Understanding Connected and Autonomous Vehicles: An Analysis of Expert Predictions about Their True Potential

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EXTENDED ABSTRACT

1. Introduction

Connected and autonomous vehicles (CAVs) have the potential to become the most powerful mobility intervention in the history of mankind; possibly greater than the conception of the wheel itself or the shift from horse-carriages to automobiles. Empowering robotic technology to take control of the car, making calculated decisions and interrelating in real-time with the road traffic environment to heights unprecedented for humans, constitutes a decisive step towards transitioning to a new Artificial Intelligence-led transport paradigm. Despite a wide spectrum of potential traffic safety, economic, environmental, social inclusion, road space allocation and network performance benefits (many of them recorded by Fagnant and Kockelman, 2015; Nikitas, 2015; Nikitas and Nikitas, 2015; Thomopoulos and Givoni, 2015; Clark et al., 2016; Milakis et al., 2017; Nikitas et al., 2017a; Nikitas et al., 2017b) that make CAVs potentially an inescapable future direction for transport provision, the road to a mobility paradigm shift is not necessarily an easy one.

As a matter of fact this paper argues that CAVs' full-scale implementation, may not be as 'predictable', 'uncomplicated', 'unproblematic', 'acceptable' and 'risk-free' as it is perceived by the automotive industry, many policy-makers on national and local level, a share of the general public and some of the existing technical and academic literature. Framing an 'unproven', 'disruptive' and 'transformative' intervention, primarily based on its competitive advantages over today's conventional automobile technologies, may create misconceptions, overreaching expectations and room for errors that societies may need to be cautious about.

The present paper has a visionary and positioning character; it means to challenge part of the conventional wisdom and develop a number of questions that need to be answered from those responsible for delivering this monumental change in transport provision. More specifically, it aims to identify and closely examine some of the impacts that could be generated by the full-scale introduction of these technologies and access some critical barriers that need to be addressed before CAVs become a truly viable option.

2. Methodology

The research methodology has a qualitative character to match the study's socio-technical focus. It is primarily based on the analysis of a series of in-depth semi-structured interviews with transport scholars from across the globe (all continents were represented in the sample) that have conducted relevant research studies or have a commanding understanding of the field. A literature review is supporting this primary data analysis to allow the generalisation

of some of the key findings to wider context as a means of creating: i) a 'road map' setting out the challenges that need to be surpassed and ii) a data-driven (and simultaneously theory-informed) taxonomy of the possible key impacts of car automation.

The interviews involved discussions meaning to identify and systematically hierarchise the likely positive and negative effects of a mobility future dictated by vehicle automation and to refine the understanding of how people will adapt to this monumental shift. Although these discussions included several references to semi-automated technologies they primarily addressed future visions of completely driverless and interconnected city-wide vehicle systems. The interviews considered the timeline of technology development (meaning to identify the point where this reaches a standard of maturity that will allow the transition to be viable in socio-economic and geo-political terms) and tried to foresee the process of the eventual uptake of CAVs as the mainstream vehicle technology and the business models that will be adopted (private usage vs Mobility-as-a-Service usage). The interviews were also designed to test some of the myths referring to CAVs with an emphasis on exploring some of the potentially darker or ambiguous sides of driverless technologies.

Theory-driven thematic analysis was employed for analysing the rich data collected. This type of analysis has been poorly demarcated generally and its use has been rarely acknowledged, but it is a widely used and effective qualitative analytic method (Boyatzis, 1998). The method chosen was in line with Braun and Clarke's (2006) widely adopted six-step process that includes:

i) familiarising with the data through transcription;
ii) generating initial codes;
iii)searching for themes;
iv)reviewing themes;
v) defining and naming themes; and
vi)producing the final written output.

This abstract submission because of its brief nature is not focusing on the use of raw extracts from the transcribed discussions *per se* but instead provides a synopsis of the main findings.

3. Key Results

There are three sets of results with which this study is contributing in a rapidly expanding literature on CAVS; results recognising the positive outputs of the transition, results describing the potentially negative effects of the transition and results highlighting the challenges that policy-makers, city planners, automotive designers, traffic engineers and manufacturers need to address before CAVS could be fully launched.

This work identifies some of the potential benefits that may be associated with the introduction of CAVs in a wide scale according to the perceptions of the interviewed experts. These beneficial outcomes, which are suggested under the premise that the transition to an A.I.-dictated transport regime will not create unforeseen problems, will be universally applied and governed by a new robust set of traffic regulations, include:

i) enhanced traffic safety meaning fewer traffic accidents, injuries and deaths;
ii) improved personal and community security;
iii) reduced traffic congestion due to more efficient road space allocation;
iv) more homogenous and effective mobility management including parking;
v) less travel delays and thus substantial time savings;
vi) increased in-vehicle productivity for CAVs occupants;

vii) less environmental degradation primarily in terms of air-pollution;
viii) reduced noise nuisance;
ix) decreased energy consumption and fossil-fuel reliance;
x) enormous car-sharing and demand-responsive public transport potential;
xi) fewer layers of social exclusion since more people will have access to 'driving';
xii) smaller enforcing, policing, insurance premiums and road signage requirements and;
xiii) smoother rides and more relaxed travelling.

Despite, these significant opportunities and the fact that CAVs may be acceptable for many drivers today (Payre et al., 2014), such an unprecedented mobility paradigm shift is naturally associated with immense levels of complexity and uncertainty. This is because, despite some initial encouraging technical results, there is a broad spectrum of challenges, social dilemmas and complex human factors issues that may arise from such an 'untested' and 'powerful' intervention that have not yet been addressed. Although in general not recognised as much as their potential benefits, CAVs could potentially be associated with numerous effects that could trouble urban societies. These could include:

i) loss of driving skills and situational awareness;
ii) user resistance to surrendering driving control;
iii)'behaviour adaptation' problems;
iv) mistrust for new technologies and agencies responsible for running CAVs;
v) privacy issues and loss of personal space;
vi) loss of feelings like 'freedom' and 'joy' typically associated with driving;
vii) likely loss of 'private vehicle ownership' rights;
viii) increased vulnerability to software and hardware flaws and cybersecurity threats;
ix) liability problems for accidents and damage issues;
x) need for a new road transport legislation framework and traffic code;
xi) loss of millions driving-based jobs;
xii) susceptibility of the car's navigation system to adverse weather conditions;
xiii) integration limitations with the non-automated part of the transport network;
xiv) overspending for necessary road infrastructure investments;
xv) social exclusion problems if CAVs become high-end products;
xvi) increased traffic congestion - more trips from a bigger pool of potential users;
xvii) demand for alternative road policing and enforcement approaches.

Finally the work identifies and discusses some of the existing barriers that are likely to impede the transition to CAVs and are still sometimes, despite their critical importance, neglected or understated:

i) Technology is still lacking. CAVs need to develop the capacity that will allow them to detect and anticipate impeding objects' behaviour even under the most complex and unexpected circumstances (Nikitas et al., 2017b).
ii) Legislation needs to be radically changed; this will not be a simple and quick fix despite a general eagerness to speed things up.
iii) Although recent studies showed that *a priori* acceptability of CAVs could be likely for many drivers today (e.g. Piao et al., 2016) the universal acceptance of such a transition is not guaranteed or certain (Schoettle and Sivak, 2014). Users might need to be convinced.
iv) CAVs should operate responsibly and replicate or do better than the human decision-making process; this is not yet achieved.
v) Some decisions are more than just a mechanical application of traffic laws and plotting a safe path (Lin, 2016). Ethical and moral issues are yet to be answered

adequately; what is the right option when CAVs might need to choose between two extremely unfortunate accident scenarios?

vi) The passive human role when 'driving' CAVs may not allow users to develop a suitable mental model of the situation that is indispensable for the recovery of system failure (Breton and Bossé, 2003) and may also lead to disengagement and discontent (Carr, 2015).

vii) CAVs need a different, very costly, transport infrastructure that will provide them with an environment fit for their use.

viii) Mixed traffic situations, where CAVs share road space with partially automated, conventional man-driven vehicles and non-motorised traffic could create serious problems and potential accident hazards. There needs to be a strategy designed to manage this co-existence.

ix) There is a risk of creating a two- or even a three-speed world; progress in delivering sufficient CAV technology may come at different rates and times for different continents, countries and cities. This will create imbalance and disharmony when transport's ultimate goal is about ensuring integration and interoperability.

x) Business models for supporting the CAVs adoption process are not clear yet; can this technology be part of the MaaS agenda and how?

4. Conclusions and Recommendations

This study's intention was to help informing the society and those responsible for putting together this mobility paradigm shift about the scale and diversity of the impacts that could be generated by the full-scale launch of CAVs. The study also tried to shed light to unresolved issues that need to be addressed before any such transition takes place. According to our analysis the shift to CAVs will require time, patience, flexibility, political persistence and continuous investment similarly to what it was discussed in Nikitas et al (2017b). The road to shifting mobility paradigms could be significantly longer, more uphill and less barrier-free than many nowadays forecast. Many trials will go wrong before agencies responsible for making CAVs the dominant vehicle technology get everything right. There will also be unforeseen problems, failures or even wide-scale accidents that could potentially create extra layers of resistance and stagnation. It should be clear that CAVs is not a panacea but rather a significant new piece of a far more complex and multi-dimensional mobility puzzle. Also similarly to what was concluded in Sochor and Nikitas (2016) '*technology is only one of the several tools in the toolbox of mobility'*. Efforts should be directed beyond enhancing technology development *per se*; investors need to focus with similar tenacity to supportive instruments and institutions like traffic regulations, mobility education, marketing campaigns that enhance acceptability and adoption. Potential distributional impacts should be also closely monitored and controlled so everybody enjoys the benefits of CAVs; CAVs should be an inclusive technology and not an inaccessible one.

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