Synergies of Connectivity, Automation and Electrification of Road Vehicles

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Abstract The combination of connectivity and automation with the electrification of road vehicles offers a multitude of synergies in both performance of the technical systems and added values for users and businesses. These synergies become manifest in e.g. a higher energy efficiency and a more convenient operation. Furthermore they may define new products and services in the automotive domain. Therefore, they are an interesting subject of innovation analysis. This paper summarizes the activities of an international working group dealing with connectivity, automation, and electrification in road vehicles which was formed under the umbrella of the International Energy Agency (IEA). These activitites include the analysis of potential synergies, an information exchange about relevant research and development activities, and discussions on future trends in innovation, business development and deployment.

Keywords Electric vehicles · Car sharing · Automated and connected vehicles · Synergies

1 Introduction

According to roadmaps of the automotive industry, the implementation of high-degree automated driving (i.e. SAE levels 3 and above) can be expected for the motorway around the years 2020–2025, and in urban environments around 2025–2030 [1]. This coincides with the phase of broad market introduction of electric vehicles: A significant market share of such vehicles has been predicted for the 2020–2025 timeframe [2]. Interdependencies between the development and innovation processes in both technology fields are likely due to (a) similarities in the electronics and data architecture of control, (b) complementarities related to energy consumption, and (c) commonalities in the systematic character of the operating environment.

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Concept cars that are connected and automated on the one hand and electric on the other, are currently or will soon be under investigation in a multitude of field tests, e.g. EN-V 2.0 by General Motors is tested in Tianjin Eco-City (P.R. China), the Lutz pods will be available for trials in Milton Keynes (U.K.), and the use of driverless cars is studied by Google. Other examples include an electric delivery van that slowly follows the driver while he is walking from door to door as recently presented by Volkswagen, an automated valet parking and wireless charging service as proposed by Renault and other vehicle manufacturers, and electrified and driverless mobility robots as demonstrated by Hitachi.

In view of these developments, the Implementing Agreement (now: Technology Collaboration Programme) Hybrid and Electric Vehicles of the International Energy Agency recently established a new working group, Task 29 "Electrified, connected and automated vehicles". It analyzes the potential synergies in road vehicles, shares information about relevant research and development activities, and exchanges ideas on future trends in innovation, business development and deployment [3]. Some preliminary findings of the working group are summarized in the following paragraphs.

2 Synergies in Technology

The interdependencies of the technical functionalities of connected and automated electrified vehicles can be systematically analyzed by relating the enabling components and systems of both fields to each other. This is shown exemplarily in Fig. 1, where the existence of such interdependencies is indicated for the technology fields covered in the industrial R&I roadmaps that have been mentioned in the introductory paragraph.

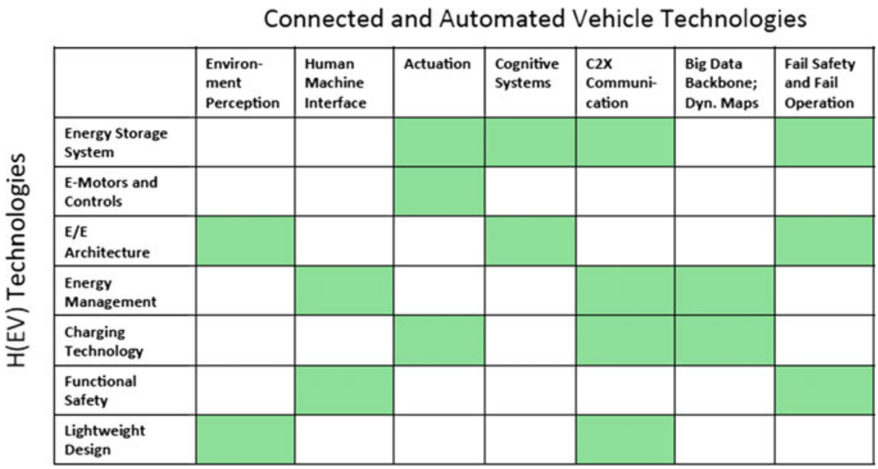

Fig. 1 Interdependencies between the key technologies of electric vehicles and connected and automated vehicles

In the following, a few of those interdependencies are described:

- **Fail Safety—E/E Architecture**: Electrified and automated vehicles are faced with comparable requirements for fail-operational design of the electric and electronic architecture—a great opportunity for exploiting synergies when designing the automobile of the future [4].
- **Actuation—Charging Technology**: Highly automated electric vehicles in combination with inductive charging can simultaneously find a parking spot with a charging-coil, position the vehicle coil accurately, and start the charging process automatically [5]. Future applications of this technology may even be dynamic, i.e. en-route inductive charging.
- **C2X Communication—Lightweight Design**: In the absence of mixed traffic and vulnerable road users, fully connected, SAE level 4/5 automated vehicles would be accident-free by definition. Hence, no passive safety measures would be needed to protect the occupants, and as a result the vehicles could be super-light. For an electric vehicle, this would mean a tremendous gain of range [6].

3 Complementarities in Energy Consumption

Connected and automated vehicles are able to choose routes and driving styles that minimize the energy consumption and ensure the best usage of the battery capacity in a hybrid or purely electric power train for a given road profile. Hence, an increased and predictable range of the electrified vehicle results. At the system level, automation in combination with cooperative driving ensures that traffic flows are optimized both in the city, the primary area of electric vehicle usage, and on the highway where it may greatly increase the usefulness of electric vehicles for longer distances.

However, due to the greater degree of convenience, automated vehicles may be driven more often and for longer distances. This may cause rebound effects to energy efficiency gains and to the synergies with electrification [7].

4 Role of Business Models

Despite the numerous opportunities for the exploitation of synergies due to the coincidence of connectivity and automation on the one hand and electrification on the other, it remains questionable whether these synergies will be used and are able to accelerate the adoption of those new road vehicle technologies. Not just higher purchase cost due to expensive sensor and energy storage systems may hinder an early adoption by private customers, but also the necessary investments in telecommunication infrastructure installations and energy storage systems, missing legal frameworks and hesitance of users may create hurdles. In the end, a connected, automated, and electrified road vehicle system might even be blocked than promoted.

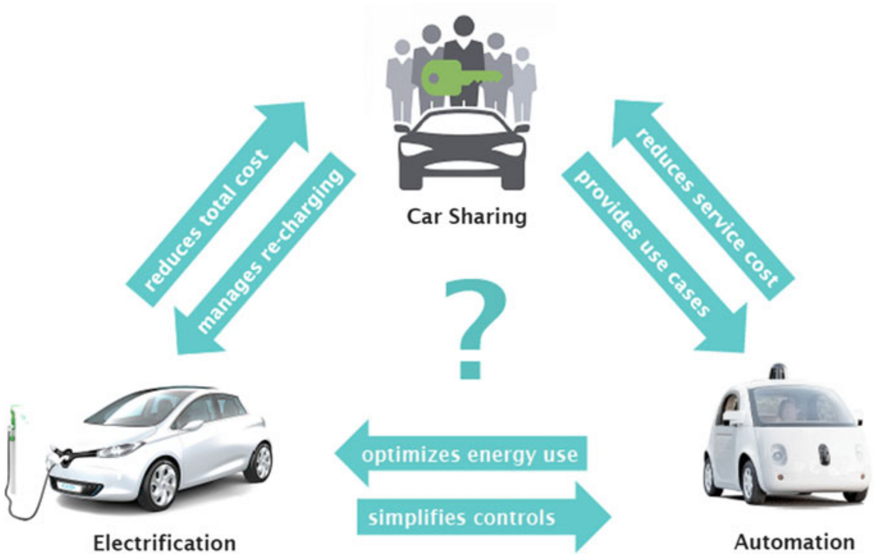

Fig. 2 Car sharing may help to unlock the potential synergies of electrification and connectivity/automation of road vehicles; the optimal vehicle design for this a subject of discussion

These issues may be solved through embedding the vehicles into a car sharing network because (a) the business model of car sharing acknowledges the fact that both electrified and connected/automated are cheaper in total cost of ownership than conventional vehicles, and (b) car sharing provides systemic functionalities like managed charging and on-demand availability that counteract limitations of individual ownership—yet another set of synergies (see Fig. 2).

5 Conclusions

In line with the findings of the IEA Implementing Agreement (now: Technology Collaboration Programme) Hybrid and Electric Vehicles' Task 29 "Connected and Automated Electrified Vehicles", the need for further research and innovation on synergies between the two fields has been promoted by the eNOVA Strategy Board Automobile Future in Germany, recently [8]. And, similar discussions are taking place in the framework of a task force "Electrification of Road Transport" at the European level currently.

From the preliminary findings, it can be stated that car sharing may play an important role in exploiting the synergies identified and in avoiding detrimental effects, e.g. in energy consumption. How the vehicle design can be optimized to fit all three domains, electrification, connectivity and automation, as well as car sharing, remains open, though.

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