The impact of autonomous vehicles in highways and freeways

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Abstract

Worldwide attempts to ameliorate the recurrent phenomenon of traffic congestion and its socioeconomic and environmental impact, involve both invasive and traffic control management-based approaches. Potential solutions have emerged, which however do not account for the potential traffic dynamics alterations, due to the advent of autonomous vehicles (AVs). The eminent penetration of AVs in the existing fleet of conventional vehicles in highways and freeways, forms heterogeneous traffic with new patterns of driving behaviour.

The efficiency of ITS equipped networks could be greatly enhanced in view of the recent technological advances of AVs, which is envisioned to induce significant improvement in traffic flow conditions and safety. The aspiring aspect stands in the development of synergistic traffic operations through V2X communication protocols (V2I, V2V, V2D, VII, I2V).

Despite the studies on communications and user interface technology, and the financial interest of automotive industry, fundamental research does not present extensive models for the complete range of autonomy degrees of AVs' fleets and the effects of their forthcoming adoption on traffic dynamics and environmental profile. Given the integration rate of active and passive safety technology (ABS, ACC etc.), it is estimated that in the coming two decades the manufactured AVs will pass from no-automation (autonomy level 0), to full self-driving automation (autonomy level 4), which will enable a driverless end-to-end journey that evokes automated driving patterns. Therefore, the imminent adjustment of driving patterns induces a need of novel advanced traffic management strategies, and the genesis of dynamic microscopic traffic models for automated driving, which account the traffic heterogeneity, the autonomy level of AVs, as well as the penetration rate in the fleet in highways, freeways and locations with high congestion levels.

Keywords

autonomous vehicles – heterogeneous traffic – dynamic modeling

1. Introduction

Traffic congestion during increasingly extended daily peak periods is an escalating phenomenon with multi-dimensional impact. It is financially and environmentally expensive and it reveals an infrastructure's incompetence to cover the required demand, which results to multiple socioeconomic and environmental issues, such as deaths and injuries from traffic accidents, expensive time delays due to traffic states and incidents, increased fuel consumption and CO_2, NO_x, SO_2 emissions. The monetization of these effects for comparability reasons, reveal a significant cost of $120 billion in 2011 in the U.S. (Texas Transportation Institute, 2012), and a projected cost of €200 billion by 2050 in Europe (Europe 2020 Flagship Initiative and C. O. M. Innovation Union, 2011). Due to congested or saturated traffic conditions, a 20% increase in the induced time delays and an 18% in the CO_2 emissions were attained during the last three decades in the U.S. (Texas Transportation Institute, 2012).

Congestion mitigation and capacity increase methods in highways and freeways were polarized between investing to the physical expansion of the infrastructure, or implementing traffic operations management through Intelligent Transportation Systems (ITS). The first approach requires a costly expansion of the network, which in spite of the temporarily capacity increase, does not address the causality, as it does not cover in long-term the demand rate growth, and defers the problem. The second approach, even though promotes an ameliorated network performance with sustainable economic and spatial requirements (Aron, Cohen, & Seidowsky, 2010; Sparmann, 2006; Geistefeldt, 2012; Brilon, Geistefeldt, & Zurlinden, 2007), the efficiency improvements that are achieved are temporary, because of the complexity of the multifarious human driving patterns, which induce the ever-growing emergence of factors that need to be comprehended to the implemented control algorithms. In particular, proactive and reactive control systems evoked numerous modeling methods to provide robust prediction of traffic dynamics, with forecasting methods that were formed based on several standard traffic spatiotemporal parameters, ensuring significant accuracy (Stephanedes, Michalopoulos, & Plum, 1981; Kaysi, Ben-Akiva, & Koutsopoulos, 1993; Stathopoulos & Karlaftis, 2003; Antoniou & Koutsopoulos, 2006; Kirby, Watson, & Dougherty, 1997; Van Lint, Hoogendoorn, & van Zuylen, 2005). Nevertheless, complexity of heterogeneous traffic behaviour and drivers' adaptability to management policies, challenge their performance that conduces to capacity decrease and to traffic flow instability.

The efficiency of ITS equipped networks could be greatly enhanced in view of the recent technological advances of autonomous vehicles, which is envisioned to induce significant improvement in traffic flow conditions and safety. The aspiring aspect stands in the development of synergistic traffic operations through V2X communication protocols, namely vehicle-to-road infrastructure communication (V2I) via traffic centers, and vehicle-to-vehicle (V2V) or vehicle-to-device (V2D) communication via on-board devices, in conjunction with vehicle-infrastructure-integration (VII) for infrastructure-to-vehicle communication (I2V). Recent studies demonstrated great advances in communications and user interface technology (Wei, Snider, Kim, Dolan, Rajkumar, & Litkouhi, 2013; Urmson, et al., 2008; Bergholz, Klaus, & Hubert, 2000; Bertozzi, et al., 2011; Maček, Thoma, Glatzel, & Siegwart, 2007; Aberer, et al., 2010). In addition, financial interest of automotive industry is communicated, in regard to market penetration of autonomous vehicles (KPMG, 2015; Boston Consulting Group: Mosquet, et al., 2015; Navigant Rearch: Alexander & Gartner, 2013; Urmson, et al., 2008; Nissan Motor Corporation, 2013; Google, 2015). Public authorities in several European countries (U.K., France, Switzerland, Germany, Finland, the Netherlands), the U.S., Canada, Australia, Singapore and Japan are prepared to authorize test platforms for autonomous vehicles, or even to establish an action plan or a legislative framework that anticipates their deployment (HM Treasury Infrastructure U.K., 2013; DfT, 2015; MEIN, DGE, 2014; UVEK/DETEC, 2015; ERTRAC, 2015; NHTSA, 2013; NHTSA: Harding, J., Powell, G.R., Yoon, R., Fikentscher, J., Doyle, C., Sade, D., Lukuc, M., Simons, J., Wang, J., 2014; Victoria Transport Policy Institute: Litman, T.A., 2015; DMVNV, 2013; LTA, A*STAR, 2014). Despite the efforts in the aforementioned axes, limited fundamental research is acknowledged regarding the effects of the forthcoming adoption of the complete range of autonomy degrees of autonomous vehicles' fleets on traffic dynamics, automated driving patterns and their environmental impact. Given the integration rate of active and passive safety technology (ABS, airbags, driver assistance systems etc.), it is estimated that in the coming two decades the autonomous vehicles that will be manufactured will pass from an autonomy level 0, which corresponds to no-automation, to a level 4 of full self-driving automation (NHTSA, 2013), which will enable a driverless end-to-end journey with the management control of lateral and/or longitudinal movements granted to the autonomous vehicle (Figure 1). Therefore, the imminent adjustment of driving behavioural patterns induces a need of multi-scale modeling of the heterogeneous traffic, namely considering the interactions between AVs and conventional vehicles, as well as the surrounding traffic conditions in terms of lane distribution, and novel advanced traffic management strategies.

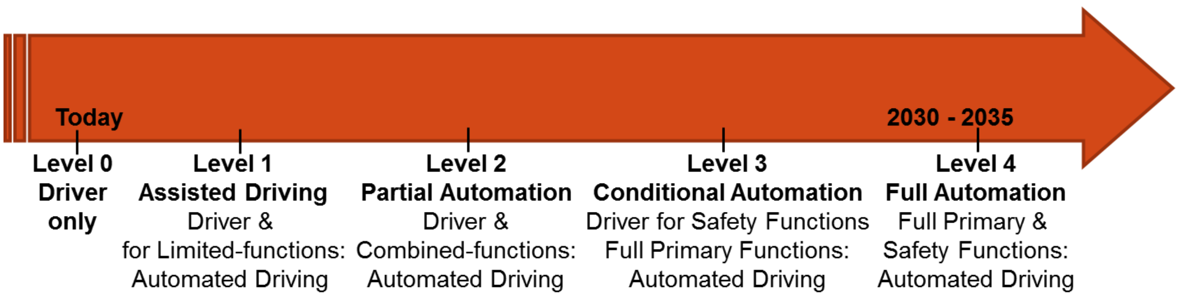

Figure 1 Autonomy levels according to NHTSA, 2013.

2. Degrees of Autonomy, Models and Architecture for AVs

The documented types and definitions for the unmanned or partially assisted guidance vehicles reflect the several degrees of autonomy that each study assumes. Hence, automated, autonomous, driverless, unmanned, or connected vehicles may correspond to the same or a different level of autonomy according to each approach. To avoid the ambiguity, in the studies cited hereinafter, if there is no specific definition of the level of autonomy, then the term employed by the study is used (automated, connected etc.). Moreover, the level of autonomy that is referred therein corresponds to low, nevertheless direct association has not been yet acknowledged. In the case of the connected vehicle (CV), the vehicle is enabled with i) Internet access, and ii) the technology to share this access with the devices mounted at other CVs and with the respectively equipped infrastructure (Monteil, Billot, Sau, Armetta, Hassas, & El Faouzi, 2013).

Although the number of levels of autonomy differs according to the scope of each study, in order to standardise and consequently resume their results, the autonomy degrees that are used hereinafter are as defined by the U.S. National Highway Traffic Safety Administration (NHTSA) (§2.1). Furthermore, studies regarding modeling of mixed traffic, on account of these cooperative systems or the autonomous systems are both constructive and will be presented separately (§2.2).

2.1 Degrees of autonomy

Although by definition an autonomous vehicle (AV) is equipped with the technology to navigate independently from a human operator, hence without active control or monitoring, several degrees of autonomy are attributed, including the no automation level (Antsaklis, Passino, & Wang, 1991; Bergholz, Klaus, & Hubert, 2000; DMVNV, 2013; NHTSA, 2013). According to the U.S. National Highway Traffic Safety Administration (NHTSA) the meaningful levels of vehicle automation are described by 5 separate levels (NHTSA, 2013). In level 0, there is no automation and the driver controls completely, solely and constantly the primary vehicle controls, but warnings such as lane departure or forward collision are provided. In level 1, automation is function-specific and independent to each other and the driver has complete and sole control, though he can either concede limited authority over a primary control function, such as adaptive cruise control (ACC), or the automated system assumes limited authority, so as to assist the driver (e.g. automatic braking). The driver is physically disengaged from the solely control of the vehicle in level 2, where a combined function automation is allowed. The self-driving is more limited in level 3, where the driver cedes full control of all primary control function to the autonomous system and he is expected to be manually engaged only if there is sufficient warning time. Lastly, in the full self-driving automation level 4, the vehicle has control of all safety driving functions and it operates for an entire end-to-end journey independently from the driver, who is not expected to be engaged for control at any time during the journey.

2.2 Methodological approaches for modeling AVs

On account of the advent of partially assisted guidance manned vehicles or entirely driverless AVs, traffic dynamics is considered to be significantly affected (Guler, Menendez, M., & Meier, 2014; Nowakowski, et al., 2010; Kesting, Treiber, & Helbing, 2010; Nowakowski, et al., 2010; Schönhof, Treiber, Kesting, & Helbing, 2007; Anda, LeBrun, Ghosal, Chuah, & Zhang, 2005). Recent studies demonstrate considerable capacity increase with CVs, in view of headways or time gaps much lower than the common ranges that are met from human drivers, as well as higher speeds, and maintained or improved road safety (Nowakowski, et al., 2010; Kesting, Treiber, Schönhof, & Helbing, 2008; van Arem, van Driel, & Visser, 2006; Anda, LeBrun, Ghosal, Chuah, & Zhang, 2005; Bose & Ioannou, 2003). However, during the transitional periods from mixed fleets of conventional and autonomous vehicles to homogeneous traffic consisted of AVs, the coexistence of stochastic driving behaviour of manned and unmanned vehicles could provoke critical issues in safety and reliability of the traffic systems. The impact of penetration rate and autonomy level is reported to be sensitive and analogous to the maximum free flow and the average speed, as higher deployment ensures lower time gaps (Kesting, Treiber, & Helbing, 2010; van Arem, van Driel, & Visser, 2006; Davis, 2006; Bose & Ioannou, 2003). Namely, for low penetration rates of low-level autonomy vehicles (Adaptive Cruise Control – ACC) are not observed favourable effects on capacity, regardless the set of time gap (van Arem, van Driel, & Visser, 2006; Bose & Ioannou, 2003). For a higher low-level autonomy vehicles (Cooperative ACC - CACC), string stability and traffic throughput are improved, and a borderline increase in traffic flow efficiency is demonstrated.

In particular, the two most inclusive studies considered scenarios for two autonomy degrees, five penetration rates and two vehicle classes (Kesting, Treiber, & Helbing, 2010), whereas the study of van Arem et al. for also only two degrees (conventional – 0, AVs equipped with adaptive cruise control – 1) included more rates and a lane reserved for this degree of AVs. Results of the latter, indicated higher speeds and lower speed variances for assigned CACC lane, though only upstream of a bottleneck in a 4-lanes highway that is merged to 3-lanes. Drivers do not select consciously the assigned lane, although they maintain a no lane-changing trajectory (van Arem, van Driel, & Visser, 2006). Therefore, it would be more meaningful to study the impact of a more realistic setup with greater number of autonomy levels, their interactions with manned vehicles, and several market penetration rates.

The models that are used to address the impact of CVs/AVs on traffic flow are mainly extensions of existing car-following or lane changing microscopic models, and macroscopic models. The known properties of increased computational effort of microscopic models and of disregarding potentially useful properties of individual vehicles, are stated as expected. The parameters of the most prevailing models are most commonly the acceleration, the desired velocity and minimum time headway (Monteil, Billot, Sau, Armetta, Hassas, & El Faouzi, 2013; Nowakowski, et al., 2010; Kesting, Treiber, & Helbing, 2010; van Arem, van Driel, & Visser, 2006; Davis, 2006; Li & Ioannou, 2004; VanderWerf, Shladover, Miller, & Kourjanskaia, 2002; Rajamani & Shladover, 2001). However, only one or two autonomy degrees are taken into consideration and without penetration rate interactions, which is a factor that affects traffic flow due to the various interactions between the percentage of AVs and conventional vehicles during the transitional periods of coexistence of the heterogeneous fleet in the networks. For the separate consideration of this rate, it is denoted that above a certain level of penetration (40% to 50%), the AVs affect the networks’ capacity (Davis, 2006; van Arem, van Driel, & Visser, 2006; Monteil, Billot, Sau, Armetta, Hassas, & El Faouzi, 2013; Bose & Ioannou, 2003). Ultimately, there is no acknowledged comprehensive model or set of models that includes both the effects of penetration rates of AVs and several autonomy levels of AVs. In this aspect, a comprehensive dynamic model for lane traffic distribution should be introduced, so as to capture the heterogeneous dynamics. A comprehensive table of the existing approaches and potentials for autonomous or assisted driving is presented in Table 1.

Table 1 Existing models and input parameters for partially or fully assisted guidance vehicles.

Methodological Approach	Input Parameters – Conditions – Assumptions	Points to be addressed
Micro/meso/macroscopic traffic flow model in single lane highway for Intelligent Cruise Control (ICC) equipped vehicles and automated vehicles (Li & Ioannou, 2004; Kanaris, Ioannou, & Ho, 1997)	Microscopic model: Provides speed and density for each vehicle in time and space. Computational effort increases by the number of vehicles under consideration. • relative distance between leading-following vehicle • relative speed between leading-following vehicle • deviation from desired intervehicular space • speed of following vehicle • speed of leading vehicle • position of following vehicle • external speed command • desired speed of following vehicle • desired time headway • average nb. of vehicles per unit length over section at time t • average nb. of vehicles per time interval at location y • average speed of vehicles over section at time t Conditions set to guarantee asymptotic control and string stability, so no position or speed errors propagate upstream. Mesoscopic model: Generates speed and density distribution at each instant in time and space, by interpolating speed and density at discrete locations. Assumption: vehicles have similar closed-loop characteristics (platoon introduction attempt). Macroscopic model: Average speed and density over section of single lane highway, due to complexity for large number of vehicles. Assumption: each vehicle affected by the preceding vehicle.	- Microscopic model: • No downstream or lateral vehicles are taken into consideration - Mesoscopic model: • Acceleration computed on assumption of no lane-changing operation • Complexity increases for large number of vehicles. - Macroscopic model: • Single lane highway due to complexity of micro/meso models • All vehicles assumed to be equipped with ICC (no penetration rate or level of autonomy)

Car-following models based on Intelligent Driver Model (IDM) / combination of driver and vehicle model (MIXIC) / constant time gap vehicle following for Adaptive Cruise Control (ACC) equipped vehicles (passenger vehicles, trucks), Cooperative Adaptive Cruise Control (CACC) equipped vehicles (Monteil, Billot, Sau, Armetta, Hassas, & El Faouzi, 2013; Nowakowski, et al., 2010; Kesting, Treiber, & Helbing, 2010; van Arem, van Driel, & Visser, 2006; Davis, 2006; VanderWerf, Shladover, Miller, & Kourjanskaia, 2002)	• Desired speed • Desired min time headway • Desired time gap • Max comfortable acceleration/deceleration • Desired deceleration • Jam distance • Coolness factor (sensitivity parameter, when equal to 1, small time gaps and no speed difference, hypothesis too relaxed) • V2V protocols to inform ACC equipped vehicles upstream, on downstream speed & density, so as to modify speed (computes acceleration and position) and actions regarding lane changing. • (20%, 100%, 20%) penetration rates • Separate lane for CACC vehicles is studied as scenario to improve performance.	• No downstream, lateral or multiple neighbouring vehicles' interactions are taken into consideration. Forward, backward or both directions-looking model could be suggested, as for conventional vehicles is proved to improve capacity and smooth traffic flow fluctuations (Treiber, Kesting, & Helbing, 2006; Wilson, Berg, Hooper, & Lunt, 2004) • No penetration rate of AVs, only for ACC, CACC, and manual vehicles, so no incorporation of interactions between multiple vehicles.
Platoon (coordinated) control algorithms for several combinations of vehicles' types (Cruise control equipped vehicles (passenger vehicles, buses and trucks included), AVs, CVs), platoons sizes, wet/dry surface conditions (Kanaris, Ioannou, & Ho, 1997; Broucke & Varaiya, 1996; Rajamani & Shladover, 2001)	• Acceleration and velocity of preceding vehicle • Acceleration and velocity of lead vehicle of platoon, v_l • Spacing error to preceding vehicle Scenarios: • Constant time gap ACC vehicle • 6.5m inter-platoon ACCs gap • 60m intra-platoons • 6/7/8-car platoon	• Early adaptation of braking behaviour on CVs/AVs. Behavioural variety for combined CVs/AVs is not considered.

2.3 Architecture for AVs

The architecture that could seize the V2I and I2V communication protocols to interact with the AVs, was only recently addressed (Kazerooni & Jeroen, 2015; Baskar, De Schutter, & Hellendoorn, 2007; Anda, LeBrun, Ghosal, Chuah, & Zhang, 2005). The studies approach the topic in a meso-/micro-scopic scale and assume organization of AVs fleet in platoons and taking into consideration also roadside infrastructure. Therefore, the framework should be extended to incorporate larger organizational level, in order to plan the decentralization of traffic operations and improve reactive times for activation of control strategies.

3. Challenges and Perspectives

The advent of AVs denotes the emergence of new driving patterns, depending on their autonomy degree and the penetration rate to the conventional fleet. With a modeled automated driving and in view of the V2V communications, headways between AVs will be reduced, leading to the capacity and safety amelioration of the existing networks. Although progress has been demonstrated in autonomous driving technologies, from theoretical and implementation aspect, the fundamental research on modeling traffic flow dynamics in the presence of AVs, and the impact on highway or freeway operations performance, is currently not extensive. Relevant literature review demonstrates that conducted studies approach fragmentally the AVs penetration to conventional fleet, by examining either low autonomy degree AVs, or certain penetration levels.

As a result, the potentials that are emerged are set on two axes i) the genesis of dynamic microscopic traffic models for automated driving, which account the traffic heterogeneity and the reformatted patterns caused by the simultaneous presence of both autonomous and conventional vehicles, the autonomy level of autonomous vehicles, as well as the penetration rate in the fleet, and ii) the deployment of and integrated architecture for adaptive traffic operational strategies addressing to mixed traffic of vehicles of every level of autonomy in highways, freeways and locations with high congestion levels. The proposed aims respectively are i) to develop microscopic dynamic models of mixed traffic to represent the modified traffic characteristics evoked by autonomous vehicles and predict in real-time the new ensued patterns, and ii) to establish the architecture for interactive cooperation between autonomous vehicles and infrastructure, namely traffic operations centers (TOC) and active traffic management systems (ATMS), which include managed lanes systems, hard shoulder running systems, ramp metering, variable speed limits (VSL) and variable-message signs (VMS). This framework is intended to anticipate congestion, and thus substantially improve networks' capacity and safety, and additionally to minimize fuel consumption and vehicles' emissions. Secondly, the exponential growth of data diversity from on-board vehicle devices, smartphones and GPS devices is set to be seized, in order to provide an input for the validation process of the developed traffic behavioural models, which would facilitate the propagation of V2X and I2V advances.

As it is of paramount importance to anticipate and sustain the management of the transitional heterogeneous traffic and the impending interactions between AVs and infrastructure, the set of comprehensive stochastic models that predict traffic effects in real-time and which is suggested to be developed, will be extensions of previously developed car-following and lane-changing models (Menendez, 2006), to address the heterogeneous traffic of autonomous and conventional vehicles, and the challenge to consider combined and individual interactions from the complete range of autonomy degrees and the various penetration rate levels of AVs. The aim to describe realistically the traffic dynamics, led to the decision of microscopic models adaptation.

In accordance to the impending altering driving behaviour, the existing framework of traffic management operations is mandated to be revised. Current traffic operational strategies could be benefited by the V2X communication features of AVs with transport infrastructures, which will be accordingly established as the cost of the process is considerably limited in comparison to extended infrastructure works. Therefore, an integrated multiple-level traffic management framework could be proposed, which transfers the management of traffic operations from a central traffic control center to roadside infrastructure, and that assigns the activation of a policy based on the local interaction of the AVs among them (V2V) and with the infrastructure (V2I, I2V). The suggested management architecture is expected to improve reaction time for the activation of an operation, as a result of the transfer of management of operations to the lower level of the framework, in conjunction with the imminent compliance of driverless or conditional to high-automated vehicles. Consequently, an implementation of the suggested design could lead to the coveted efficiency amelioration of the traffic operational strategies, by alleviating congestion effects and increasing capacity.

An integrated approach could be introduced that anticipates the advent of autonomous vehicles and automated driving, through i) the development of a set of dynamic stochastic models that account for the heterogeneity of autonomous and conventional vehicles and for a range of autonomy degrees and penetration levels of the AVs, and ii) the design of traffic management architecture that will enable the interaction of AVs with future adaptive ATM systems, seizing the V2I technological advent of the various levels and degrees of AVs. AVs have factors that render them having faster reaction times and a more rule-guided behaviour than human drivers. Therefore, enabling implementation of optimal cooperative policies by introducing a dynamic framework for operational traffic strategies and a stochastic representation of mixed traffic for a combination of driving characteristics of vehicles, will ensure a flexible adaptation of the strategies to the fluctuations of traffic performance. As a result of the more submissive driving behavioural characteristics of the AVs, a) the inter-vehicle space is expected to be considerably diminished as part of a platooning formation, b) the transit reliability due to congestion or incidents decrease to be greatly ameliorated, and hence c) fuel consumption and vehicles' emissions to be reduced. Additionally, even though the parameterisation of a solely driverless system is anticipated to yield significant prediction accuracy, the interactions between a transitional fleet consisted of AVs of various autonomy degrees and conventional vehicles set a challenging modeling task, which will be evaluated during the validation process of the suggested stochastic models through microscopic traffic simulation.

4. Conclusions

Partially assisted guidance vehicles have been gradually introduced into conventional fleets for the past two decades, while fully autonomous vehicles will prevail in road networks in the following two. The interactions between manned and unmanned vehicles evoke issues regarding driving behaviour patterns and safety that demand the development of appropriately adapted driving models, since the existing ones are dictated by human drivers' behavioural characteristics, parameterised accordingly to represent the traffic dynamics. Moreover, the V2X communications that are available in AVs can be employed to ameliorate the operation of traffic management strategies and better coordinate the transitional fleet of vehicles with mixed capabilities and interactions.

The present paper reviewed the existing methods for modeling driving behaviour for fleets of vehicles consisting of several penetration rates and autonomy degrees, as the last were defined by NHTSA for comparative reasons across the models. The majority of cited studies aim to improve the performance of traffic systems through microscopic modeling by extending car-following or lane-changing models for manned vehicles, although meso- and macro-scopic models are also developed, in an attempt to investigate the platooning concept. The potentials for mitigating delays with the advent of AVs are directed towards the formation of a model that captures the driving patterns not only of the vehicles with a certain degree of autonomy separately, but mostly their interactions, as during the penetration of AVs both conventional and autonomous vehicles of several degrees coexist. The amelioration of the heterogeneous traffic management is suggested to be addressed through an integrated architecture that utilise the potentials of the AVs' communication protocols, decentralising traffic operations and mitigating the implementation time needed for control strategies. In particular the perspectives are to:

1) Provide dynamic traffic distribution prediction of the heterogeneous traffic, through an extension of existing car-following and lane-changing models that would enable the capture of prevailing traffic patterns, in view of the transitional shift of driving behaviour from conventional to automated, on account of the five degrees of autonomy and various levels of penetration rate of AVs, combining also data by on-board vehicle devices (V2D).

2) Optimize the operation of adaptive active traffic management (ATM) strategies, such as dynamic managed lanes systems, dynamic hard shoulder running systems (HSR), adaptive ramp metering, dynamic variable speed limits (VSL) and variable-message signs (VMS), with the optimization of the introduced dynamic stochastic models. The objective function is to maximize the utilisation of each lane, and hence the throughput, by employing also the intelligence of AVs to interact with the infrastructure (V2I) and among them (V2V), in order to ultimately ensure the efficient and timely implementation of the corresponding ATM.

3) Establish an integrated architecture for decentralised management of traffic operational strategies that interact with AVs and roadside infrastructure. The purpose is to reduce reaction time between triggering and implementing the activation of an ATM system that central management imposes, in order to rapidly coordinate approaches that support cooperative automated driving and harmonize the efforts towards maximization of capacity, regulation of safety and preservation of minimal environmental impact (fuel consumption and CO_2 emissions). This comprises conveying the information to the driver for guidance or navigation, according to the autonomy degree of the AV.

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