Less is More: Climate Change and Automated Vehicles in Urban Areas

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Abstract
We present our vision on how to mitigate anthropogenic climate change in the context of (automated) vehicles. We therefore analyze current challenges of privately owned cars and suggest a novel way to assess vehicle sustainability. Furthermore, four considerations indicate how technology, legal regulations and stakeholders in the area of urban mobility could overcome the trade-off between benefits of current traffic and sustainable, climate-friendly future means of transportation. With our ideas we aim to spark discussions within the research community, while acknowledging that they are partially far away from being implemented soon within urban environments.

Author Keywords
Automated vehicles; car sharing; climate change

CCS Concepts
•**Human-centered computing** → **Collaborative interaction;** *Ubiquitous and mobile computing;*

Introduction
Climate change could have drastic effects ranging from extreme weather conditions to limiting the human habitability of the earth [5]. To reduce unwanted outcomes of the human-made climate changes, the European Union

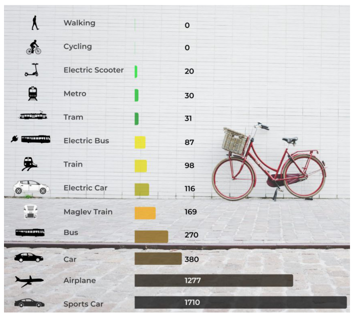

Figure 1: Energy efficiency in transportation [1].

Figure 2: Space requirements of bus, cars and bicycles [6].

stated several goals[1]: 40% less greenhouse gas emissions, a supply of 32% renewable energy, an energy efficiency improvement of 32.5% (percentage values compared to levels from 1990). However, these goals do not suggest strategies on how to achieve them. Since CO_2 emissions originating from urban traffic are amongst the main accelerators of global warming [2, 3], the domain of mobility should be revised especially regarding the consumption of fossil fuels. A key challenge for the future of mobility therefore is to retain the benefits of current mobility while overcoming the dependency on fossil fuels. Aspects which are related to mobility are economic growth and the quality of life, which also includes a conflict: today's economy mainly runs on fossil fuels whereas the quality of life for people in urban areas suffers from pollution through non-renewable energy. Thus, legal regulations should include short term actions with long term goals and neither neglect stakeholders of fossil fuels nor the reduction of air pollution to foster acceptability. Automated vehicles (AVs) are expected to become an increasing part of everyday traffic [4]. This work presents ideas on how to involve automated vehicles in urban traffic while considering climate change. Moreover, we hope to spark discussions within the human-computer interaction and automotive community.

Background

Privately used cars are among the least energy-efficient and least climate-friendly means of transport, see Figure 1. According to the website *Ecohungry.com*[2] electric cars are less energy efficient than established public transportation, e.g., metros or trams. Even if the electric energy originates completely from renewable sources, building a car and especially batteries always includes carbon dioxide emissions and interference with nature. Additionally, the service life of private cars is shorter than for vehicles of public transport[3].

The operation of personal cars occupies a bigger part of roads compared to buses or bicycles, as shown in Figure 2. The current amount of private vehicles requires wide roads with multiple lanes and dedicated parking lots at manifold locations spread in cities. Hence, providing such territories for vehicles leads to lesser opportunities left for pedestrians or cyclist and limited areas for lawns, parks, trees or lakes, which could bind CO_2.

We see that private (automated) cars are a major cause of climate change due to their unsustainable production, wide spread use, consumption and short service lifespan. On the other hand, such vehicles provide a high degree of independence: individually owned cars do not rely on a fixed schedule. Therefore, we argue that the domain of privately owned vehicles should be reconsidered to provide as much personal freedom as necessary, while being as climate-friendly and sustainable as possible. The increasing level of shared vehicles, automation and connectivity could provide a basis for novel solutions thereof.

Vehicle Sustainability Assessment Rating

Assessing sustainability remains an open challenge. A rather bad example is an efficiency label[4] provided by the German car industry. This label includes a rating for vehicles ranging from A+ (*green, very efficient*) to G ((*red, low efficiency*). The corresponding calculation is based on estimated CO_2 emissions during usage divided by the weight of the car. A result is that a big and heavy car can receive a greener label than a smaller car with less absolute energy consumption and emissions. For example, an

[1] EU Climate & Energy Framework*; accessed: Feb. '20*
[2] Ecohungry.com*; accessed: Feb. '20*
[3] Lifespan of Main Transport Assets*; accessed: Feb. '20*
[4] Energy efficiency label; accessed: Feb. '20

- Absolute amount of CO_2 emissions during production of vehicle parts, assembly of the car and shipping of the product to the place where it is finally sold.
- Amount of CO_2 emission per 100km of urban driving.
- Consumption per 100km of urban use.
- Type of energy source, e.g., bio fuel, fossil fuel, electric, hydrogen or others, weighted by sustainability.
- Average of physical space the product occupies for each driver and passenger in m^2.
- Estimation of distance the car will be used for per person (whole lifespan), in km.
- Estimation of service life-span of the product, in years.
- Estimation of CO_2 emissions of maintenance throughout the products life span.
- Estimation of CO_2 emissions through vehicle disposal.
- Percentage of recycled parts built in the vehicle.
- Percentage of recyclable parts of the vehicle.

Audi Q7 has a "better" efficiency rating than a *Citroen C1*, while the *C1* produces less absolute emissions. As a basis for rating climate-friendliness and to overcome potentially misleading ratings, we suggest a novel way to assess vehicle sustainability. This includes a unified measurement which should be provided by non-commercially interested institutions. A usable sustainability-score should combine observed mean values or fair estimations of the aspects listed in the sidebar. Such a rating can be useful to asses the value of actions in the domain of urban traffic. A rating-score combining the mentioned attributes could indicate the sustainability of proposed strategies and ease comparison between them.

Approaches to Reduce Traffic Emissions

We believe that mitigating anthropogenic climate change and limiting global warming requires a holistic approach including legal regulations, manufacturers, service providers and customers. The theoretical solutions in this section are presented in relation to the parties that could influence an implementation of introduced approaches. The aforementioned assessment criteria for sustainability could provide a basis to decide which vehicles are used in which way or how they are combined in an eco-friendly manner by comparing corresponding sustainability scores.

(1) Encourage Car Sharing

The efficiency of automated cars should be maximized by avoiding empty driving or parking vehicles and cars which only transport individual users. Thus, we think that time-shared vehicles should be designed and provided by manufacturers in a sufficient amount. To motivate manufacturers, car sharing could be financially rewarded by a state or city council, e.g., through tax reliefs. To offer passengers shorter (shared) travel times, shared automated vehicles could receive higher priorities at intersections. Additionally, an optimal usage of empty cars for freight should be rewarded. Furthermore, legal regulators could demand mandatory software for automated vehicles which avoids traffic jams and prioritizes energy-efficient routes over shorter or quicker paths. Software tools on mobile devices or public displays could guide users to find and book such shared rides in urban environments. Corresponding user interfaces should indicate where cars can be accessed and loaded. A seamless interaction of means of transport could support the acceptance of ride sharing. For example, combining bus rides with shared vehicles and electric scooters could be supported by adaptive guidance applications on mobile devices such as smartphones or wearables. Ideally, such apps could show the best options to access vehicles as efficiently as possible in real time.

From an HCI perspective, challenges of time-shared automated cars are related to designing the vehicles in a way that the in-vehicle interfaces allow the passengers to maintain the benefits of individual driving (e.g. related to privacy and personal preferences) while the car is shared with other riders. One benefit of personally owned cars is that they can be highly customized (e.g. personal settings, music, connected devices, luggage etc.). Thus, a challenge for shared vehicles is to provide this customized experience across all cars a user might use throughout the day.

(2) Consider Origin of Energy & Propulsion Technology

In order to achieve sustainable traffic, the source of energy should be renewable. Shared automated vehicles running on fossil fuels do not counteract climate change in the way renewable energy sources could. Therefore, we suggest that governments support customers to buy vehicles which are not running on fossil fuels, e.g., with access to certain points of interest or financially. This could motivate manufacturers to invest in the development of renewable propulsion technologies, since the corresponding market demand could rise. However, the generation of electric energy, hydrogen, bio fuels and others should be strictly controlled to reduce emissions and harm of nature during production. Otherwise the exhaust pipes of current combustion engines of cars get transferred to factory chimneys of non-renewable power plants, without reducing the overall use of fossil fuels or CO_2 emissions.

(3) Regard Stakeholders
Main stakeholders of the current automotive industries are manufacturers of vehicles, suppliers, mechanics and customers. The industry aims to constantly increase their businesses and will only build and develop products if there is a financial benefit. If the amount of individually owned vehicles declines, the automotive industry will find alternative business models. Due to this market disruption, manufacturers might need to focus on selling vehicles to service providers or even commercialize renting models themselves. This could reduce the overall amount of sold vehicles but increase earnings of manufacturers per car. The current traffic infrastructure in urban environments consists of gas stations, repair shops, and vendors of vehicles. These institutions could be revised to feature meaningful support of shared automated vehicles. An alternative adoption of such service points could be that they provide renewable power supplies (gas stations), exchanges of empty batteries (repair shops) or rental points (vehicle vendors). To achieve this goal, matching human-computer interfaces should be provided to make payments possible in a ubiquitous and unobtrusive manner, e.g., via mobile payment solutions which allow easy to use micro-transactions for transport services. Customers of shared automated vehicles could be attracted by lower costs and a shift of responsibilities regarding the state of a vehicle from individuals to commercial providers. Additionally, social cues and the image of eco-friendly driving could be established as a status symbol through targeted marketing campaigns. To this end, users of shared automated vehicles could receive priorities in boarding them related to the individual usage frequency, become rewarded with digital awards on social media platforms or public displays.

(4) Implement Legal Regulations
We think that legal regulations should rather motivate using climate-neutral transport than generally forbidding fossil fuels. This could be done through: tax reliefs; urban planing of infrastructure, e.g., certain roads which are only allowed for climate friendly vehicles; a limitation of the amount of vehicles in cities prioritizing efficient vehicles or even fossil fuel car-free days. Furthermore, an open accessible counter of CO_2 emission per person could be introduced to create awareness of individual ecological footprints and reward low emissions with social benefits, such as, free access to cultural sites or leisure facilities.

Discussion & Conclusion

This work presents an approach for a novel vehicle sustainability rating and perspectives on how to mitigate anthropogenic climate change. An establishment of the aforementioned considerations is to be discussed. An implementation might be limited due to manifold interests groups of manufacturers, energy suppliers and a wide network of infrastructure e.g., gas stations and repair shops. Moreover, acceptance by society may not be given. If an implementation of presented considerations takes place, it will probably be a step-by-step process taking years or decades. However, the goal of this work is to present ideas on how to mitigate climate change in the area of automated vehicles. We aim to spark discussions within the research community on how to shape mobility for a climate-friendly future.

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