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DRIVING SUSTAINABLE CHANGE: ANALYZING AND PROMOTING THE ADOPTION OF ELECTRIC VEHICLES

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The mobility is undergoing significant changes, including the emergence of battery-operated vehicles, user-ship models, autonomous driving, and digital mobility services. To address these shifts, we propose a human-centric design framework for transitioning to electric vehicles (EVs). This framework empowers policymakers to shape the future of mobility by considering the interplay of social and personal factors influencing individual mobility behaviors. Using quantitative representations of socio-economic identities and data-driven social network analysis, we uncover the mechanisms driving the adoption of new mobility paradigms. This understanding facilitates the design of policies and services aligned with these insights. Applying our approach to real-world data from ICE vehicles in Italy, we demonstrate the framework's potential in designing effective policies that promote greener mobility habits. Policymakers can leverage this framework to implement policies fostering the adoption of greener mobility options, thereby contributing to the fight against climate change and promoting inclusiveness in the transition to sustainable mobility.

1. Introduction

Mobility is a vital aspect of our lives and cities, and it will continue to be crucial in the future of Smart Cities. Before the pandemic, transportation accounted for 20% of overall energy consumption [1], contributing significantly to greenhouse gas emissions. Addressing climate change requires reducing these emissions, and Electric Vehicles (EVs) play a key role in achieving greener mobility and pollution reduction [2]. However, obstacles hinder the widespread adoption of EVs, including ownership costs, driving range, and charging time [3]. Fuel prices, consumer characteristics, availability of charging stations, and social norms also influence adoption. Achieving full electrification is a complex process due to these factors.

To address this challenge, we propose an integrated and human-centered framework that considers the conflicting constraints arising from infrastructure limitations, management issues, and user needs. By examining both personal inclinations and social influences, our framework takes into account users' social connections to understand how interactions can promote sustainable mobility habits. This insight can inform the design of social-aware public policies that leverage users' social bonds to encourage acceptance of new mobility solutions.

Aligned with the aforementioned considerations, this study introduces a human-centered architecture designed to assist policymakers in three main areas: (i) analyzing the adoption of electric vehicles (EVs), (ii) developing intervention policies to encourage EV adoption, and (iii) quantitatively evaluating the costs and benefits of these policies using available data.

2. Main contribution

Figure 1 illustrates the conceptual framework, depicting the various stakeholders involved in a mobility system, including users, the environment or network, management, and infrastructure.

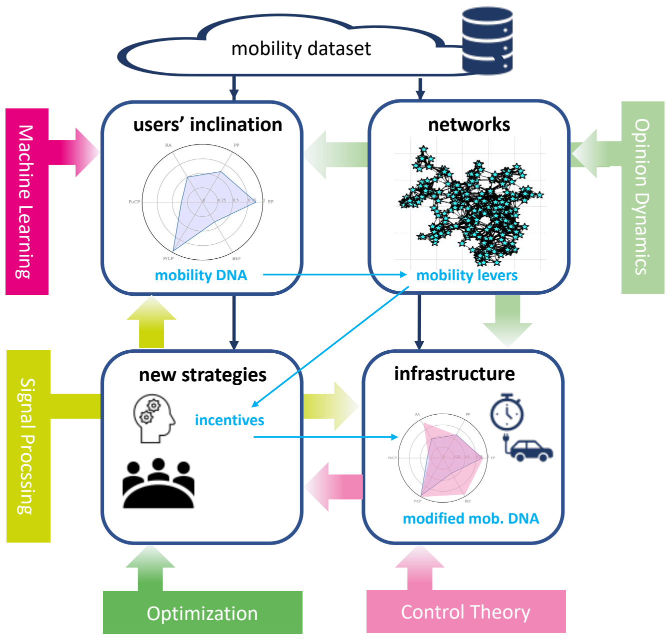
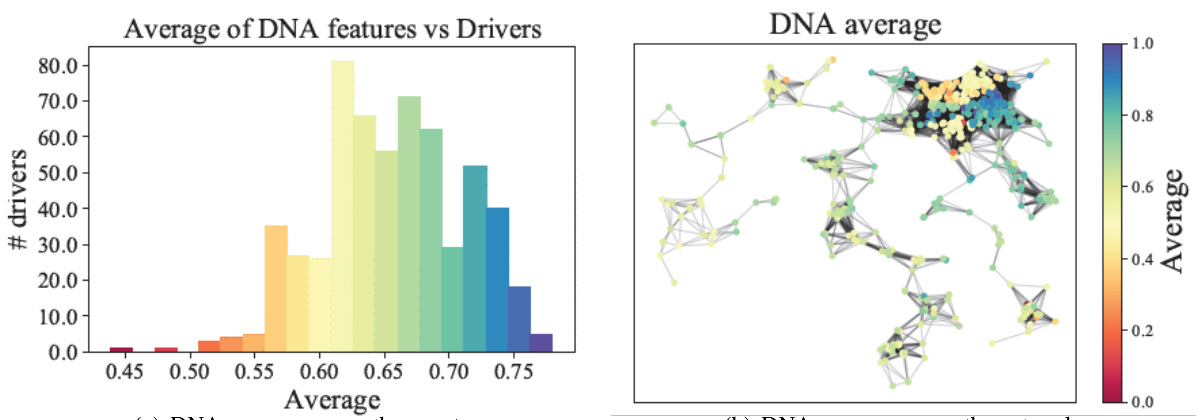


Figure 1: Interactions between different players and methodologies in the proposed human-centered design.



(a) DNAs averages over the agents.

(b) DNAs averages over the network.

Figure 2: DNAs average distribution over the network and the drivers.

By leveraging a dataset of anonymized trips, we progressively demonstrate how quantitative and unbiased information on individual mobility behaviors can provide insights into users' adaptability to EV adoption when combined with known limitations of EV technology and available infrastructure. Building upon the work of Fugiglando et al. [4], our contribution is the introduction of a novel concept known as the users' EV-adoptability DNA [5]. This compact indicator combines synthetic features that characterize the adaptability of each individual to an immediate switch to an EV based on their travel patterns. Unlike the user description used in our previous work [6], this granular representation enables policymakers to visualize key factors influencing the spread of EVs while allowing for flexibility in augmenting it with additional socio-economic features, if available.

Additionally, we propose an approach that utilizes the available mobility data to establish a proximity bond between agents, thereby enabling the assessment of the role played by homophily (similarity) in the adoption process. Through simulations, we mathematically describe the impact of individual adaptability to EVs and proximity-based relationships on the diffusion of EVs within a community. This formalizes the interplay between different layers of our proposed framework. To model the adoption phenomenon, we employ an irreversible cascade model [7] to characterize the effect of social contagion on EV adoption. This model results in a binary representation of individual attitudes, where a transition from one predisposition state to the other is driven by users' attributes surpassing a personal threshold. In contrast to McCoy and Lyons (2014, [8]), where individual thresholds are randomly assigned, our framework associates thresholds directly with each individual's resistance to adopting EV technology, thus connecting them to the EV-adoptability DNA. In our perspective, the thresholds represent the minimum number of EV-accepting neighbors required for an individual to consider EVs as a viable mobility solution through mutual influence alone.

To analyze and design policies, we propose the use of the cascade model within limited time periods in our framework. Through extensive simulations, we demonstrate how our framework can be applied to study the evolution of users' predispositions toward EVs over time, test various policies to promote EV adoption based on enforcing purchase power and the public charging potential, and quantitatively analyze their socio-economic and environmental impact.

To evaluate the effectiveness of the implemented policies, it is crucial to analyze their outcomes from a human-centered perspective, considering factors such as sustainability, environmental impact, and social inclusiveness. In order to achieve this, we introduce a comprehensive set of Key Performance Indicators (KPIs) that provide a self-contained framework for quantifying these seemingly subjective aspects. These indicators enable us to assess the policies based on various perspectives, including efficiency, effectiveness, and sustainability. By utilizing these KPIs, we can quantitatively compare different policies, extending the evaluation beyond the mere measurement of changes in individual attitudes towards EVs. This approach allows for a more holistic and comprehensive assessment of the policies' impact.

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