Examining Factors Affecting Takeover Time in Automated Driving using Machine Learning Algorithms

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virtual vehicle

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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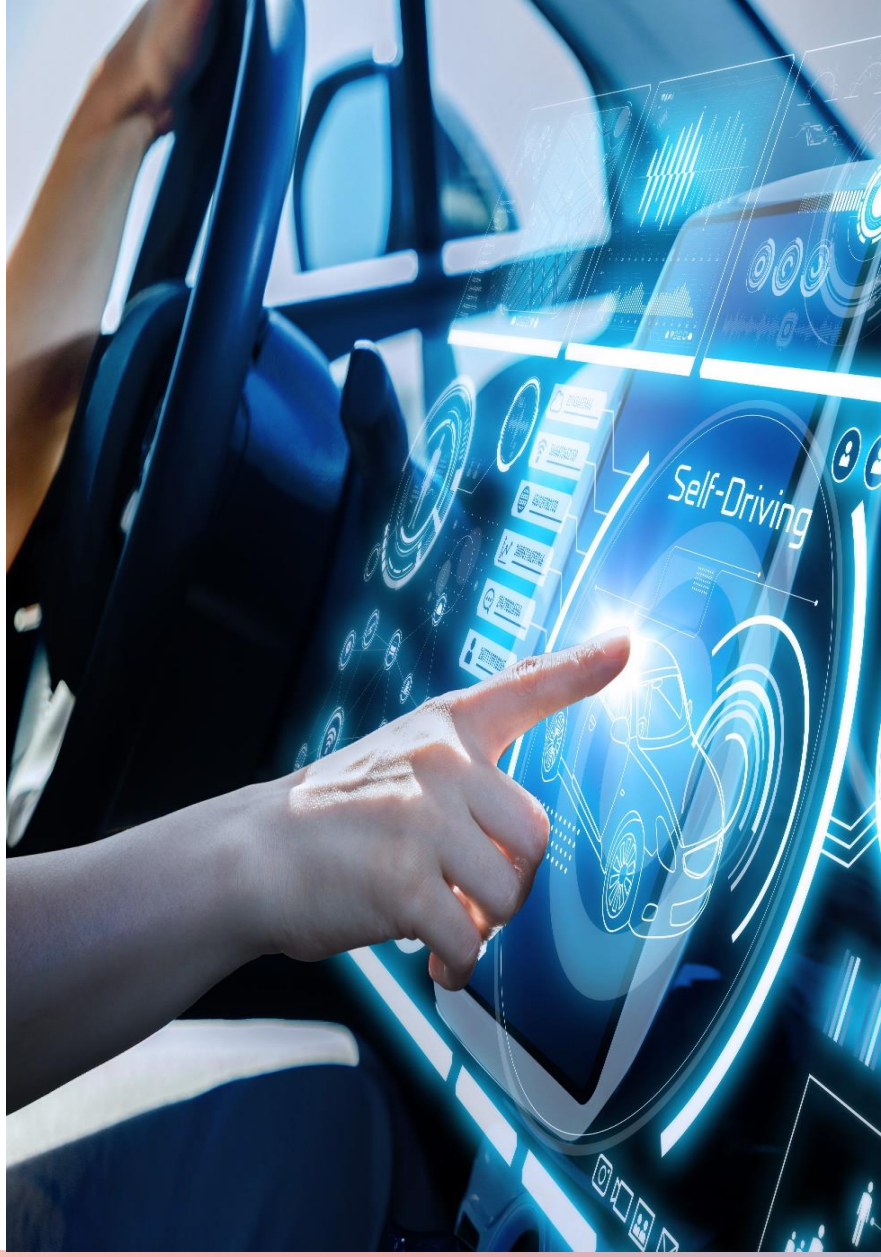
Introduction

- 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

- An “HADRIAN-tailored” **safety and impact assessment** methodology was developed using special **Key Performance Indicators (KPIs)** as a basis.
- Special focus was given to **Take-Over Requests** (TORs) and transitions between AD levels.
- The present study aims at understanding with Machine Learning algorithms the **factors influencing Takeover Time** in Automated Driving.
- **XGBoost feature analysis** was employed to identify the most influential KPIs affecting the takeover time from automated to manual driving.

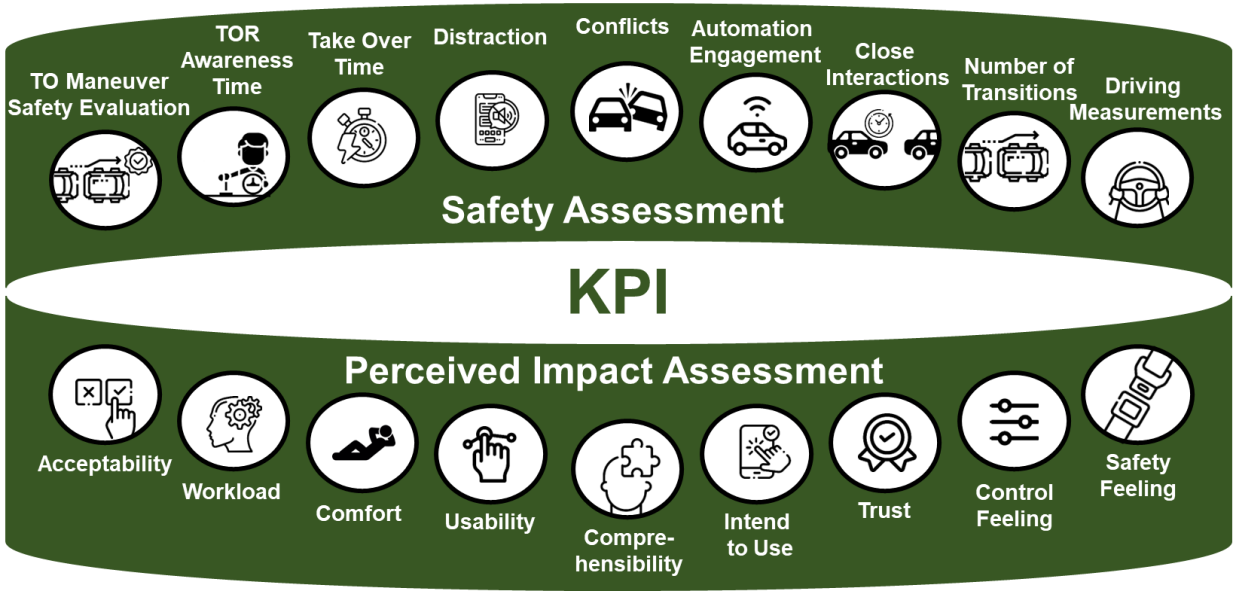
Integrated fluid HMI

- 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 off 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

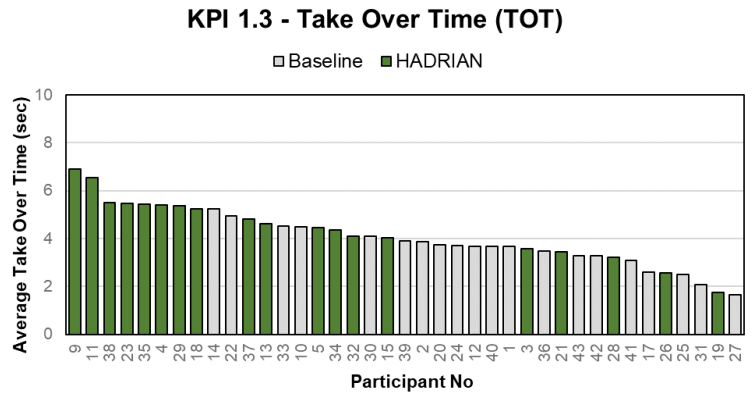
KPIs Overview

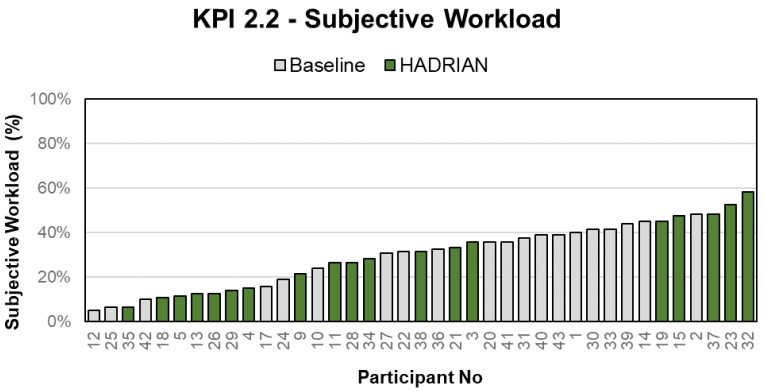
- This **KPI-based assessment** consists of:
  - 9 KPIs related to **safety** and driving performance
  - 9 KPIs related to the **impact on the drivers' perspectives**
- The detailed **mathematical equations** for calculating the KPIs are fully reported in the HADRIAN documentation.



KPIs Results

- **KPIs** were estimated through driving, eye-tracking metrics, and subjective measurements obtained during HADRIAN simulator studies.
- HADRIAN contributions notably **optimize takeover processes**
  (KPIs: Takeover Manoeuvre Safety Score, Take Over Request Awareness Time, and Take Over Time).
- **Further insights** into takeover time KPI are explored through XGBoost analysis.
- HADRIAN innovations reduce **subjective workload**, increase slightly comfort, usability, trust, control and safety feeling.



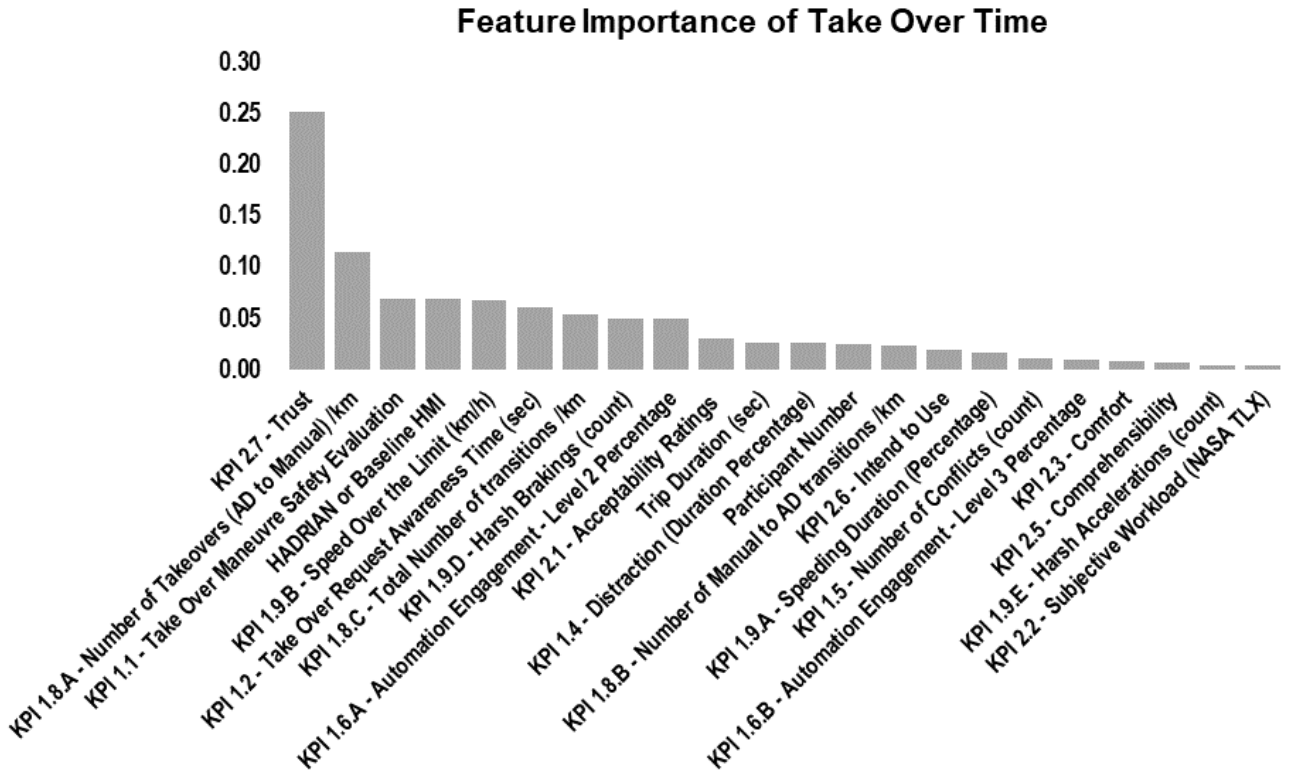


Feature Importance

- **XGBoost algorithm** run in R-Studio using the xgboost package
- **Data split**: 75% training set, 25% test set
- **Learning rates (eta)** from 0.01 to 0.3 for optimal model for takeover time (KPI 1.3)
- Extracted **errors** provide insights into predictive performance:
  - *Mean Squared Error (MSE): 1.377*
  - *Mean Absolute Error (MAE): 0.979*
  - *Root Mean Squared Error (RMSE): 1.174*
  - *Accuracy rate: 0.749*

Feature Importance

- Gain scores from feature importance analysis reveal **key insights** into takeover time.
- **Driver's trust** in HMI is the dominant factor, indicating significant influence on driver's responsiveness during automated driving.
- **Frequency of takeover requests** acts as a crucial alert mechanism.
- **Safety score** during manual takeover maneuvers indicating that takeover time is crucial for smooth maneuvers (speed, longitudinal acceleration, and deceleration).
- **HMI condition** (baseline vs. HADRIAN HMI) impacts takeover time.



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Conclusions

- KPIs show **safety, performance and user experience improvement** with HADRIAN HMI prototypes compared to baseline configurations.
- XGBoost results validate and strengthen existing literature, **highlighting driver trust in HMI**, frequency of takeover requests, and HMI conditions are crucial factors influencing takeover time.
- Takeover time is interconnected with and thus affects the smoothness and safety scoring of the subsequent **manual takeover maneuver**.
- Understanding **takeover mechanisms** and safety metrics is essential for optimizing human-machine interactions in autonomous vehicles.
- These insights could help **HMI stakeholders** enhance autonomous driving safety.


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