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INNOVATIVE SOLUTIONS FOR SHARED E-TAXI SERVICES IN A GREEN AND EFFICIENT URBAN TRANSPORT SYSTEM

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Abstract

The aim of this article is to map the existing and potential solutions to achieve more innovative solutions for shared e-taxi services. As the role of mobility continues to grow, innovative means of transport need to be developed in order to reduce the number of private cars, while maximising safety. The authors collected the relevant national and European Union policies, incentives, strategies, and trends for shared electromobility. Such alternative solutions are going to be used through highly automated transport devices. Firstly, the currently available (e-) car-sharing systems and electric taxi services were compared based on different characteristics and features (efficiency, sustainability, costs etc.). One of the included examples was the TX electric taxi vehicle produced by the London Electric Vehicle Company (LEVC). Interviews with experts were conducted to determine initial experiences and to forecast the possible market share of e-taxis. The operational costs and CO2 emission savings as a comparison of traditional and electric taxis were calculated as part of this article. Beyond the present solutions, it is important to examine the options for the coming decades, as humanity will need to make a much greater effort than it has done so far to achieve transport-related plans and climate protection goals. In this context, the authors are looking at connected electric self-driving and the first stages of it. It can be assumed that with the spread of advanced self-driving technology the transport sector as well as other areas of life will change radically, and humanity needs to prepare for this global transformation. This change will bring new opportunities; the future of transportation will be about autonomous vehicles. The authors compile a systematic overview of such innovative technologies with complex effects to explore their opportunities and threats. Finally, the authors aim to provide a summary about the conditions for the use of innovative technologies in autonomous vehicles.

Keywords: autonomous vehicles, electromobility; shared e-taxis

1 Introduction

The common goal of people living in a city is to live in a liveable and pollution-free place, but current technology makes this impossible. The policy objectives and actions for sustainable mobility need to be strongly represented at EU level.
The unsustainable conditions resulting from traditional transport have been recognized by several developers, manufacturers and service providers, so that more and more innovative solutions are emerging that have some form of a positive effect on urban mobility. One of these alternatives is Shared (e-) Mobility, one of the most important sectors of the Sharing Economy, which has become an increasingly popular form of transportation today.

The structure and operation of this still new system, as well as its effects on certain areas of life, needs to be examined [1]. In addition to Shared Mobility, it is important to introduce the concept of electric/hybrid taxi services, as this form of passenger transport is playing an increasingly important role in transportation in large cities. An example to this trend is the new TX electric taxi by London Electric Vehicle Company (LEVC). The rise of electric propulsion entails various important developments that not only reduce negative environmental impacts but also lower the cost and improve the safety, and technical characteristics of vehicles. As such, this article aims to study the levels of self-driving already have in series production today, as well as the systems that can be expected in the future, which will allow full self-driving with the greatest possible safety. This initiative raises several issues to be clarified at environmental, technical, social, and legal levels, as intelligent functions and self-driving will also significantly change the current situation of passenger transport [2].

2 Strategic background

The authors collected the relevant European Union policies, incentives, strategies, and trends for shared electromobility. Sustainable means of transport and innovative solutions play a major role in EU energy and climate policy decisions. The main objectives of the transport policy are to reduce the amount of greenhouse gasses and the burden on the environment, to reduce dependence on conventional fuels, to support e-mobility and to improve the quality of life by improving transport safety and increasing the competitiveness of EU areas in a sustainable way [3]. In 2011, the European Commission drew up a White Paper as a roadmap for achieving unified, sustainable European mobility. In addition to the unification of transport and infrastructural expansions, attention has been focused on reducing emissions from transport, on a greener transformation of conventional car production, and on changing the current oil-based energy coverage. The main goal of the draft is to achieve a 60 percent reduction in emissions by 2050 in addition to the development of transport [4].
The World Health Organization (WHO), which is in line with EU policy, is urging further solutions to noise pollution, but data on noise exposure is still scarce in some countries, making identifying and developing noise reduction plans difficult. Nevertheless, most EU Member States have already taken the first steps towards noise-free transport. These include low-noise asphalt pavement, the development of quieter tires, the expansion of electric car infrastructure, and the installation of urban green spaces. Although the introduction of a congestion charge and the construction of a Low Emission Zone (LEZ) system is costly, it is efficient in reducing urban pollution and traffic, especially in cities where local problems prevent more serious interventions (e.g., construction of new bypasses, overpasses, underpasses, roundabouts). [5] These initiatives also prove useful for air pollution and highlight the value of developing a complex strategy on pollution and addressing it with a coherent plan that includes technological developments, a strong environmental policy and public awareness raising [6].
The promotion of e-mobility has become much more important in the current EU transport development policy. The policy points out that the development of technology and infrastructure for some alternative means (electric / hybrid vehicles) is essential and emphasizes the importance of using renewable energy sources and conventional technologies as one of the most important aspects of transport is energy use [7]. In addition to the inevitable increase in transport, it is necessary to ensure that an increasing proportion of the user society chooses environmentally friendly electric / hybrid vehicles, which must be implemented primarily at Member State level. As one of the most significant events in the early history of electromobility, in 2014 the European Parliament and the Council enacted the Alternative Fuels Infrastructure (AFI) Directive, which required all Member States to develop a strategy for alternative fuels and alternative propulsion vehicles [7].

3 Sustainable taxi services

3.1 Technical development of electric taxi vehicles

Thousands of taxis can be seen in the centres of Europe's major cities. It is important to spread sustainable taxis because, unlike cars, taxis travel around the city all day, which results in a multiplication of the harmful effects of average car driving in the busiest downtown areas. The service providers' fleets have to consist of modern and environmentally friendly vehicles. It is not easy to comply with the increasingly stringent EU regulations, so the state is supporting service providers with the electric taxi tenders. The regulations clearly set out the requirements for the technical parameters of taxis. For example, in Budapest only vehicles with an environmental rating of at least EURO5 and a maximum age of 10 years can operate as taxis. As age influences the environmental impacts of vehicles, restrictions of vehicle-age can be an effective way to keep impacts at bay [8].
Many manufacturers have begun to develop electric vehicles specifically designed for the sustainability of taxiing. As an example, the authors of this article present the London Black E-Cab TX, manufactured by the London Electric Vehicle Company, which is gaining popularity and legitimacy due to ever-tightening regulations, and subsidies to support electromobility. The new electric London taxi, the LEVC TX is a passenger vehicle that effectively combines the features of traditional and innovative transport [9]. This has been available in Hungary since 2020, see Figure 1.

Figure 1 The first LEVC TX in Hungary, source: own photo

3.2 Comparison of diesel and electric taxis

The manufacturer emphasizes the cost-effectiveness and environmental friendliness of the TX compared to conventional vehicles. It also tries to illustrate this with the calculator on its website. The calculator allows for differentiation of costs and CO2 emissions on a daily, weekly, monthly and annual basis compared to conventional diesel cars. For the comparison vehicles with the same function have been chosen, thus the differences between the new electric TX, the 7-passenger Peugeot minibus, and the traditional London TX4 Black Cab have been analysed in terms of cost and emissions, see Table 1.

Table 1 Comparison of diesel and electric 7-passenger passenger taxis used under average passenger transport conditions in terms of cost and emissions (200 km per day, 1,23 € / l diesel price, 5 working days per week, 10 years) own table and calculation using data from www.levc.com [10]

Car type	Price [€]	CO_2 emission in operation [g/km]	CO2 emission (in 10 years)	Fuel cost [€/month]	All Costs [€/km]
Peugeot E7 2.0 diesel	31.851	199 g/km	95 520 kg	approx. 504 € (10 l/100 km)	~ 0,064 €
TX4 2.5 diesel (2019)	64.516	222 g/km	106 560 kg	approx. 742 € (15 l/100 km)	~ 0,13 €
Electric TX	81.334	29 g/km (without range extender: 0 g/km)	13 920 kg (without range extender: 0 g)	approx. 232 € (5 l/100 km) (without range extender: ~0 EUR)	~ 0,17 €

A 10-year long evaluation period has been chosen based on the passenger transport regulations in Budapest, as vehicles older than this can no longer operate as taxis. The total cost per kilometre includes the purchase price, operation (taxes, insurance) and average servicing (replacement of wearing parts) over 10 years, i.e. 480,000 km. It is important to note that the table does not show the drastic decline in the value of diesel cars over time, the growing CO_2 emissions, the fluctuation (rise) in the price of diesel, the subsidy for electric cars, the tax breaks and the reduction in range due to battery degradation [9, 10]. Without using of range extender (a low performance internal combustion engine) the CO_2 emissions and the fuel cost are nearly zero.
As can be seen in the table, a significant reduction in CO_2 emissions can be achieved by using an electric TX, which for a conscious driver can be as low as nearly 0 g/km (if the range extender is not used). However, even using this small engine, the beforementioned electric TX only produces 13-15 % of the emissions of the two traditional vehicles. To give a sense of the weight to this figure, it is important to explain the results in another way. Using the electric TX (even with the range extender) can achieve the same improvement (in local CO_2 emissions) as if there were about 85 % fewer regular taxis on the streets of cities. In addition, noise pollution levels would also be significantly reduced, which could clearly improve the quality of urban life and reduce environmental impacts [9, 10].

3.3 Interviews with experts

Interviews with experts were conducted to determine related initial experiences and to forecast the possible market share of e-taxis. György Derzsy, the leading salesman of the Gablini salon and Bence Kovács, vehicle test engineer at Bosch, see business potential in TX, and think that car-sharing systems are very popular. According to them, both carsharing systems and new services have a place in a 21st century big city, so they'll complement each other. While taxis are available to everyone, car-sharing solutions are only possible under certain conditions, however these services will be more of a serious opponent of public transport. They noted that the new TX is an extremely divisive vehicle. Anyone who has tested or seen it so far has expressed a definite positive / negative opinion about it. This car has the potential to build a cultural attitude that will set it apart from traditional taxis and lure many people into taxiing. The main consideration will be to increase and improve the performance of the electric motor and battery. From 2023 onward, only fully electric vehicles will be produced, and as such, the current serial e-hybrid system will be replaced. A TX Shuttle model will also be produced, modelled after the TX, which will be designed specifically for longer distances (e.g. airport transfer). In addition, significant price reductions can be expected due to cheaper battery technology and the expansion of production lines.

4 Taxiing the future: driverless taxis

4.1 SWOT analysis

Beyond the present solutions, it is important to examine the options for the coming decades, as humanity will need to make a much greater effort than it has done so far to achieve transport-related plans and climate protection goals. In this context, the authors are looking at connected electric self-driving and the first stages of it. However, with the spread of advanced self-driving technology, the transport sector as well as other areas of life will change radically, and humanity needs to prepare for this global transformation. This change will bring new opportunities; the future of transport will be about autonomous vehicles, [11].
A systematic overview was compiled of these innovative technologies with complex effects to explore their opportunities and threats, with the SWOT analysis chosen to evaluate and classify the features. The authors of this article believe that future self-driving cars, car-sharing and taxis will be transformed into a mode of transport, and as such the commonalities will be shown in Table 2.

Table 2 SWOT analysis of self-driving electric cars (robotic taxis)

	Electric cars	**Autonomous driving**
Strength	Missing emissions (at use) Cost and energy efficiency Less complex technology with fewer components [14] Maximum compliance with the most stringent regulations and restrictions Positive image in society Noiseless, dynamic running characteristics Modern, spacious passenger compartment [9]	Significantly increased road safety High occupancy rates [1, 16] Time efficiency (no searching for parking spaces, congestion, etc.) [16] Increase of open urban spaces (parking spaces, lanes) New services and economic opportunities [2] Personalised taxation and fee systems Wide range of users [11] Favourable fares
Weakness	Time and cost-intensiveness of building the proper infrastructure Sustainability of battery technology [12] Sustainability of electric vehicle production (building new factories, new equipment) [12] Tackling the charging of electric self-driving vehicles, developing electrical infrastructure Increased raw material needs for manufacturing [12] Difficulty of end-of-life vehicle recycling [12] Long term return of initial investments (e.g. vehicle procurement, infrastructure development)	Initial technological and infrastructure problems [13] Affordable mass production Setting up clear legal and regulatory policies Social crises arising from workforce transformation (taxi drivers, bus drivers, parcel delivery, chauffeur services, etc.) [14, 16] Extensive data requirements to start the test phase Standardising difficulties in infrastructure deployment due to regional differences, difficulty to adopt good practices Possible software failures Ethic and legal problems due to responsibility for accidents
Opportunities	Expanding projects and investments of related initiatives Stricter road standards on emissions and safety Transferring of electric self-driving technology to freight transport and public transport [10] Increased production due to automated production [14] Younger generation's commitment to technology	
Threats	Changing social habits and unstable trust in technology (in case of system failures) [16] Overuse of technology, potential privacy abuses [1] Increasing supply of raw materials [12] Lobbying by the traditional car industry and insurers to block related solutions Expected legal restrictions on self-driving (strict EU regulations)	

With the help of the SWOT analysis, it has become clear that the spread of self-management will be affected in almost all areas of life, so this should be treated as a complex topic. Self-driving, which can also be called the taxiing of the future, will wash together the various modes of passenger transport and can also help to develop new means of transport. However, in addition to adopting the new technology, it is important to consider the affected industries, entrepreneurs, and employees as well.

4.2 Conditions for the use of autonomous vehicles

A summary about the conditions for the use of innovative technologies in autonomous vehicles can be provided based on the SWOT analysis delineated above.

One of the biggest disadvantages of conventional taxiing is the high fees, so one of the main criteria for sustainable transport (affordable price) cannot be met, as some sections of society are excluded from use. Although the proliferation of electric taxis has improved, it is still a costly service. This can be explained by the fact that the high price is not only derived from the price of fuel and the use of the vehicle, but also the presence of the taxi driver. In the case of self-driving vehicles, such a cost no longer needs to be taken into account, and as such a significant reduction in passenger fares is expected.

Relating to the current battery technology, it is important to mention the production of electric vehicles. Existing vehicle-factories are not always compatible with the production of electric cars, as the later are made with completely new platforms and technical structures, so new factories and production lines have to be built / reformed. This consumes a large amount of area and raw materials, which further increases the environmental loads, [11, 12].

One of the weaknesses concerning autonomous vehicles is the possibility of ethic and legal problems. Members of the autonomous vehicle industry should solve the problems due to responsibility for accidents. In recent years several well-known accidents happened that highlight the significance of higher risks of such vehicles and the responsibility of the users was clearly demonstrated. Regulations focus on the technological requirements, while the ethic aspects are not completely emphasized.

A completely new technology with an internet-based software background will emerge from the initial technological and infrastructural problems. Many examples of vulnerabilities in Internet networks have already been observed in other sectors, so, especially in the initial period, various problems can be expected in this sector as well. As these problems threaten the entire transport system, possible network failures / external digital attacks can have grave consequences.

Freight transport is also a major problem not only in terms of emissions but also in terms of road safety. During journeys of hundreds / thousands of kilometres, the chances of human errors increase, making transport even more dangerous. In this case, self-driving would increase not only safety, but also performance, as there would be no need for mandatory rest periods.

The need for transformation in the automotive industry is inevitable. Self-driving will put entirely new manufacturers and developers at the forefront of the industry, leading to the weakening of traditional market players. Automotive companies that will not be able to adapt will seek to mitigate and delay this transformation.

5 Conclusions

As the role of mobility continues to grow, innovative means of transport need to be developed in order to reduce the number of private cars, while maximising safety. Sustainable means of transport and innovative solutions play a major role in EU energy and climate policy decisions through supporting e-mobility and improving the overall quality of life.

Alternative solutions should be used in taxi services, one of the examples being the TX electric taxi vehicle produced by the London Electric Vehicle Company (LEVC). The operational costs and CO_2 emission savings were calculated as a comparison between traditional and electric taxis to identify the different characteristics and features (efficiency, sustainability, costs etc.).
Interviews with experts were conducted to determine the initial experiences and to forecast the possible market share of e-taxis. Based on their opinions, the authors of this article came to the conclusion that the main consideration would be to increase and improve the performance of the electric motor and battery, as well as to reduce costs in order to achieve a higher market share.
Beyond the present solutions, it is important to examine the options for the coming decades, as humanity will need to make much greater effort than it has done so far to achieve transport-related plans and climate protection goals. In this context, it is important to look at connected electric self-driving and the first stages of it. A systematic overview was compiled of these innovative technologies with complex effects to explore their opportunities and threats.
The SWOT analysis has provided a summary about the conditions for the use of the innovative technologies in autonomous vehicles. The main aspects are the follows: high fees, sustainability of electric vehicle production, emergence of initial technological and infrastructural problems, application in freight transport and the need for transformation in the automotive industry.
Based on the above outlined data, the authors state that the spread of advanced self-driving technology will cause significant changes and that humanity needs to prepare for this global transformation. This change will bring new opportunities; the future of transport will be about autonomous vehicles.

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