HADRIAN has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875597.

Safety and Impact Assessment

Marios Sekadakis, Christos Katrakazas,
Marianthi Kallidoni, George Yannis

National Technical University of Athens (NTUA)

May 9, 2023

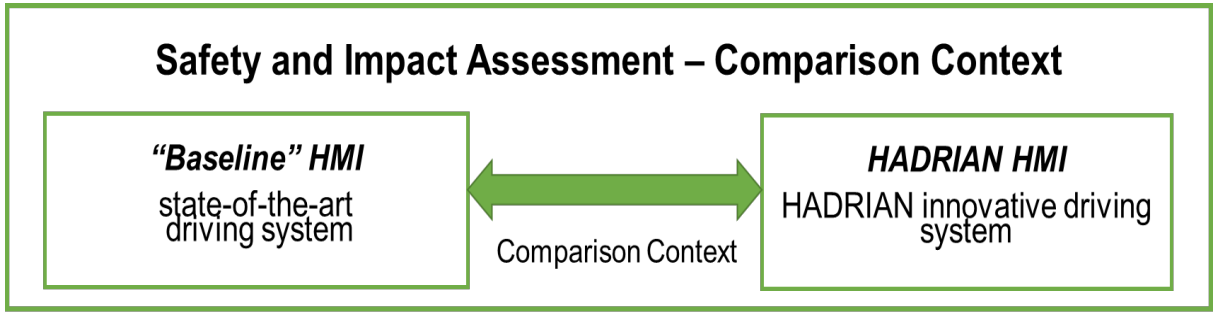
ASSESSMENT PURPOSE

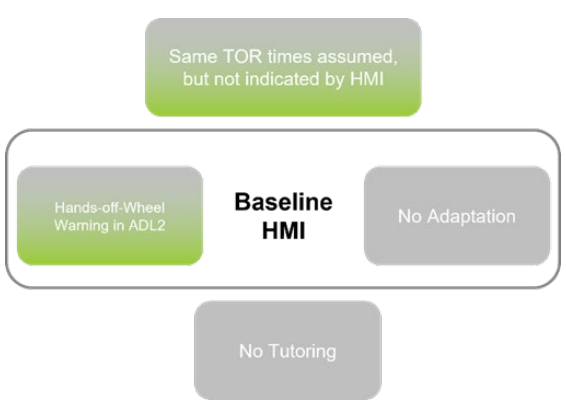
- The **purpose of the Safety and Impact Assessment** was to evaluate the improvements achieved through the HADRIAN Human Machine Interfaces (HMIs).
- To this end, an HADRIAN-tailored assessment methodology was developed focusing on **Automated Driving (AD)** for up to SAE Level 3 from a human-centered perspective.
- Special focus was given to **take-over requests** and AD-level transitions.
- The overall aim was to evidence **safe and acceptable AD developments**, including guidelines for safer human-centered AD technologies and recommendations for future policy making.

ASSESSMENT COMPARISON CONTEXT

- The assessment analyzed the results from the experimental **driving simulator studies**.
- The **HADRIAN system was compared with** state-of-the-art in-vehicle systems, serving as **"baseline" systems.**
- For instance, in one out of seven HADRIAN HMIs in simulator studies; the HADRIAN **“integrated fluid HMI”** included the following functionalities:
  - 5 seconds time for take-overs in ADL2, 15 seconds time for take-overs in ADL3: the countdown information is displayed to the driver
  - Ensured time interval in which ADL3 driving is possible: the duration is displayed to the driver
  - Tutoring video before the drive, outlining the driving functions, correct system use, and driver responsibilities

and many more

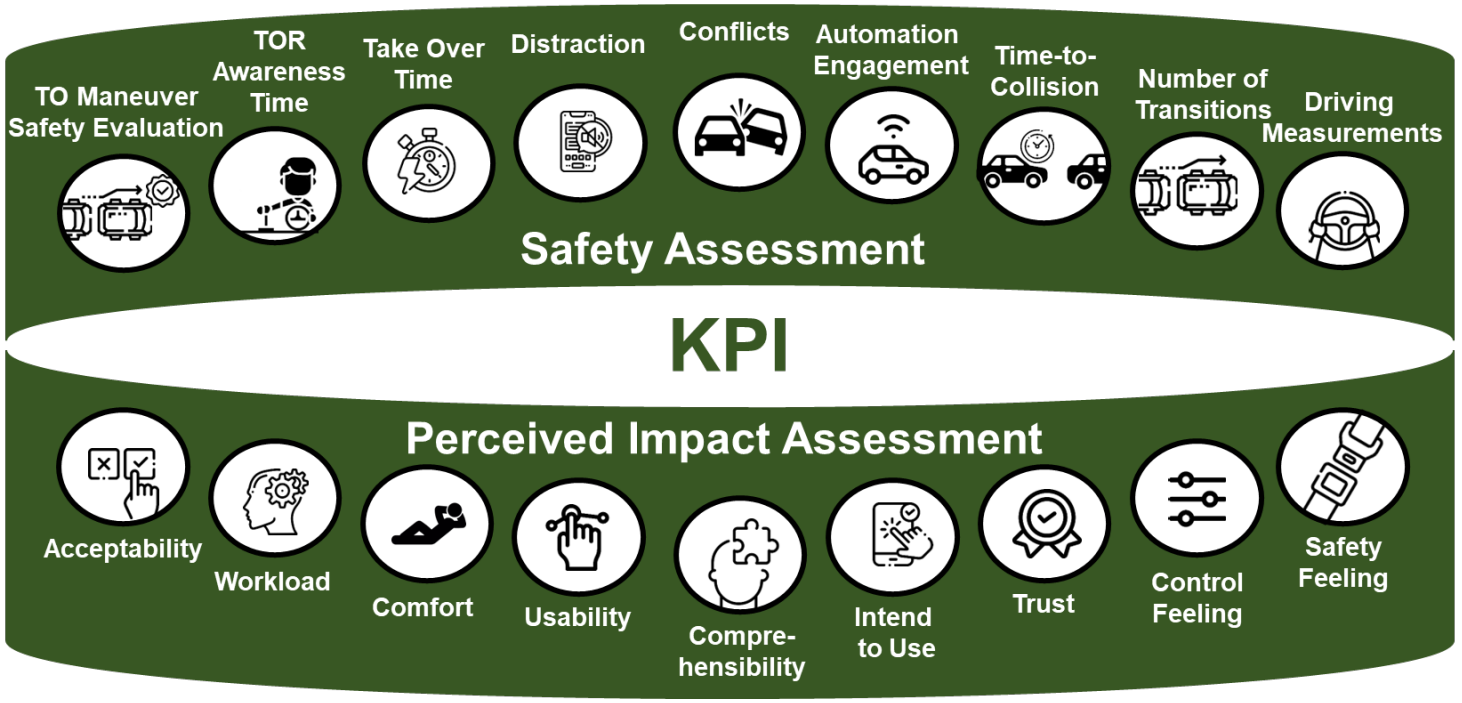




Baseline HMI versus HADRIAN HMI

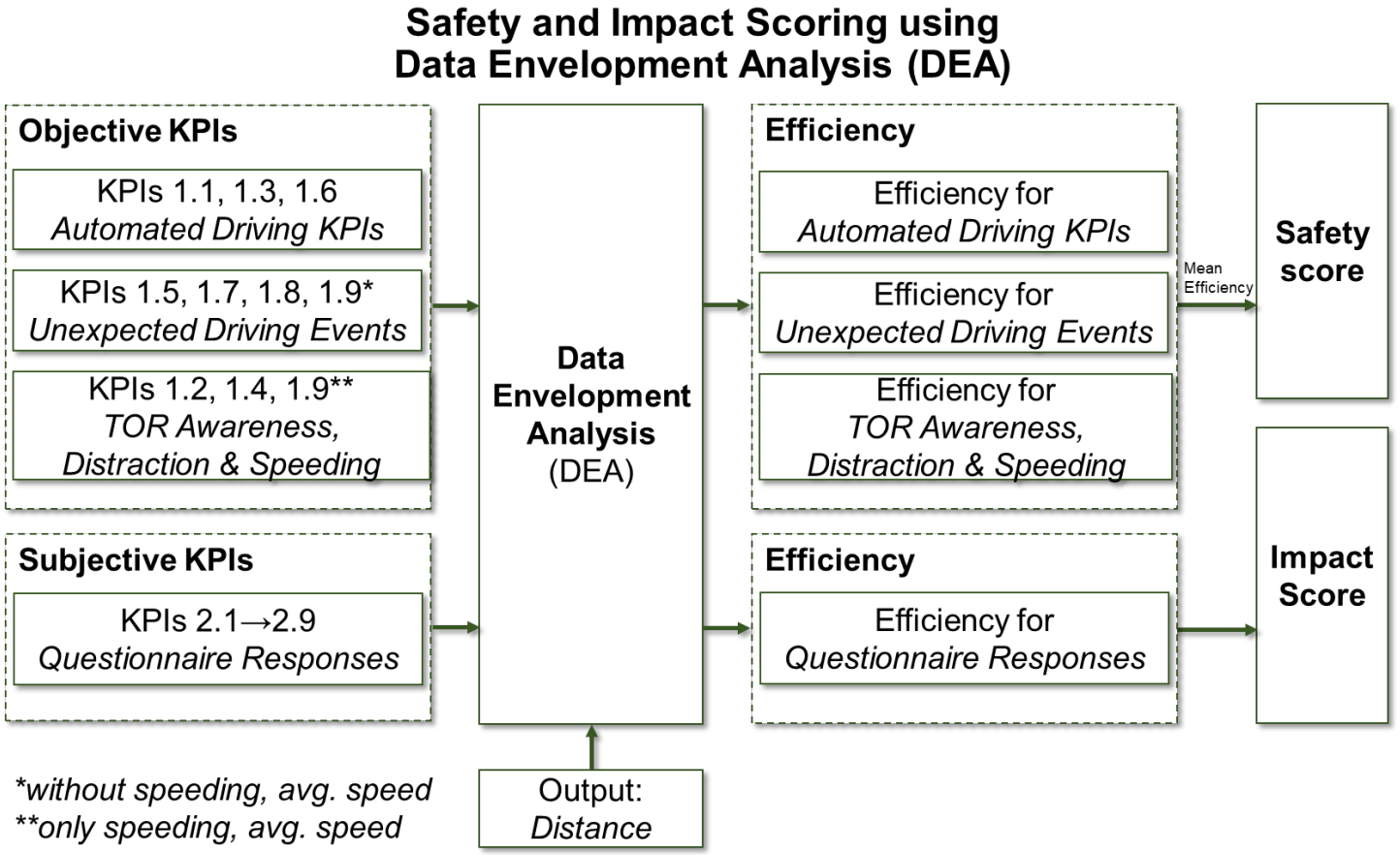
ASSESSMENT KPIS

- The safety and impact assessment methodology shaped specific **Key Performance Indicators (KPIs)**.
- **9 KPIs for safety** and **9 KPIs for the perceived impact** of drivers.
- The KPIs were estimated through driving, eye-tracking metrics, and subjective measurements obtained during the **HADRIAN simulator studies**.



SCORING METHOD

- **Data Envelopment Analysis** (DEA) was applied to obtain scores based on KPIs for both the “Baseline" and HADRIAN HMIs.
- DEA is used for **efficiency and productivity analysis** of similar units, widely used in business, economics, and management.
- An input-oriented DEA model was developed aiming to **minimize the KPIs** (inputs) maintaining the same distance (output).
- The total safety score was calculated as the **average efficiency** of three homogeneous KPI groups for each driver.



HADRIAN EFFECT ON KPIS

- For analyzing the **effect of the HADRIAN HMI** on the KPIs, descriptive statistics, plots, statistical testing (i.e., Mann-Whitney U test and Student's t-test), and KPI dashboards were developed.

- Excerpts from the plotted trends and KPI dashboard are given for the HADRIAN **"integrated fluid HMI"**. It can be concluded that:

  "The driver is more prepared for a take-over request with a longer take-over time and takes less time to scan the necessary driving information with the HMI indications. The HADRIAN HMI supports to perform a smoother take-over maneuver with reduced speeds, harsh acceleration and braking events."

"Excerpt from the assessment on HADRIAN integrated fluid HMI"

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]

[1]Mann-Whitney U Test, [2]Student'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]**

HADRIAN

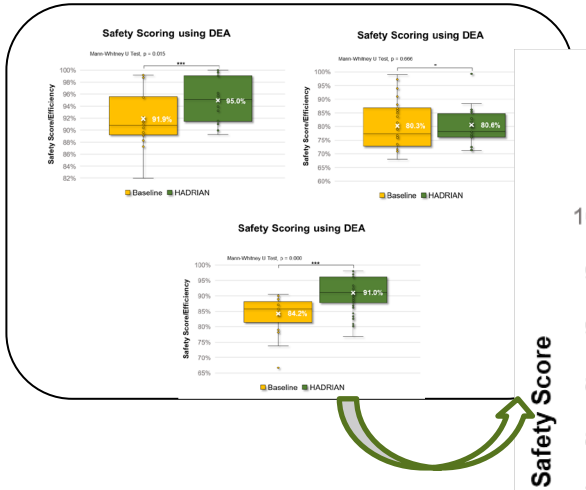
KPI	Title	HADRIAN HMI Trend*	Average Percentage Change	p-value
2.1	Acceptability ratings	−	-7.36%	0.311[2]
2.2	Subjective Workload	+	-9.05%	0.500[1]
2.3	Comfort	+	7.44%	0.203[2]
2.4	Usability	+	1.35%	0.777[2]
2.5	Comprehensibility	−	-2.45%	0.498[2]
2.6	Intend to Use	−	-3.05%	0.605[2]
2.7	Trust	+	1.99%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

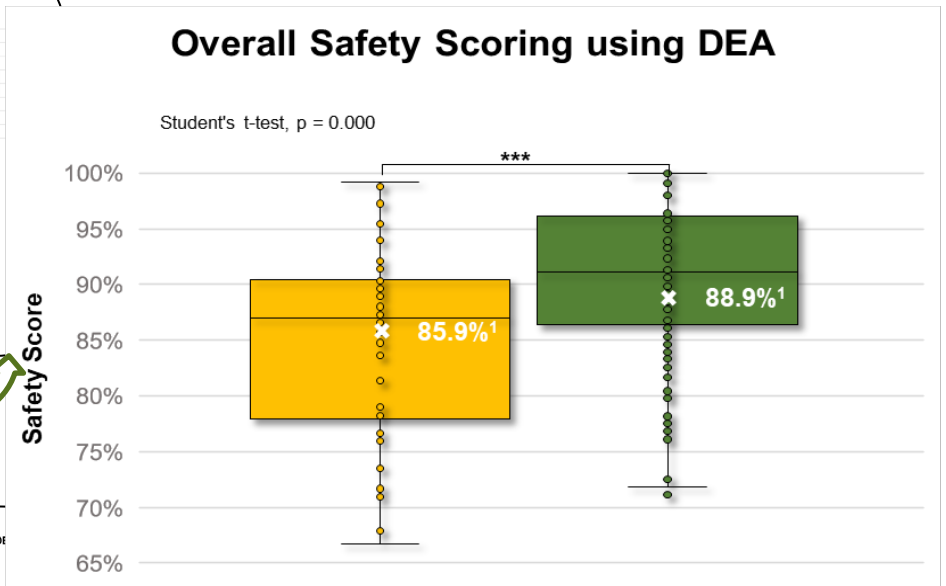
[1]Mann-Whitney U Test, [2]Student's t-test,
*Positive, Negative, Neutral effect on driver impact compared to baseline HMI and based on the plotted trend
p-values denotation: [1, 0.7], (0.7, 0.05), **[0.05, 0]**

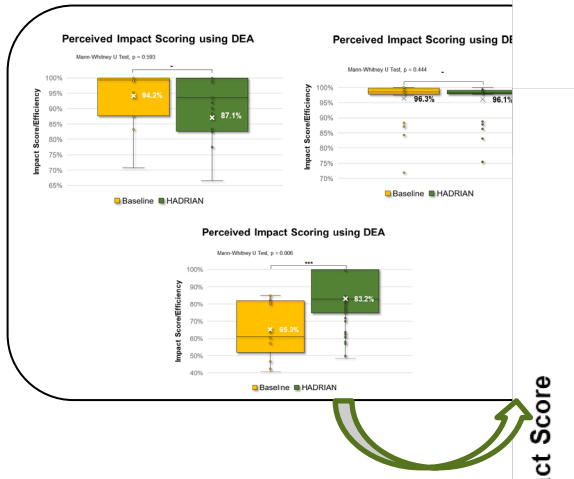
HADRIAN

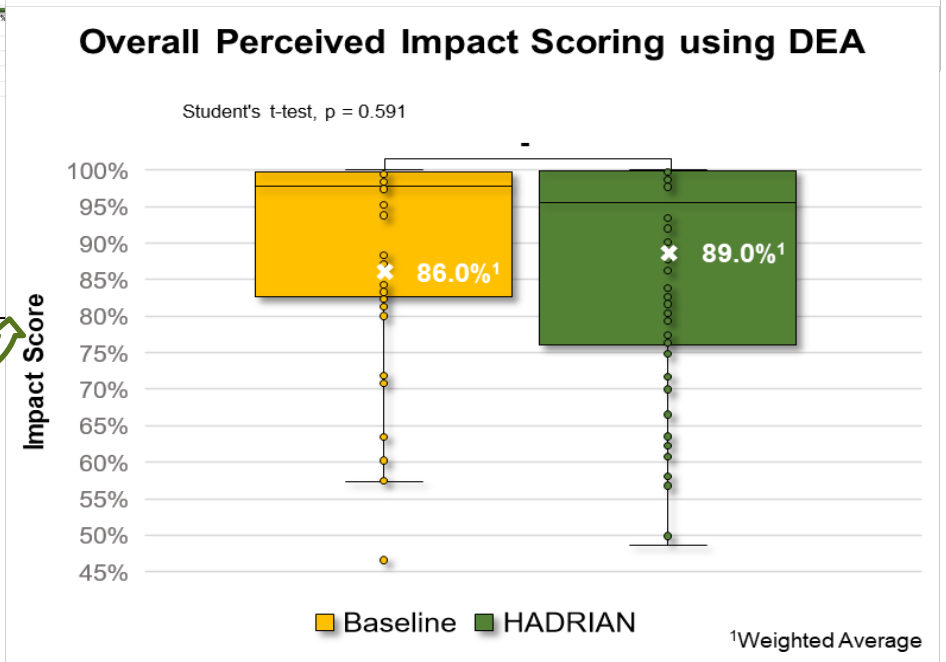
OVERALL SCORING

- The **DEA scores** of overall safety and perceived impact applied on 225 observations of 3 studies and are presented in boxplots:
  - The HADRIAN overall weighted **safety score was improved by 3.40%** compared to baseline HMI.
  - The HADRIAN safety score was revealed to have a **statistically significant higher safety performance**.
  - The overall weighted **perceived impact score was improved by 3.46%** with the HADRIAN HMI.









CORNERSTONES OF HADRIAN HMIS

- The **HADRIAN "Integrated fluid HMI"** had a great improvement in takeover performance and distraction prevention as well as outperformed with less mental or cognitive effort, higher comfort in use, and control feeling.
- The **HADRIAN "Visual HUD Support System"** improved performance on limiting safety-critical events i.e., conflicts, TTC events, speeding and harsh cornerings and outperformed with higher comprehensibility, intent to use, and safety feeling.
- The **HADRIAN "Haptic Feedback on the Steering Wheel"** was found to be capable of reducing mainly harsh cornering events, conflicts and close TTC events as well as outperformed with higher usability, intent to use, and control feeling.

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

For accessing the full reports and publications of HADRIAN:

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

Human Error Probability (HEP) Assessment

Christian Groß, Caitlyn Velasquez, Peter Mörtl

Virtual Vehicle Research GmbH (ViF)

May 9, 2023

HUMAN ERROR PROBABILITY (HEP) ASSESSMENT

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

- Automated Driving
- Take-Over
- Avoid Accidents
- Safe Design Principles
- Understand Human Error Sources
- Measure Error Probability
- Without Empirical Data