Envisioning the futures of mobility and the emergence of a Connected, Coordinated and Automated Road Transport

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Abstract

"We are on the cusp of one of the fastest, deepest, most consequential disruptions of transportation in history" [1]

Roads across the world will shortly become populated with vehicles that are able to drive autonomously and communicate with their surroundings, totally transforming the way in which we currently move from one place to another. Significant advances have already been made in the past: from the emergence of the first affordable vehicles in the early 1900s, to the development of passive and active safety technologies in the 70s, and the advent of Intelligent Transport Systems (ITS) and driver assistance technologies since the 80s, which together are supporting the optimization of road transport. Advances in the field of Artificial Intelligence (AI), on which autonomous vehicles heavily rely, are developing steadily at present and will bring extensive changes to our mobility and transport systems, revolutionising all aspects of our society and life. The impacts of such a revolution on road transport can be far-reaching, from drastically reducing road accidents to allowing efficient traffic flows and driving road transport emissions down. According to some authors, the forthcoming technologies and impacts of the AI revolution will probably be significantly greater than those of the digital and even industrial revolutions [2]. Uncertainty in predicting those impacts remains high though, especially given the intrinsic complexity of the road transport system. It is unclear how Connected and Automated Vehicles (CAVs), mixed with conventional legacy vehicles, will behave in real traffic. Their promising impacts in energy/fuel efficiency could be partially outweighed by higher travelling speeds [3], or in the case that these technologies will stimulate more travel as a result of safer, cheaper and more comfortable and productive driving conditions (e.g. [4],[5]). Besides, many of the expected benefits associated to CAVs would most probably not materialise until they constitute a significant part of road travelling, which can take a time which is difficult to be predicted.

Parallel to the development of these technologies, a paradigm change in mobility use is already on the way, with a growing use of shared mobility and Mobility-as-a-Service (MaaS) travel options. MaaS (or TaaS), represents a shift away from personally owned modes of transport towards on demand pay-per-use mobility solutions. It seamlessly combines transport options from different providers, handling everything from travel planning to payments ([6]). Societal, economical and technological drivers are accelerating the MaaS disruption. Urbanisation, climate change, the sharing economy, big data or the need to better match demand and supply are some examples of MaaS enablers ([7]). But it's only with fully connected and automated (and possibly also electric) vehicles that MaaS can express all its potential being able to contribute disrupting mobility ([1]). The widespread of personal mobility also in cases where parking is costly and challenging is motivated by high value given by people to the reliability of and the accessibility to the transport service rather than just to its cost-effectiveness. The certainty of a vehicle available coming to pick you up when requested is crucial for any substantial change in the mobility patterns to happen. At this point however it is easy to argue that the demand for personal mobility (although consumed as a service) will be even higher than what we have today and it's important to start understanding how the future road transport system will be able to accommodate such an increase.

Objective of the paper is to analyse how the possible oncoming technological and business models disruptions and the potential associated travel behavioural shifts could affect the road transport and mobility system in the next 10-30 years, which challenges may exist at a traffic management level and possible needs for new approaches to traffic control. In particular some illustrative scenarios of the possible paths to the future road mobility are drawn up taking as a basis the scenario-axes technique. The purpose of this illustrative exercise is not to predict the future mobility but to provide some alternatives that encourage thoughtful thinking and stimulate anticipatory action already at present. The result of this phase is summarized in Figure 1. Four main scenarios are identified based on the deployment of automation and shared mobility.

Where technology will not be able to increase the capacity of the road transportation system and will mainly provide a better driving experience to its users, a significant deterioration of traffic conditions could be expected.

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Political pressure will be on the transport externalities (e.g. energy consumption and the related pollution, travel time, etc.). Demand management strategies need to be introduced and a possible higher level of coordination will be required. The concept of Connected, Coordinated and Automated Road Transport (C2ART) is introduced, in which the traffic management system of a region is able to regulate from vehicle operations to the access to the system.

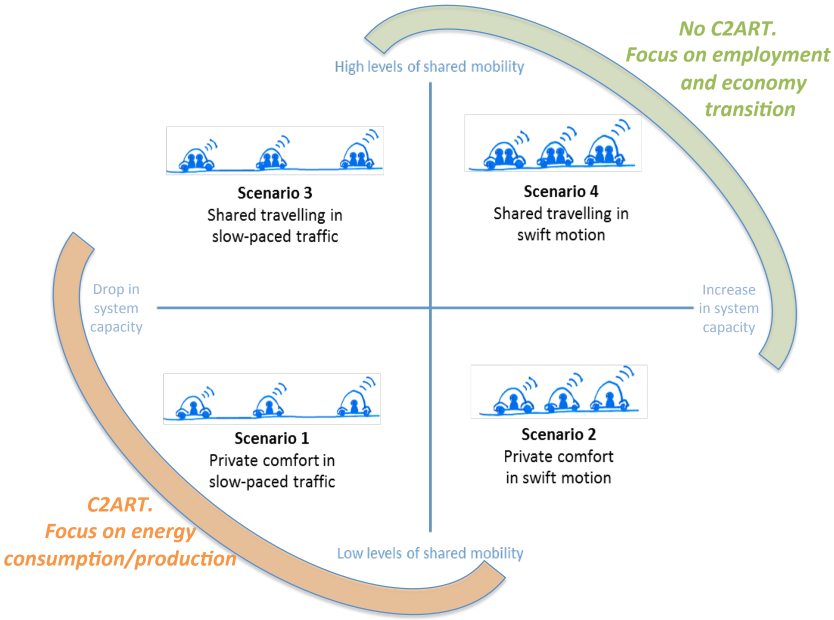

Figure 1. Four future mobility scenarios

On the contrary, where technology will be able alone to increase the capacity of the road transportation system and vehicles will be mainly used as shared means of transport, any increase in traffic demand will be absorbed by the system. The space made available by the no-longer necessary parking areas will make road transport efficient. No need for traffic coordination at a central level will be necessary. Focus will however on the societal implications of the transformation and how to deal with the possible change in the skill/employment structure.

Once the different scenarios are outlined, the remainder of the paper focuses on the C2ART concept and different enhanced traffic management approaches are defined and tested by means of traffic simulation to understand the possible increase in the transport system capacity (if any) made possible by a higher level of coordination. Both toy networks and realistic traffic scenarios are used to this aim. The concepts of individual optimum vs. system optimum, and of free access vs. controlled access to the transport system will be explored and applied to the different test cases to understand their potential application in a future C2ART system. In the scientific literature, achieving a system optimum traffic assignment is a very intensively investigated problem ([8]). In particular, the study analyses a classical marginal cost-based way to achieve system optimum flow distribution on the network, which can use different models and optimization principles. In addition, a breakdown probability minimization principle in terms of 3-phase traffic theory is also considered as a possible way to increase network efficiency [(9]). Finally, an approach based on the optimization of flow distribution in time is also considered ([10,11,12]). The main goal of this optimisation is a prevention of "capacity drop" phenomenon and losses in network productivity. General approach implies taking into account departure time as an optimization parameter. With wide implementation of connectivity (V2I, V2V) more advanced approaches may becomes feasible such as a time-slot reservation principle and a "traffic flow formation management" approach ([13]).

Results highlight the significant potential of enhanced traffic management schemes and the necessity to use them both in order to keep the level of service of the road infrastructure at an acceptable level and to limit the shift from mass transit to personal mobility that the new technologies may generate. In this light, the concept of traffic management system should evolve towards a mobility management system in which all means of transport are integrated in a seamless way in order to provide the user with the best option to satisfy his mobility needs.

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