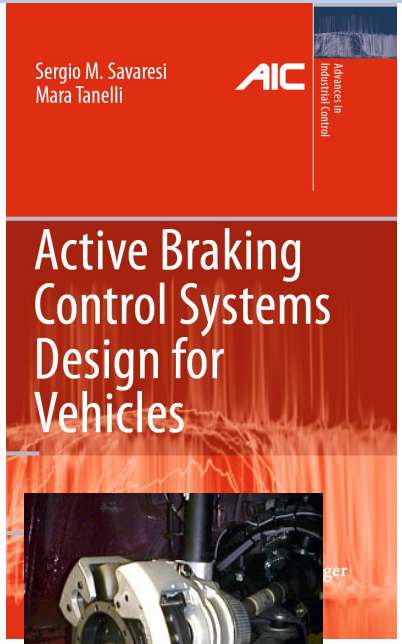
Inclusive and smart mobility

Mara Tanelli - Politecnico di Milano
mara.tanelli@polimi.it

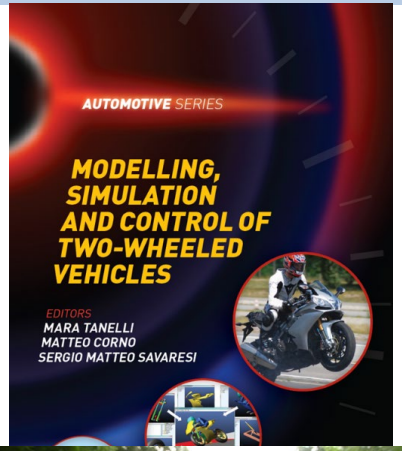
DEWIS Symposium – Gendered and Inclusive Research and Innovation
Delft, Nov 14th 2022

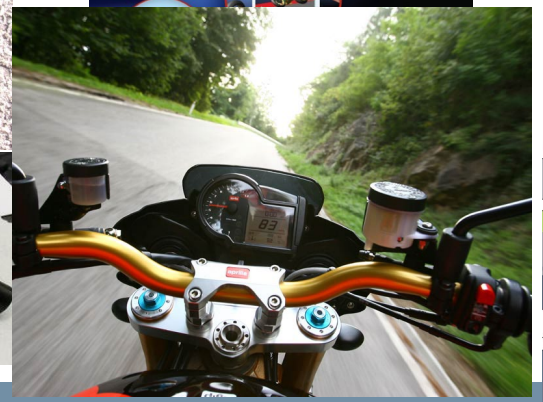
My research path and main interests

Braking control…

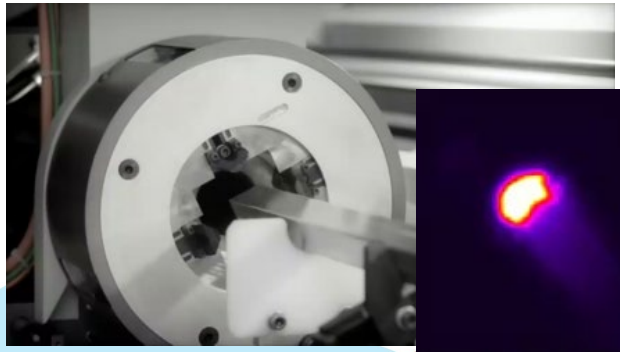


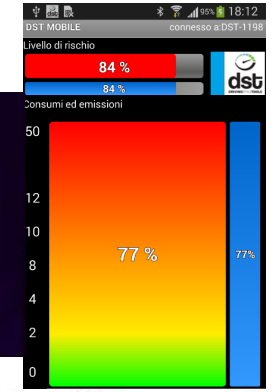
Vehicle control…





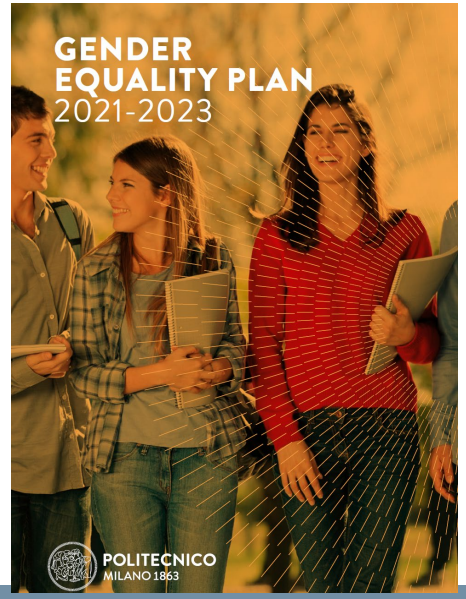
Smart Mobility and industrial analytics…

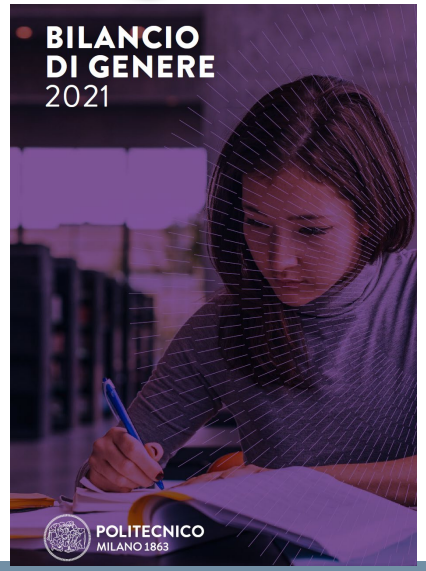




Civic engagement and institutional services

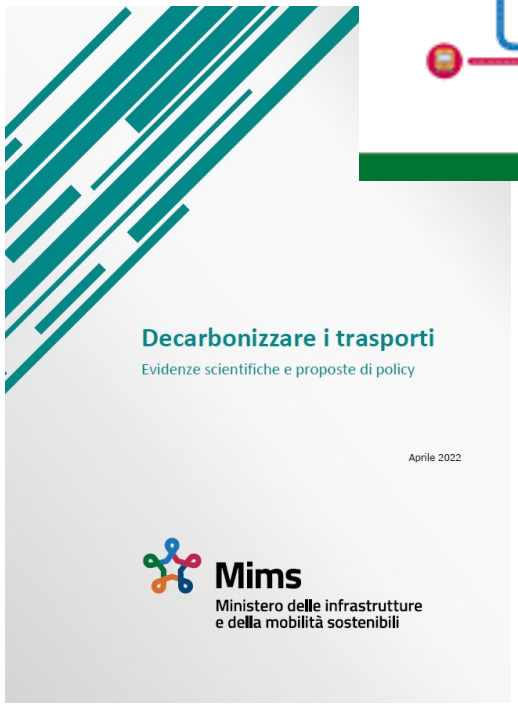
Member of STEMI
Structure for the Ecological Transition of Mobility and Infrastructures @MIMS





IEEE Control Systems Society™

Chair of the Technical Commitee on Automotive Controls



Main focus of this talk: smart, diversity-aware and inclusive mobility… WHY?

Climate emergency and decarbonization goals

Prominent role of **road transport** in gas emissions and energy consumption

Real changes are possible only being aware of the **human-factor centrality**

There is a strong need of sustainable and inclusive mobility solutions accounting for individual diversity, captured by socio-economic factors that go beyond mobility habits

The evolution of mobility and its users: a socio-techical problem

Mobility is undergoing disruptive changes

From ICE 2 Electric vehicles

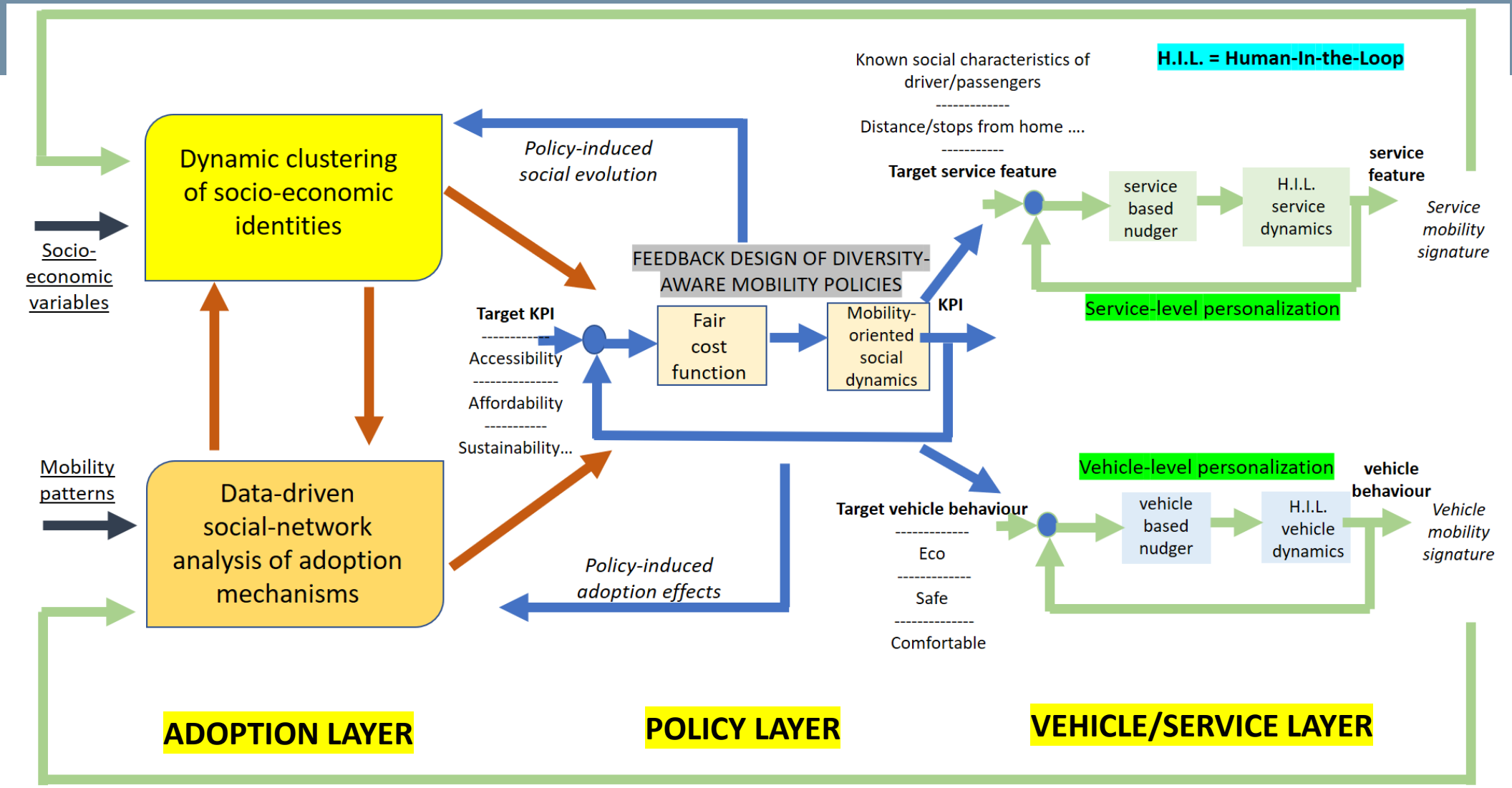
From human to autonomous drive

From ownership to usership

From analog to digital mobility (MAAS)

- Key to success is **massive adoption** → **substantial individual behavioural changes**
- Technology players **cannot ignore societal challenges**: the gender gap; the digital divide; a widespread ageing; an ever-increasing multiculturalism.

How to deal with this? With a 3-layers approach



The adoption layer

Model the attitude towards innovative mobility solutions

Adopt a **data-driven** approach to:

- ✓ **Extract the main socio-economic drivers** to the adoption of innovative mobility solutions
- ✓ **Embed** the selected information in **compact indicators** → **Users' mobility-DNAs**
- ✓ **Enable** a realistic picture of the **adoption processes**

Study the adoption dynamics through network analysis

Build **social networks** that:

- ✓ **Connect users** according to specific proximity measures
- ✓ **Model the adoption dynamics of new mobility paradigms** within a network-based evolution accounting for opinions' spread
- ✓ Give a basis model on which to test **fair policies** to support adoption

Adoption layer: example of results

The Sharing-DNA is a compact, yet comprehensive, tool **to characterize individual attitude towards shared mobility** accounting for socio-economic and behavioural factors

Available Data

- **2014 EU survey** on mobility issues
- **39 questions** related to personal information and mobility habits

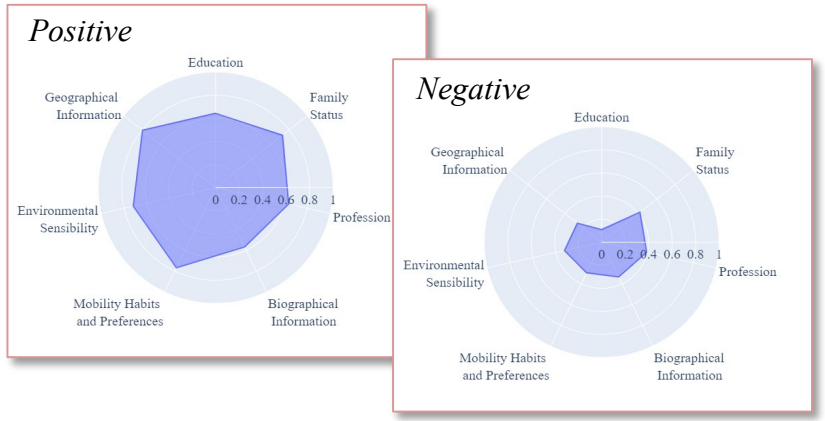
European Commission
eurostat

The objective

Extract primary socio-economic drivers to the adoption of **sharing services**

Target question

Results and applications



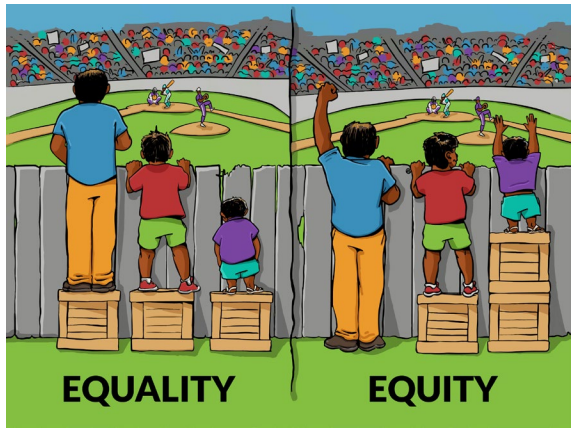
IEEE Smart Cities

Presented at International Smart Cities Conference, Paphos 26-29 Sept. 2022

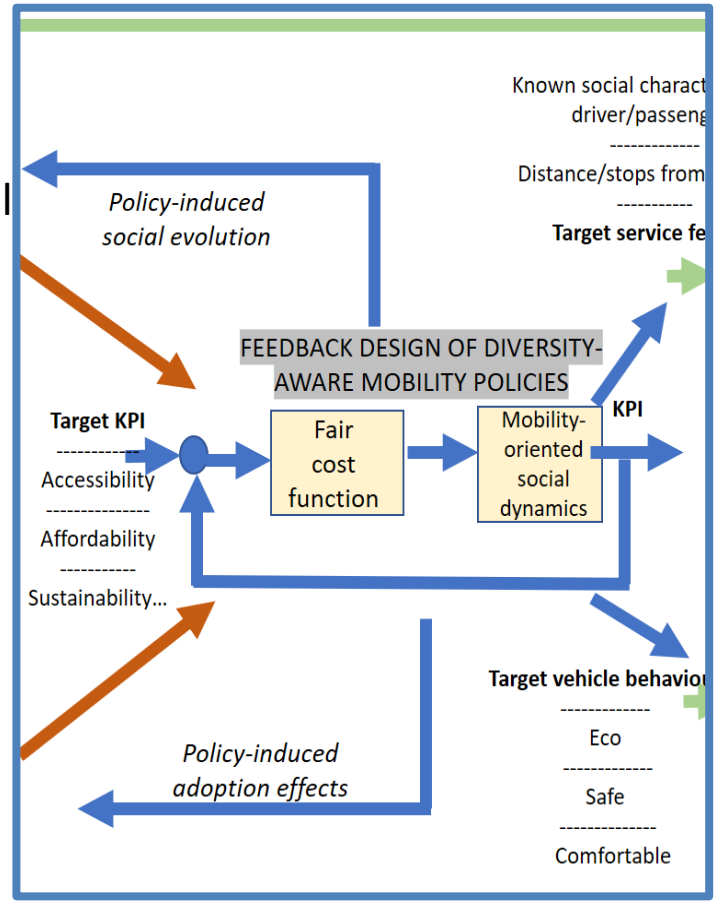
Design policies that enact social-justice principles

Enable an extended cost-benefit analysis to design policies that:

- ✓ **Foster adoption** while **accounting for individual features and diversity** in the users' pool
- ✓ Allow one to formulate policies that **quantify social justice principles and fairness attributes** in the same way we usually do for performance and budget constraints (e.g., **equality and equity**)
- ✓ **Enable closed-loop policy evaluation** at **design time**



Everyone benefits from the same support **Individual support induces equal access**



The policy layer: example of results

The Fair-MPC is a **fair model predictive control system** and represents an innovative tool to design **dynamic fair policies** that **quantitatively** account for social justice

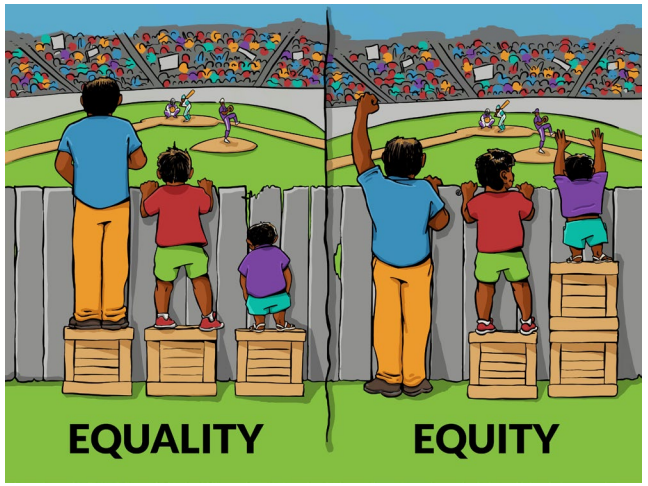
The **global output** defined according to the agents' dynamics described by a set of **LTI systems**

Budget constraint: agents share the same inputs to achieve their objectives

Centralized MPC

Agents' target

$$\begin{aligned}
\underset{\tilde{u}}{\text{minimize}} \quad & J(\tilde{\mathbf{u}}, \tilde{\mathbf{y}}, \tilde{\mathbf{r}}) && && \text{(4a)}\\
\text{s.t.} \quad & \tilde{\mathbf{x}}^i_{k+1} = \mathbf{A}^i \tilde{\mathbf{x}}^i_k + \mathbf{B}^i \tilde{\mathbf{u}}^i_k, && \forall i \in \mathcal{I}^N, \forall k \in \mathcal{I}^L_0, && \text{(4b)}\\
& \tilde{\mathbf{y}}^i_k = \mathbf{C}^i \tilde{\mathbf{x}}^i_k + \mathbf{D}^i \tilde{\mathbf{u}}^i_k, && \forall i \in \mathcal{I}^N, \forall k \in \mathcal{I}^L_0, && \text{(4c)}\\
& \tilde{\mathbf{x}}^i_0 = \mathbf{x}^i_t, && \forall i \in \mathcal{I}^N, && \text{(4d)}\\
& \tilde{\mathbf{u}}^i_k \in \mathcal{U}^i, \tilde{\mathbf{y}}^i_k \in \mathcal{Y}^i, && \forall i \in \mathcal{I}^N, \forall k \in \mathcal{I}^L_0, && \text{(4e)}\\
& \sum_{i=1}^{N} \|\tilde{\mathbf{u}}^i_k\|_1 \leq \bar{U}_t, && \forall k \in \mathcal{I}^L_0, && \text{(4f)}
\end{aligned}$$



Fair objective function

$$J(\tilde{\mathbf{u}}, \tilde{\mathbf{y}}, \tilde{\mathbf{r}}) = J_p(\tilde{\mathbf{y}}, \tilde{\mathbf{r}}) + J_u(\tilde{\mathbf{u}}) + J_e(\tilde{\mathbf{y}}, \tilde{\mathbf{r}})$$

$$J_p(\tilde{\mathbf{y}}, \tilde{\mathbf{r}}) = \sum_{i=1}^{N} \sum_{k=0}^{L-1} \|\tilde{\mathbf{y}}^i_k - \tilde{\mathbf{r}}^i_k\|^2_{\mathbf{Q}^i}$$ Individual Performance

$$J_u(\tilde{\mathbf{u}}) = \sum_{i=1}^{N} \sum_{k=0}^{L-1} \rho^i \left(\|\tilde{\mathbf{u}}^i_k\|_1 - \frac{\bar{U}_t}{N} \right)^2$$ Equality

$$J_e(\tilde{\mathbf{y}}, \tilde{\mathbf{r}}) = \sum_{i=1}^{N} \sum_{k=0}^{L-1} \left\| \tilde{\mathbf{e}}^i_k - \frac{1}{N} \sum_{j=1}^{N} \tilde{\mathbf{e}}^j_k \right\|^2_{\mathbf{P}^i}$$ Equity

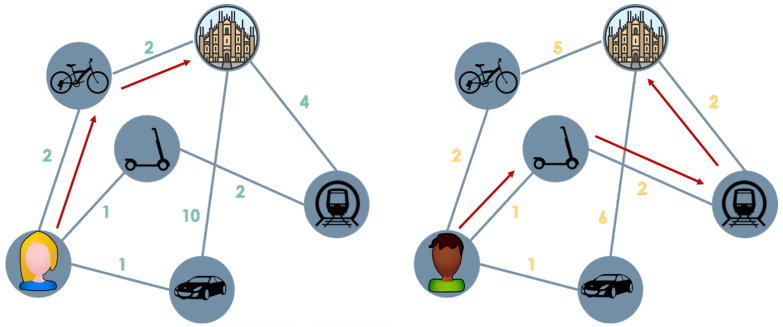
Under Submission at the IEEE Transactions on Automatic Control

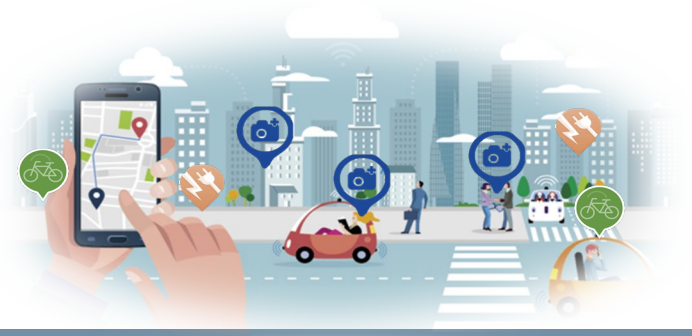
The vehicle/service layer

From models to concrete services and vehicles settings

Learn from **users' experience** to define **personalized solutions** ensuring

- ✓ **accessibility and usability** of the services
- ✓ actual **effectiveness of the designed policies** in fostering the adoption mechanisms





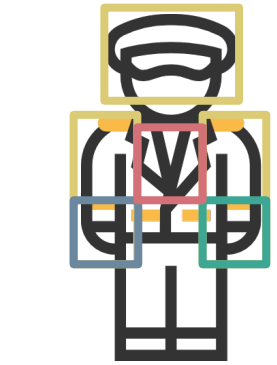
The final objective

Personalize the final services and vehicles that enact the mobility solutions by making them "move" towards the individual (unique) user and *viceversa,* leveraging behavioural economy (e.g., nudging) and control/decision theory:

- ✓ To **support mobility stakeholders**
- ✓ To offer each user **concrete and diversity-aware mobility solutions**
- ✓ To **realize nudging via advanced Human-Machine Interfaces** (HMIs), allowing ADAS and autonomy adaptation, within a diversity-aware framework

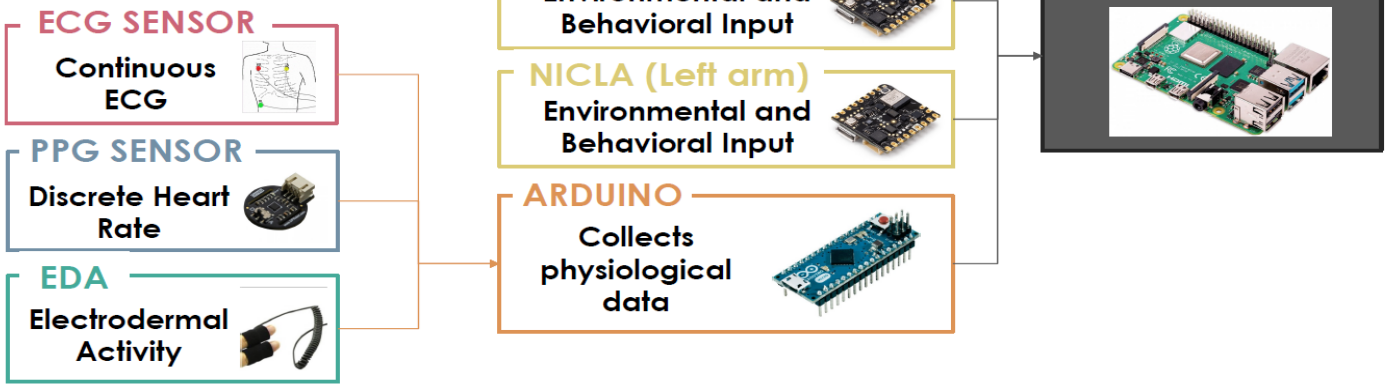
The vehicle/service level: example of results

Track a **pilot/driver psycho-physical status** in real-time through a machine learning based analysis of **environmental, behavioural and physiological data**



Data collection

Minimal set of **non-invasive sensors**



Preliminary results

Differences in normal and stressful driving conditions are especially visible in non-expert drivers. We will investigate how results change w.r.t. diversity dimensions (towards diversity-aware ADAS)

LEONARDO Project winner of the challenge «Solvers wanted» promoted by Leonardo S.p.a.

Smart and inclusive mobility: the impact

- This approach can initiate a new scientific reasoning in *mobility and beyond, which can be applied to all contexts in which **technological variables** highly interplay with **human behaviours***.

- This new conception will open the way to **diversity-aware and socially-disaggregated data-gathering, design and interpretation processes** → great impact on public policies and product/service development, where **economically/environmentally convenient and socially just decisions** must be taken.

Thanks to: Valentina Breschi, Fabrizio Dabbene, Jessica Leoni, Alberto Lucchini, Sabrina Milani, Chiara Ravazzi, Eugenia Villa

mara.tanelli@polimi.it