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Key Performance Indicators for safe fluid interactions within automated vehicles

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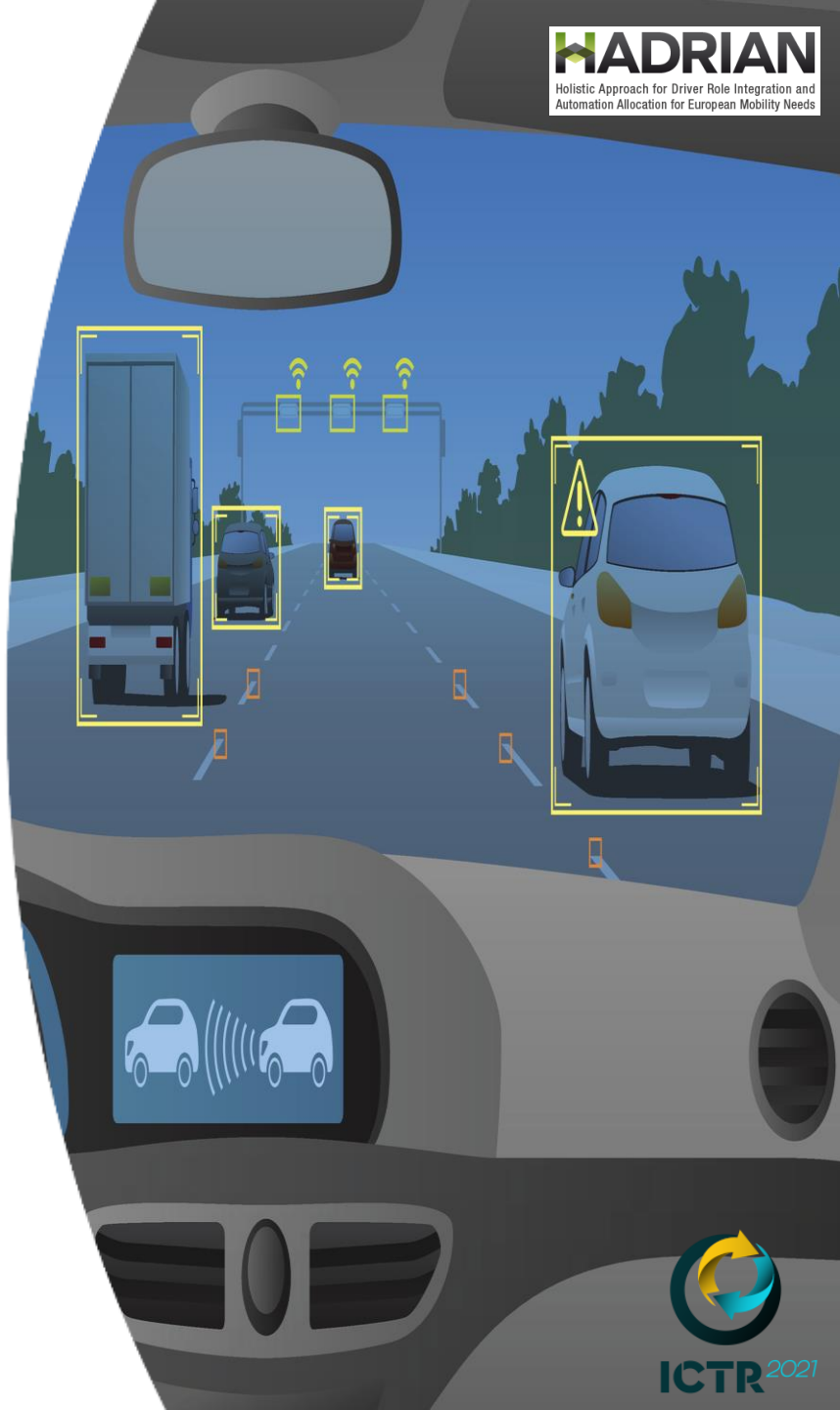
Introduction

- Connected and Automated Vehicles (CAVs) are expected to dominate the market share in 2050 [1].
- At the intermediate automation levels prior to the highly automated, human inputs and interventions are required.
- Human Machine Interfaces (HMIs) are expected to play a key role between user-vehicle interaction.
- The role of HMI is to make humans understand what is expected of them in terms of environment monitoring and active intervention[2].

[1](Talebian & Mishra, 2018), and [2](Carsten & Martens, 2019)

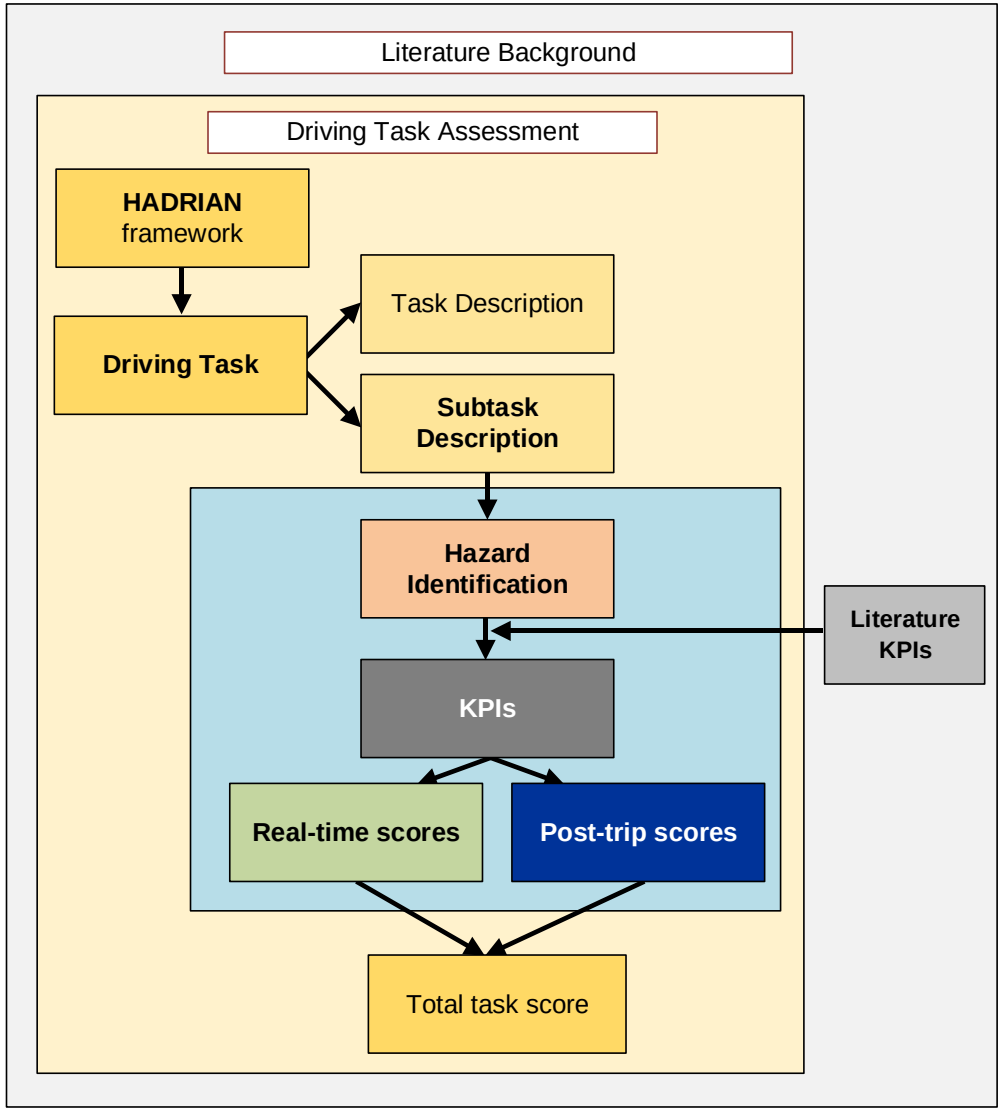
Background

- This study identifies critical KPIs that are capable of assessing the safety and general impact of fluid interactions between the user and the HMI.
- The work included in this study was conducted within the EU H2020 HADRIAN project.
- HADRIAN aims at developing an innovative and seamless fluid-HMI that provides “fluid” interactions between the driver and the AV.



Methodology (1/3)

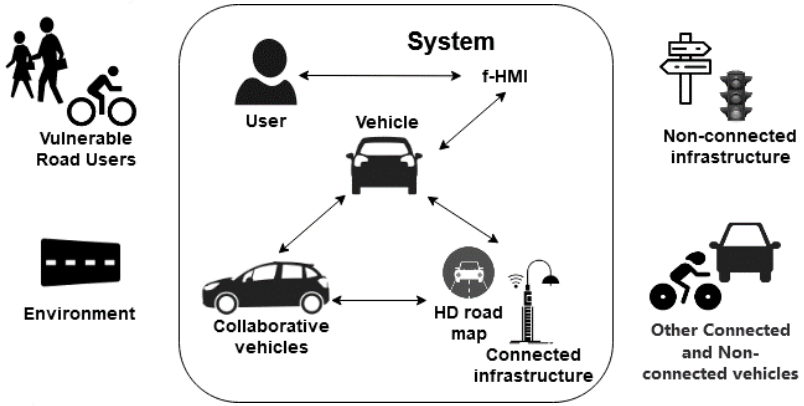
- Within the HADRIAN framework, the parameters (i.e., levels of automation and innovations) and use cases were defined by framing them into desired driving scenarios or tasks.
- Each driving task (includes necessary descriptions and elements in the driving scenarios) analyzed into description and subtasks.
- An analysis procedure named hazard identification revealed the risk factors which were potentially present during the driving tasks/scenarios.



Methodology (2/3)

Hazard Identification Procedure

- Hazard identification broke down the operational driving tasks into several subtasks.
- For all the segments, different needs and hazards were recognized within the user's driving system (New "system" concept).
- Hazards were matched with existing literature KPIs to investigate if there were capable of assessing them. Many KPIs were adapted to HADRIAN needs.



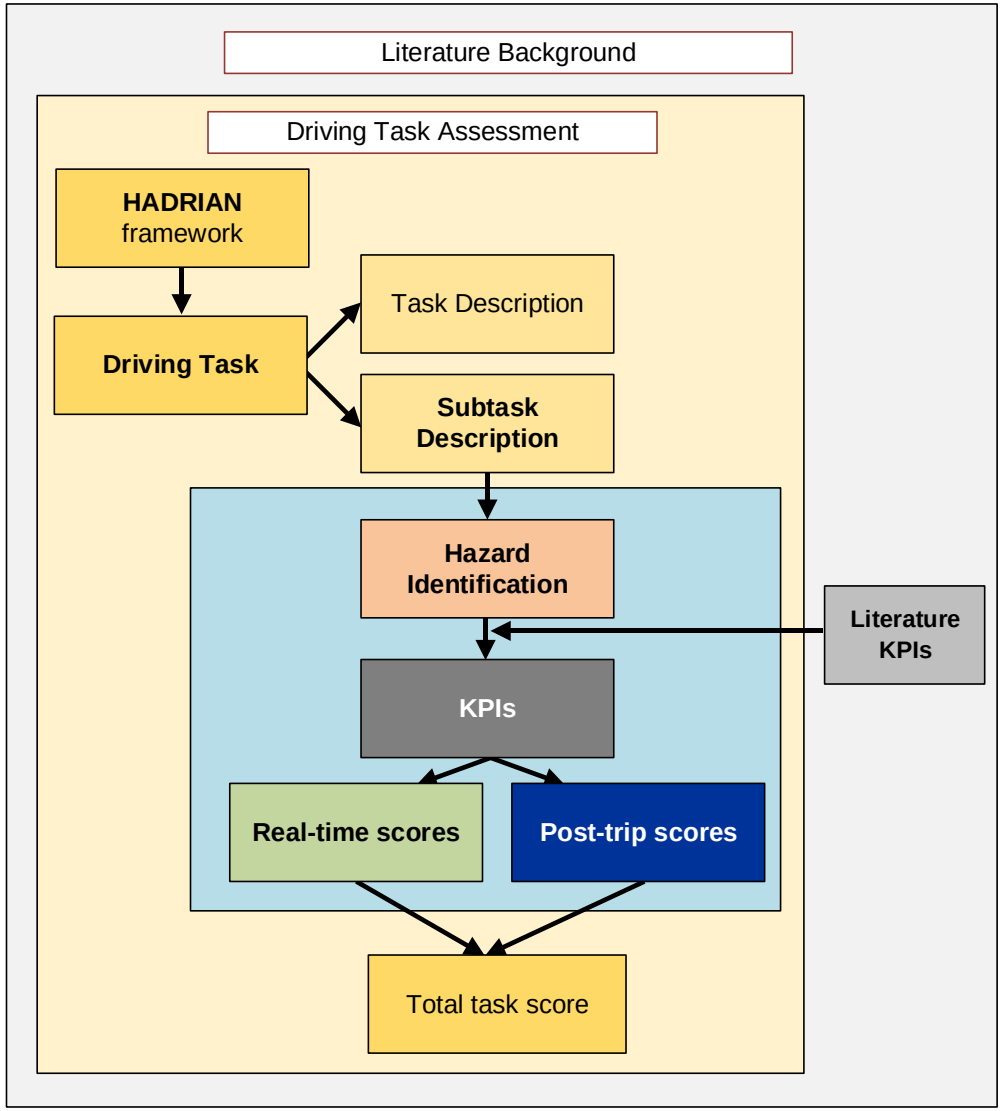
New "system" concept

Hazard Identification Example

Driving Task	Task Description	Driving Subtasks	Hazard	Relevant KPIs
Harold (the elderly driver) drives on a highway at SAE Level 3. As the end of the automated driving is estimated, the HMI signals Harold to start to take over.	Transition ADL 3 -> Manual	• Understanding the signals coming from the system • Reacting to system signals • Transition into manual mode	The takeover time might be not enough.	• Take-over Time
			The operator might provoke an accident.	• Accident Severity Level • TTC • Number of Harsh Decelerations

Methodology (3/3)

- Relevant KPIs were identified with the purpose of quantifying the potential risk factors within the driving scenarios. These KPIs were based on the existing knowledge from literature:
  - Derived from previous research projects and metrics related to driving performance and safety.
- A list of KPIs was developed by concretizing the obtained KPIs. The list was designed to be applied within the HADRIAN project by measuring two different scores i) the real-time score and ii) the post-trip score.
- In the final phase of the assessment, a total score is aimed to be evaluated in order to compare directly the safety impact of HADRIAN system innovation to a baseline system.



KPIs Grouping

- KPIs were grouped into two main categories, namely safety and general impact.
  - The safety group contains KPIs such as accident or safety risk, driving safety threshold, driver's state, driver's emotions, driving condition, and driver's health.
  - In the general impact group, the subcategories were comfort, acceptance & usability, trust, reliability, and accuracy.

	KPIs subcategories
Safety	Accident or Safety Risk
	Driving Safety Threshold
	Driver's State
	Driver's Emotions
	Driving Condition
	Driver's Health
General Impact	Comfort
	Acceptance & Usability
	Trust
	Reliability
	Accuracy

KPIs List

- Example of 64 KPIs:

KPI	KPI Description	Type of Required Data	Units
Accident or Safety Risk			
Accident Severity Level	Accident severity level regarding the following categories: a)Non-Injury, b)Minor Injury, c)Major Injury, d)Fatal	Driving Data	Categorical
Number of Crashes	Number of crashes in total or per km	Driving Data	Count
Number of Incidents	Number of incidents in total or per km (excluding crashes)	Driving Data	Count
TTC	Number of times when TTC (time to collision) is below 1 sec	Driving Data	Count
Number of Harsh Decelerations	Number of hard brakings (harsh decelerations) in total or per km (or hour)	Driving Data	Count
Number of Hard Shoulder usage	Number of instances using the hard shoulder	Driving Data	Count
Number of Unexpected Take-overs	Number of unexpected take-overs due to unexpected events (in total or per km)	Driving Data	Count
Driving Safety Threshold			
Brake Reaction Time	Brake reaction time	Driving Data	S
Take-over Time	Duration of take-overs (in total or per km)	Driving Data	S
Headway Time	Headway Time between the front and the following vehicle passing the same point.	Driving Data	S

Critical KPIs

- Special focus is given on take-over time and number of take-overs, as these will ensure seamless interaction between the user and the vehicle.
- Headway time, TTC, and the number of harsh events to ensure a safe and smooth travel within an automated vehicle.
- Within the general impact group, the most significant KPIs are envisioned to be comfort, safety feeling, required attention as well as trust since these will lead to more acceptable and reliable interactions and driving.

KPIs use

- The KPIs list is only the basis to capture the enhancement that new HMIs would need to prove compared to a baseline HMI.
- Additional KPIs can be introduced at later stages of the project by exploiting data from field or simulation trials.
- A thorough validation of the existing KPIs in field trials should shed more light on the safety performance and acceptability of new HMIs.

Conclusions

- This study identified 64 critical KPIs capable of assessing the safety and general impact of fluid interactions between the user and the HMI.
- The obtained KPIs could guide stakeholders in optimizing the safety assessment procedures for human-centered autonomous vehicles.
- By investigating the KPIs list, policymakers could also identify the most critical for specific applications.

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