152 ¹
		Harsh Accelerations	Neutral	20.30%	0.715 ¹

¹Mann-Whitney U Test, ²Student's t-test, *Positive, Negative, Neutral effect on safety compared to baseline HMI and based on the plotted trend p-values denotation: [1, 0.7], (0.7, 0.05), [0.05, 0]

Perceived Impact KPIs

KPI	Title	HADRIAN HMI Trend*	Average Percentage Change	p-value
2.1	Acceptability ratings	-	-7.36%	0.311 ²
2.2	Subjective Workload	+	-9.05%	0.500 ¹
2.3	Comfort	+	7.44%	0.203 ²
2.4	Usability	+	1.35%	0.777 ²
2.5	Comprehensibility	-	-2.45%	0.498 ²
2.6	Intend to Use	-	-3.05%	0.605 ²
2.7	Trust	+	1.99%	0.914 ²
2.8	Control Feeling	+	6.13%	0.423 ¹
2.9	Safety Feeling	Neutral	0.66%	0.924 ²

¹Mann-Whitney U Test, ²Student's t-test, *Positive, Negative, Neutral effect on driver impact compared to baseline HMI and based on the plotted trend p-values denotation: [1, 0.7], (0.7, 0.05), [0.05, 0]

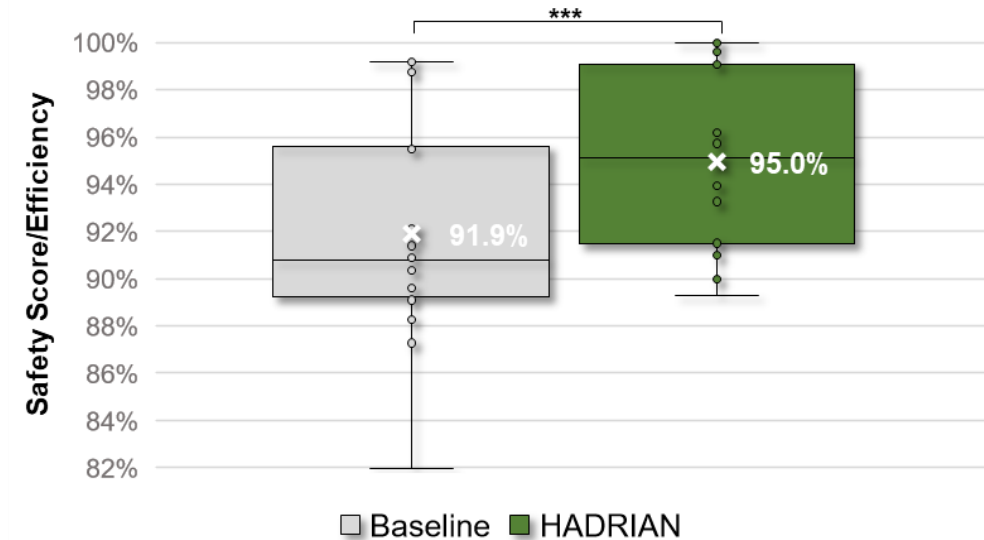


Safety Score

- HADRIAN HMI demonstrated a **significant increase** in safety score ($p < 0.05$), indicating enhanced safety for autonomous driving.
- **Positive effects** on safety, as indicated previously, were observed in several KPIs, contributing to the overall safety improvement.
- Despite some KPIs displaying **negative trends**, the positive effects outweighed any negative impacts, emphasizing the potential for further safety enhancements with more positive KPIs.

Safety Scoring using DEA

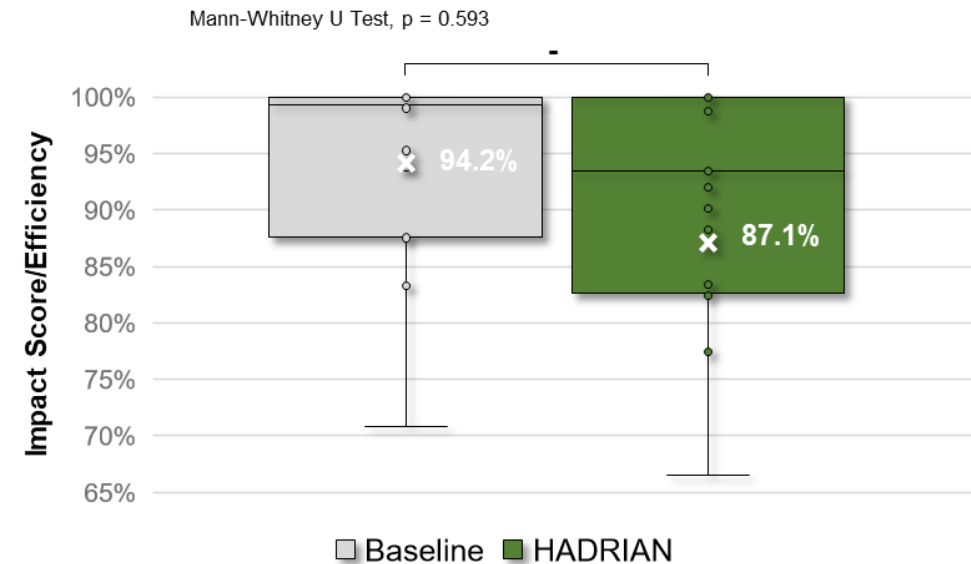
Mann-Whitney U Test, $p = 0.015$



Perceived Impact Score

- DEA assessed the perceived impact score of the HADRIAN conditions on driver subjective perspectives, revealing a **decrease** in perceived impact scoring, indicating a decline of 7.54%.
- Despite the overall decrease in perceived impact scoring, the **majority of KPIs** (5 out of 9) showed a positive effect of the HADRIAN system.
- The subjective nature of the perceived impact score suggests that drivers may have felt **unfamiliar** with the complex and interventive driving setup.

Perceived Impact Scoring using DEA



Conclusions

- HADRIAN HMI exhibited significantly **higher safety scoring** than the baseline, attributed to improved takeover performance and reduced distraction:

"The driver exhibits improved readiness for takeover requests with extended takeover time and quicker scanning of driving information aided by HMI cues. The HADRIAN HMI facilitates smoother takeover maneuvers with decreased speeds, harsh accelerations, and braking events."

- Despite lower perceived impact scores, most drivers reported **positive effects** on subjective workload, comfort, usability, trust, and control.
- It is possible that drivers may not have accurately **perceived the safety enhancements** offered by the HADRIAN innovations.
- These findings provide valuable insights and an assessment method for HMI **stakeholders**, aiding in evaluating safety implications and human interaction with autonomous driving technology.





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