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How may connected automated driving improve quality of life?

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Abstract

This paper describes a framework for evaluating the impacts of automated driving progressed by Internet of Things (IoT) on quality of life (QoL). The work is carried out under the European H2020 programme in the AUTOPILOT[1] project. The evaluation framework addresses the impact of different use cases on personal mobility, sustainability and well-being. The challenge is approached from three angles: how IoT can *accelerate*, *enhance* or *enable* the development, functionalities, performance and benefits of automated driving functions (ADF). An overview of the methodological approach for analysing the large-scale impact of connected and automated driving on QoL is provided, challenges related to the evaluation of pilot tests are discussed and first results presented. Use cases include automated valet parking, urban driving, highway pilot, platooning and car sharing.

Keywords:

automated driving, IoT, quality of life

Introduction

Automated driving is largely anticipated to yield benefits for people and society: road safety, traffic flow, user comfort and mobility are expected to improve. Initial research suggests that most benefits are likely to be realised only with connectivity between vehicles and the road environment (DfT 2016, Milakis et al. 2017). Connectivity can be implemented with many technologies, and Internet of Things (IoT) is a promising concept as more and more different objects are connected online.

The objectives of the AUTOPILOT project (Automated driving progressed by Internet of Things, 2017–2019) under the European H2020 programme are to define and implement an IoT architecture for automated driving (AD) and to realise IoT-based automated driving use cases. Five AUTOPILOT use cases will be evaluated on one or several of six pilot sites: Automated valet parking, Urban driving,

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Highway pilot, Platooning and Car sharing. The pilot sites are located across Europe: Helmond-Eindhoven region in the Netherlands, Livorno in Italy, Tampere in Finland, Versailles in France and Vigo in Spain. In addition, an associated pilot site is located in Daejeon, Korea.

The project evaluation approaches the challenge from three angles: how IoT can *accelerate*, *enhance* or *enable* the development, functionalities, performance and benefits automated driving functions (ADF) and services for automated vehicles (AV). The evaluation includes technical evaluation, user acceptance evaluation, business impacts as well as impacts on quality of life. The FESTA V approach as described in the FESTA framework (FOT-Net 2017) forms a basis for the evaluation. FESTA consists of a methodology and guidelines for designing and conducting Field Operational Tests (FOT) of Intelligent Transport Systems, and analysing the results and determining the impacts of the systems tested. The methodology puts much emphasis on the definition of research questions and hypotheses as the basis for designing the evaluation. This paper focuses on the quality of life assessment, which studies the impacts of the AUTOPILOT functions on personal mobility, traffic safety and efficiency, the environment and well-being (Figure 1).

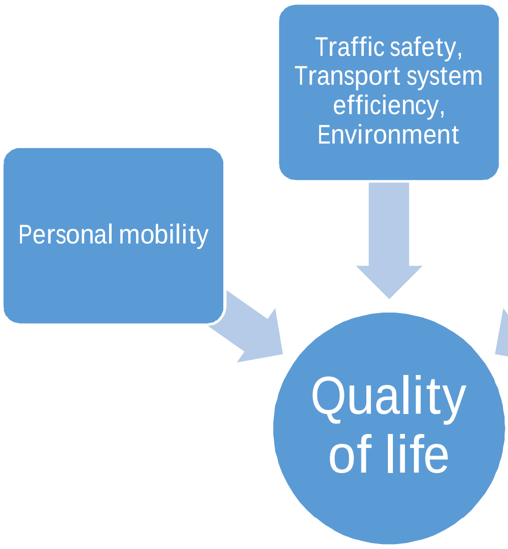

Figure 1 - Components of quality of life assessment

The methodology for evaluating quality of life impacts of automated driving enhanced with IoT and the status at the time of writing is presented. Due to the complexity of the topics AD and IoT, an iterative approach is taken and the methodology will be revisited and updated throughout the project. The work is continuing with detailed planning of data collection and user tests including survey questionnaires. User tests are planned to start in late summer 2018. First stakeholder interviews took place in June.

Quality of life concepts and impact mechanisms

Personal mobility

Mobility is typically defined as the potential for movement of people or goods, in which the realised movement happens. Revealed mobility is used as an imperfect measure (Innamaa et al. 2013). The mobility model originally developed for the TeleFOT project will be used as a basis and enhanced to cover IoT effects. The model consists of three pillars of mobility: amount of travel, travel patterns and journey quality. It helps to clarify the aspects, which specifically need to be measured and evaluated in order to analyse mobility impacts. (Innamaa et al. 2013.)

Figure 2 provides a conceptual framework for the analysis of the impacts of connected driving on mobility and traffic system. When studying the impacts of AUTOPILOT functions, a special focus will lie on exploring the potential of the technology for improving quality of life (including e.g. journey quality) on an individual and societal level, but also conflicts between those levels will be explored. Improving quality of life on individual level may lead to undesired effects on the transport system as a whole. For example, enabling people to use travel time more efficiently, sitting in a more comfortable way, and additionally enabling users who are currently not able or not willing to drive to use a vehicle, might result in an increase in individual traffic, vehicle kilometres travelled and emissions. On the other hand, the technology may bring improvements on traffic system level that do not necessarily provide significant directly observable benefits to the users. The best case, according to the proposed evaluation framework, is when the implementation of the technology supports achieving improvements to both personal mobility and the traffic system.

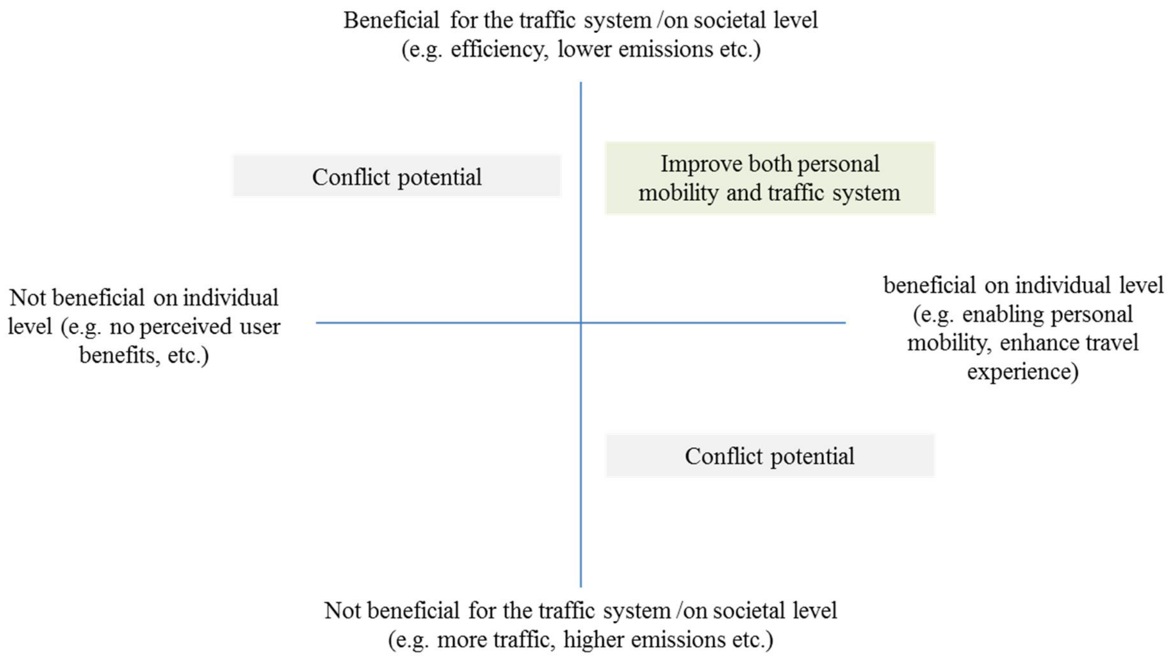

Figure 2 - Dimensions for personal and social mobility (framework created by Stephan Müller, see Kolarova et al. 2018)

Sustainability and efficiency of traffic system

Impacts on sustainability are evaluated in terms of safe, green and efficient transport. The *safety assessment* approach is based on the system nature of transport: when one element of the system is affected, the consequences may appear in several elements and levels of the system, both immediately and in the long term. The assessment follows the theoretical background of three dimensions of traffic safety: exposure, accident risk and accident consequences (Nilsson 2004). As actual crashes are rare events, proxy measures will be used such as instances where the driver must take control of the vehicle, near-crash situations and situations reported as uncomfortable or risky by the passengers. Also changes in driving speed and vehicle/driving behaviour may affect safety. The assessment will aim to cover both unintended, direct and indirect as well as short-term and long-term impacts of AV with IoT. *Traffic efficiency* describes how efficiently, in terms of average travel time and delay, people and goods are able to move through the transport network. The primary objectives to study are whether and to what extent AV and IoT have an effect on traffic flow and roadway capacity. This is influenced by several factors and their interactions: environmental factors (e.g. the layout of the road, weather conditions), vehicle factors (e.g. length of vehicles), and vehicle/driver behaviour factors (e.g. preferred headway). Changes in traffic flow depend on the penetration rate of AV but also on the regulations regarding car following behaviour. By providing enhanced performance through connectivity and better anticipation of unforeseen events, IoT is expected to positively affect some of the aspects of capacity and traffic flow and thereby enable, enhance or accelerate perceivable benefits of automated driving.

Wellbeing

AV certainly will not be a magic wand for drivers' wellbeing, but they have potential to offer accessible choices and possibilities within the larger urban transportation scheme. Therefore, the use of AV is expected to improve the lives of people who are already drivers and of those who have not been able to drive before. Indeed, mobility-restrained individuals, as well as citizens with more complex access needs, could benefit from automated driving in terms of access to services and psychological well-being (Trommer et al. 2016).

The wellbeing assessment includes impacts on health and equality. Direct impacts for AV users are expected, but also the well-being of other road users and society in general will be influenced by AD; for example, AD might influence the traffic flow in certain areas, positively or negatively. Connectivity may bring its own benefits and problems, such as issues related to data protection, privacy and cybersecurity. On the other hand, connectivity through IoT may bring new benefits, for example with regard to the rise of health monitoring IoT devices.

If automated vehicles are very attractive and easily available, people might be tempted to use them even for shorter journeys, which have previously been carried out by active travel modes such as walking and cycling. This can have a negative impact on public health in general.

A detailed literature study on the potential effects of (connected) automated driving on health and well-being is carried out. As well-being is a complex and far-reaching topic, and changes are difficult to assess in short pilot tests, a versatile approach is taken in the evaluation. Methods include user surveys and interviews as well as stakeholder interviews and expert assessment.

Expected benefits of IoT for automated driving

Most impacts of IoT on automated driving are expected to arise via improvements of vehicle operations, such as changes in car following behaviour, interaction with other vehicles and vulnerable road users (VRU), synchronisation of speed patterns, connectivity, enhanced situational picture and change in sustainability of driving. Some effects are expected also due to increased travel quality, such as comfort. An overview is provided in Figure 3. These factors of IoT affecting quality of life will be assessed and amended during the course of the project. Moreover, they can be used as descriptors in developing pathways and scenarios on how connected driving will improve personal mobility, the traffic system, and society in general. The proposed approach requires considering in the analysis objectively measured data (such as the mentioned aspects in the fields environment, vehicle characteristics, and driving behaviour) as well as subjective data, such as perceived comfort level.

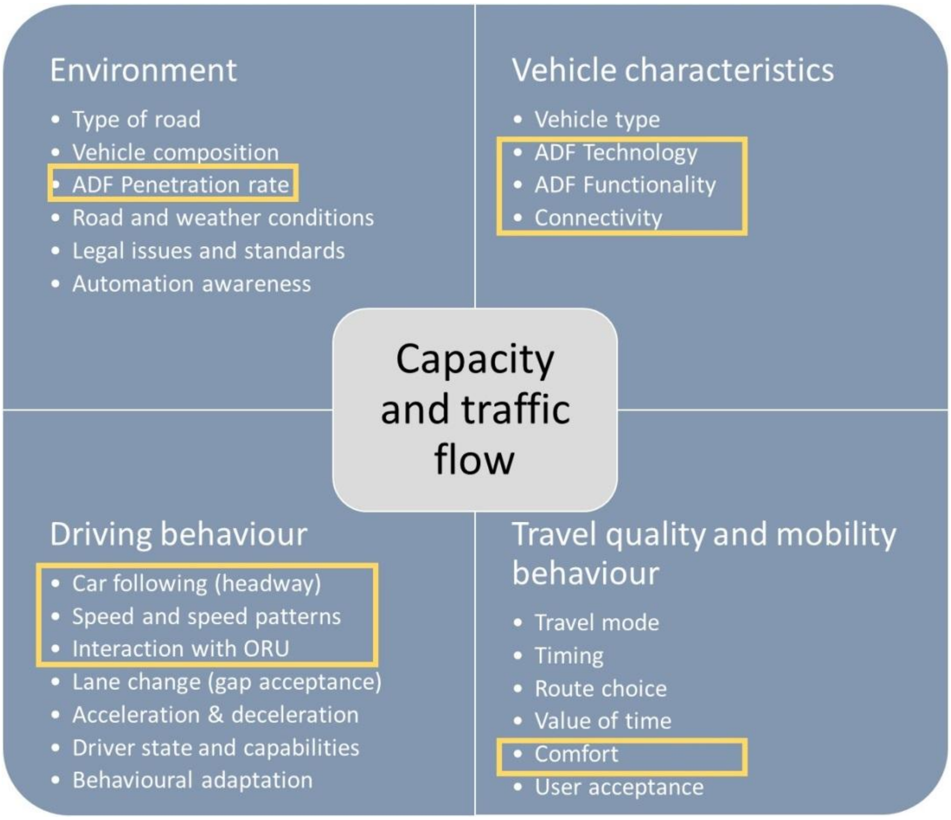

Figure 3 - Factors of automated driving affecting capacity and traffic flow (The areas where IoT is expected to play an important role are highlighted with yellow borders).

Scenarios of automated driving

Different scenarios of introducing automated driving on the market can be defined. Fraedrich et al. (2015) discuss three general transition pathways to fully automated driving – evolutionary further development of driver assistance mainly in private vehicles, revolution of personal mobility due to raising market share of mobility and vehicles on demand, and a transformation of personal mobility combining the advantages of personal mobility and public transport. The use of IoT might progress automated driving in all three scenarios. The use cases tested in AUTOPILOT refer to the first two scenarios – first, automation in future private vehicles, and second, enabling flexible car –and ridesharing concepts using IoT and automation. Hence, considering impact of automation in personal

mobility in the quality of life evaluation of the project, potential and challenges related to the implementation of the tested services in the context of private or shared fleet will be addressed.
Scenarios for automated driving are also being discussed in other projects, such as CARTRE (Coordination of Automated Road Transport Deployment for Europe). These available scenarios are used for reference and as a frame for the quality of life evaluation in AUTOPILOT. The link to other ongoing work by expert groups is helpful because of the complexity and uncertainties in the field of automated driving.

Methodology

Pilot tests

Effects on quality of life are mediated through changes in vehicle and travel behaviour that are induced by AD and IoT. These changes are studied in the pilot tests. Versatile data is collected through measurements from the vehicles as well as from potential users and stakeholders with questionnaires and interviews and/or focus groups. Impacts on quality of life are then estimated with well-structured expert assessment and simulation (where applicable) based on the data obtained.
Automated driving poses challenges to the execution of pilots: as we are dealing with experimental vehicles, there are limitations on where, when and by whom the vehicles are allowed to operate. In addition, the question of a baseline, i.e. what the automated driving in the pilot drives should be compared with, is difficult to solve. Thus, the study design needs to be flexible and allow for exploration and iteration during the project. When testing AV, in most cases it is mandatory to have a professional operator inside the vehicle for safety reasons. Nevertheless, all opportunities to collect valuable information such as user experiences and expert workshops will be used. Potential end users (general public) will be involved as passengers of the AV when it is possible and feasible. To complement, and to reach a wider audience, tests or surveys without user experience can be considered. In those tests, use cases will be introduced comprehensively using pictures or videos. The professionals operating the AV (safety drivers) will be involved in some parts of the assessment. In addition, the views and needs of other stakeholders, such as local authorities, tourist information services, service providers and parking operators are of importance.
As the potential impacts are numerous and wide reaching, and long-term trials are not possible in this pilot project, a scenario-based approach will be used. The new opportunities offered by the AUTOPILOT functions will be presented with examples, which are easy to relate to. Scenario building is a commonly used method to study new concepts and identify possible users and contexts of use for new products or services. There is a lot of interest in the media regarding automated driving, but the actual functionalities, which will be available to consumers at the initial phases, are not that familiar to the public. The advantages of this approach include making ideas more concrete to the users and describe complicated situations and behaviours in meaningful and accessible terms (Heinilä et al. 2005).
A simple and plausible system dynamics based model will be developed to (a) assess the factors and variables that influence the quality of life as a result of the AUTOPILOT functions becoming available, (b) test scenarios and (c) evaluate the effectiveness of policy measures. This model will help understand

the underlying structure of relationships producing the observed patterns, which can be obtained from many AD-related or FOT (field operational test) projects.

Research questions and hypotheses

Research questions and hypotheses were compiled both with a top-down approach, starting from the impact areas, and bottom-up approach, starting from the use cases to be tested. Compared with driver assistance systems (ADAS), the formulation of research questions for AD and IoT is more difficult because ADF are more complex and comprehensive. Thus, the research questions and hypotheses used for the evaluation in the project have a more explorative character.

As the impact of automated driving, and the role of IoT, is more far-reaching than that of ADAS, it is important to iterate between the two approaches, trying on the one hand to be as precise and detailed as possible, and on the other hand not losing sight of the wider impact automation may have. The analysis phase will show whether we will be able to succeed in this.

Ensemble of methods

The evaluation framework applied in the project is comprised of a broad ensemble of methods combining qualitative and quantitative as well as subjective and objective methods to address the multifaceted topic of quality of life. On the one hand, results and recommendations from expert working groups on the topic of automated and connected driving are used in developing and adjusting the evaluation framework. Moreover, local and national relevant stakeholders will be involved in the evaluation by participating in workshops or structured interviews. Potential users as well as a test user perspective will be explored using qualitative and quantitate surveys. In the following part of the paper, a brief introduction of the planned activities is given.

Stakeholder interviews to find out about the cities' needs and expectations

Addressing the impact of the implementation of the technology requires considering interests of different stakeholders involved in the development, testing and implementation of the project. The transition to advanced automated driving using IoT offers opportunities but also sets new challenges for the stakeholder involved in the development, testing and implementation process. Thus, specific needs, requirements and expectation of different stakeholder groups are addressed in the project conducting interviews with the relevant local and national stakeholders. Potential stakeholder groups, which will be involved in the evaluation process, include potential (end) users, service operators, city and municipality administration, telecommunication operators, vendors, transport and city planners, etc. The evaluation of the wider impact of autonomous driving progressed by IoT on society and quality of life will therefore provide systematically analysis of the potential of and challenges related to the implementation of the tested use cases.

Data sources

The quality of life evaluation combines subjective as well as objective data acquired from different sources. Subjective data will be collected from test drivers and passengers, while objective data will be measured from the automated vehicles. This includes for example speed patterns and headway. The objective data will be used to evaluate changes in efficiency of the transport system and emissions with traffic simulation software. The data collected from users is needed especially for impacts on mobility and wellbeing, while stakeholder views are useful for estimating societal effects.

User acceptance survey

The evaluation of quality of life is closely related also to the evaluation of user acceptance. User expectations, needs, requirements and concerns related to the technology are addressed in an online survey. The survey sample includes, as mentioned above, potential users who likely have little experience with automated and/or connected driving. Nevertheless, the online survey will, complementing the field test evaluation, provide valuable input on how the broader public perceive the potential benefits of the technology and which expectations and concerns they may have. The main focus of the survey is on user preferences and concerns, but also the impact of the use cases on personal mobility are studied. The survey addresses different scenarios using the same questionnaire structure to facilitate comparison of the results. The scenarios are introduced using short stories presented with text and pictures. After each part of the presented scenario, requirements and concerns related to the corresponding scenario part are addressed in closed questions. After introducing the whole scenario, participants are asked to evaluate the described service and indicate how the service might change their individual mobility behaviour if it was available.

Stakeholder events

To ensure involvement of relevant local stakeholders, dedicated events for introducing the use cases and discussing expectations and requirements of different stakeholder groups, will be conducted at each test site. These events can be used twofold – for dissemination purposes and for evaluation purposes. The challenge using the events for evaluation purposes is that the capabilities and potentials of the technology might be present for dissemination purposes in a way which don´t allow a critical discussion on potential benefits but also challenges and risks of implementing the technology on local level. Nevertheless, the events will open the opportunity to reach relevant local stakeholders and thus, these events are planned to form a part of the evaluation activities.

First results

At the time of writing, first results of stakeholder interviews and the user acceptance questionnaire are available. Stakeholders at two pilot sites have been interviewed about their expectations towards the project and the potential of the AUTOPILOT services. The main potential is seen in more efficient use of time and (parking) space as well as increased safety and fluency of traffic. The challenges named were related to robustness and reliability of the service technology, compatibility of different systems and organisation of the transition phase with both automated and manually driven vehicles.

The user acceptance survey for the first scenario, a service providing a ride in an automated vehicle in the gardens of Versailles in France, has been conducted and analysed. In total, 1600 respondents from eight countries participated in the survey. Results show that people across Europe seem positive towards the service and are interested in trying it. Two thirds of respondents state they would like to use the service when visiting Versailles. The automated vehicle seems to be more attractive than renting a car or using a tourist bus.

Next steps and expected outcome

The planning of the evaluation continues with detailed planning of the pilot test, including test protocols and questionnaires, in cooperation with the five pilot sites. User questionnaires are finalised and guidelines written for the execution of the pilot tests to ensure a harmonised approach across the project. The questionnaires include a common part used at all pilot sites to ensure cross-site evaluation as well as some pilot site and AD function specific questions to address the differences at the sites.

The outcome of this work will identify the impact of the IoT solutions on the quality of life of different travellers across Europe and on the society, and will offer guidelines and strategies for successful real-life deployment of the project’s IoT solutions to Europe and the world. By using the broad ensemble of methods combining qualitative and quantitative, objective and subjective data collection we aim to ensure that the social impact of automated driving with IoT is evaluated in a comprehensive way. The qualitative methodology will explore key success factors for improving quality of life with IoT and AD, while quantitative surveys and traffic simulations aim to quantify the impact. Links to past and ongoing projects and to expert networks on automated driving provide reference and support in the complex topic of automated driving and its potential impacts.

This conference contribution will present the first results of the quality of life evaluation in the project AUTOPILOT. Moreover, besides discussing first insights on the potential and challenges of connected driving for the society, it will also provide requirements on a methodology approach for evaluating the societal impact of technologies with different use cases and different geographical contexts.

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