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Policy challenges of increasing automation in driving

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ABSTRACT

The convergence of information and communication technologies (ICT) with automotive technologies has already resulted in automation features in road vehicles and this trend is expected to continue in the future owing to consumer demand, dropping costs of components, and improved reliability. While the automation features that have taken place so far are mainly in the form of information and driver warning technologies (classified as level I pre-2010), future developments in the medium term (level II 2010–2025) are expected to exhibit connected cognitive vehicle features and encompass increasing degree of automation in the form of advanced driver assistance systems. Although autonomous vehicles have been developed for research purposes and are being tested in controlled driving missions, the autonomous driving case is only a long term (level III 2025+) scenario. This paper contributes knowledge on technological forecasts regarding automation, policy challenges for each level of technology development and application context, and the essential instrument of cost-effectiveness for policy analysis which enables policy decisions on the automation systems to be assessed in a consistent and balanced manner. The cost of a system per vehicle is viewed against its effectiveness in meeting policy objectives of improving safety, efficiency, mobility, convenience and reducing environmental effects. Example applications are provided that illustrate the contribution of the methodology in providing information for supporting policy decisions. Given the uncertainties in system costs as well as effectiveness, the tool for assessing policies for future generation features probabilistic and utility-theoretic analysis capability. The policy issues defined and the assessment framework enable the resolution of policy challenges while allowing worthy innovative automation in driving to enhance future road transportation.

1. Introduction

In recent years, rapid developments in automotive technology have placed public policy in the catch-up mode [4,13,44]. Advances in information and communication technology (ICT) have enabled the profession to go beyond the original intent of the intelligent vehicle and highway system (IVHS) initiative of many decades ago and now we are in the era of developing technology for connected cognitive vehicles. Further, experimental autonomous vehicle technology has recently been tested successfully. The development and the scenario of wide-spread applications of increasingly automated vehicles in public road networks pose policy challenges. Although an economically viable autonomous vehicle is not likely to be in the market for many years, autonomous driving as a public policy issue has already emerged. The State of Nevada (USA) has passed a new bill (A.B.511) that directs the Nevada Department of Transportation to allow autonomous vehicle testing in certain geographic areas of Nevada [21].

Among policies for future generation, a framework is needed for assessing automated systems and guiding the progress of promising automation in driving for the benefit of road users, the economy and society at large. For example, among other policy issues, public agencies have to establish the process and method for assessing new systems that generally have multiple and uncertain effects. Also, public agencies need to know how their mandate to plan and operate road network is likely to change should these new systems be accepted in the mass market [13].

This paper defines three levels of technological advances, and presents a policy framework for meeting the challenges of automation and an associated method for quantifying the cost-effectiveness of new systems in support of policy decisions.

2. Level of technological advances

2.1. Nomenclature and key definitions

Over the years, the vision of the *intelligent vehicle* became increasingly ambitious. An intelligent vehicle in its advanced form should have cognitive features that mimic non-distracted and non-aggressive driving tasks. A *cognitive vehicle* is intended to assist the

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driver, and if necessary in dangerous conditions, it has the capability to take corrective active safety action if the driver is incapacitated or highly distracted or if the driver wishes the vehicle to take over driving for a limited duration of time. However, driving an intelligent cognitive vehicle does not take the driver out of the loop [9,12,26]. The design attributes of a cognitive vehicle are influenced by human factors in driving [5]. An *autonomous vehicle* is self-reliant and fully automated, and it is designed to make mission-critical driving decisions. Autonomous driving in a real life traffic network takes the driver out of the loop [4,31] and the driver will be free to engage in non-driving tasks from the start to the end of the trip. Some highly speculative descriptions of autonomous driving claim that the driver need not be in the driver seat [4,25]. However, in the technical literature, there is no mention of who has the ultimate authority to take corrective action in case of vehicle or system failure.

It is useful to further clarify the definition of automated driving and autonomous driving. In automated driving, driving tasks are automated for specific operational tasks. Examples include automated stability control, automated reduction of speed and if necessary automated application of brakes, automated parking. In the case of autonomous driving, all driving tasks are automated for all operational tasks. This implies the use of autonomous vehicles with unlimited coverage [4].

2.2. Why automate driving tasks?

According to a World Health Organization study, if current trends continue, by 2020, annual fatalities due to vehicular accidents are projected to increase to 2.34 million. It is the leading cause of injury mortality [45]. Driver error is the primary cause of about 90% of reported crashes involving passenger vehicles, trucks, and busses [40]. Distracted driving is emerging as a major cause for concern. The implication is that if drivers can be assisted with affordable and reliable technology in avoiding errors or at least their harmful effects can be reduced, the society will gain net economic and other benefits.

Safety research suggests that common errors in driving result from lack of timely driver action or reactions to unpredictable events and incomplete information. These random external factors typically evolve into complex interactions that the driver without some assistance may not be prepared to handle. This is the reason for accepting a role for the machine provided that the driver perceives it to be reliable. We know for sure that human driver makes mistakes in the driving environment with its uncertainty attributes. What about the machine? The uncertainties also work against the machine. According to expert opinion, contemporary or even advanced machines in the foreseeable future cannot attain anywhere near the level of holistic human cognition [31].

The current generation of consumers is aware that machines can be designed to play a useful and economical role to assist humans. In spite of the attraction of driving a vehicle, consumers have accepted limited automation in road vehicles provided that it is not perceived as a source of nuisance [12,31]. To take it a step farther, according to those who believe that technology can be designed and taught to be reliable, the higher the level of automation, the better. This viewpoint leads to the position that fully autonomous driving will lead to almost zero collisions. However, the mainstream viewpoint is that it is prudent to demand high standards of reliability and favorable cost-effectiveness before deployment approval can be given for any level of automation [4,31].

2.3. Levels of technological advances and forecasts

Studies have been reported on progressive deployment of automation in road transportation. For example, see Refs. [35] and [36] on automated highway system. Advances in the performance of sensing, computing, and communication devices and their integration have resulted in a variety of driver assistance system that have passed the demonstration phase and some are appearing in new vehicles. These systems have limited automated driving capability and in this paper, these are considered as level I pre-2010 technology development (Fig. 1). The level II technological advances will feature a higher degree of artificial intelligence and due to design advances, these will be regarded as cognitive vehicles.

Although *autonomous research vehicles* are here already and automated highway tests have been carried out, according to expert opinion it will take much time to develop vehicles with autonomous driving capability for use in real world complex traffic networks [4,31]. Therefore, autonomous vehicles and autonomous driving are regarded as level III (2025+) of technological development (Fig. 1).

2.3.1. Level I pre 2010

Since the emergence of the *intelligent vehicle and highway system* (IVHS) field a few decades ago, considerable progress has been made in all aspects of *intelligent transportation systems (ITS)*, including services [28]. On-going advances in information and communication technologies continue to find applications in vehicle design, in-vehicle infotainment/information systems, and an increasing number of ITS services.

The level I systems are mainly for providing information, guiding drivers, and in some cases warning drivers about potentially dangerous conditions (Fig. 2). These are in essence passive systems intended to help the driver to take appropriate actions such as navigation, correct lane positioning, etc. However, there is also the beginning of the trend of automation for reasons of safety such as electronic stability control and/or convenience (e.g. adaptive cruise control). Although level I technologies are functionally mature, these generally exhibit high cost. According to forecasts, their high cost norm will not continue for long due to technological advances and mass production for global markets [1].

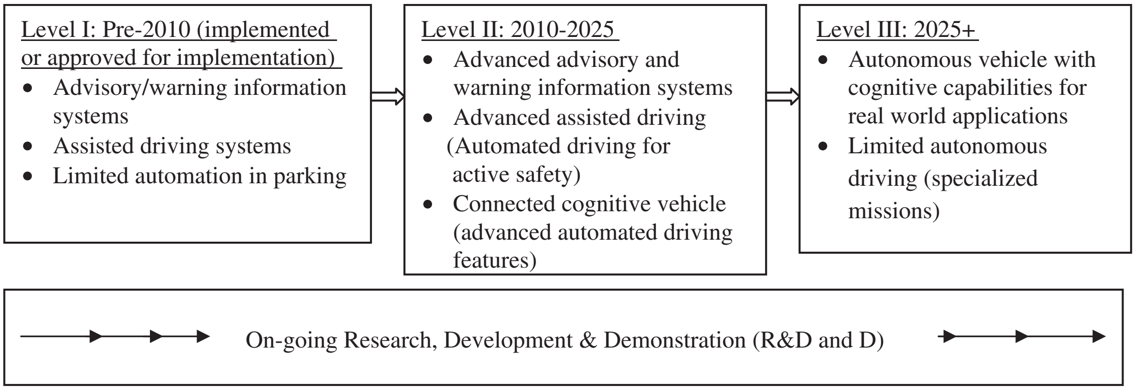

Fig. 1. Levels of technological advances and approximate time frame.