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Overview and analysis of Vehicle Automation and Communication Systems from a motorway traffic management perspective

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ABSTRACT

During the last decade, there has been an enormous interdisciplinary effort by the automobile industry and numerous research institutions worldwide towards the development, testing and employment of a variety of Vehicle Automation and Communication Systems (VACS) with the main aims to improve road safety and driver convenience. Some VACS, however, have a direct impact on road efficiency as well and could therefore be exploited to relieve road networks from the significant congestion problems and their negative consequences for travel times, safety, fuel consumption, the environment and the quality of life in general. In other words, some of the available VACS could also be used as novel or innovative sensors, actuators and tools towards a new era of traffic management. This paper provides an overview of proposed and available VACS and discusses their perspectives from the motorway traffic management point of view. Classifications of the different systems in this respect are also provided, while SWOT (Strengths–Weaknesses–Opportunities–Threats) analyses are used to identify specific exploitation ways. Current trends and future perspectives of VACS within a motorway traffic management context are finally summarised.

1. Introduction

Traffic congestion on metropolitan motorways is a serious threat for the economic and social life of modern societies, as well as for the environment, which calls for drastic and radical solutions. Some conventional traffic management measures currently applied, face limitations. During the last decade, there has been an enormous effort to develop a variety of *Vehicle Automation and Communication Systems* (*VACS*) that are expected to revolutionise the features and capabilities of individual vehicles in the next decades. VACS are systems that undertake different vehicle functions at various levels of automation, which, enhanced by communication features enabling varying levels of cooperation among vehicles and/or vehicles and the infrastructure, aim at assisting, improving and easing the driving task. They are typically developed to benefit the individual vehicle, without a clear view or complete understanding for the implications, potential advantages and disadvantages they may have for the resulting, accordingly modified traffic characteristics. Thus, the gradual introduction of VACS

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brings along the (often neglected) necessity and continuously growing opportunities for accordingly adapted or utterly new traffic management actions and strategies.

This paper presents the results of a study aiming at addressing existing or envisaged VACS options, assess their relevance for motorway traffic management (MTM), and develop, for a most relevant subset of VACS, appropriate exploitation possibilities towards a more efficient motorway traffic flow. The study has been based on an extensive review of proposed, available or evolving VACS carried out by Diakaki et al. (2014).

The paper is organised in five more sections. Section 2 discusses the emergence of VACS and the factors that boosted their rapid development and evolution observed in recent years. Section 3 presents an overview of VACS, and proposes a taxonomy from the perspective of their potential implications to motorway traffic flow. Section 4 focuses and further studies and analyses VACS that have been identified to have direct motorway traffic flow implications; while relevant SWOT (Strengths–Weaknesses–Opportunities–Threats) analyses are presented and discussed in Section 5 in an effort to identify specific ways of exploitation of their most promising features towards an efficient MTM. Section 6 finally, summarises current trends and future perspectives of VACS within a MTM context.

2. The emergence of VACS

The modern automobile was born in 1886 when Carl Benz applied for a patent for his "vehicle powered by a gas engine", known today as Benz Patent Motor car. In 1902, the automobile mass production was launched by Ransom Olds at Lansing, Michigan, USA, while in 1908 the great developments of the mass production concepts introduced by Henry Ford led to the "Ford Model T", the first broadly affordable automobile. Since then, the automobile has become a symbol of human mobility freedom and a symbol of status. Unfortunately, however, the traffic-related facts and statistics seem relentlessly.

According to the World Health Organisation (WHO), the following 10 facts hold for the global road traffic safety (WHO, 2013):

- Every year, there are 1.24 million road traffic deaths worldwide.
- 92% of road traffic deaths occur in low- and middle-income countries that share only 53% of the world's registered vehicles.
- Vulnerable road users account for half of all road traffic deaths globally.
- Controlling speed, reduces road traffic injuries; a 5% cut in average speed can reduce the number of fatal crashes by as much as 30%.
- Drinking alcohol and driving increases the risk of a crash.
- Wearing a good-quality helmet can reduce the risk of death from a road crash by 40%, and the risk of severe injury by over 70%.
- Wearing a seat-belt reduces the risk of death among front-seat passengers by 40–65%, and the deaths among rear-seat car occupants by 25–75%.
- Infant seats, child seats and booster seats can reduce child deaths by 54–80% in the event of a crash.
- Prompt, good-quality pre-hospital care can save the lives of many people injured in road traffic crashes.
- Since 2007, 88 countries have reduced the number of road traffic deaths, in 87 countries the number of road traffic deaths has increased, and at the global level it has remained stable.

These facts, which have been derived through information on road safety from 182 countries, accounting for almost 99% of the world's population, indicate that the total number of road traffic deaths worldwide remains unacceptably high, while only a few countries have comprehensive road safety laws on key risk factors such as drinking and driving, speeding, use of motorcycle helmets, etc. (WHO, 2013).

At the same time, according to the International Energy Agency (IEA, 2013):

- Transport is the second largest sector in terms of emissions, releasing 22% of global CO_2 emissions in 2011.
- The fast emissions growth of the transport sector was driven by emissions from the road sector, which increased by 52% since 1990 accounting for about three quarters of transport emissions in 2011.
- Global transport fuel demand is expected to grow by nearly 40% by 2035.

Motivated by such facts and statistics, an enormous continuing interdisciplinary effort has been applied by the automobile industry as well as by numerous research institutions around the world to plan, develop, test and start deploying a variety of VACS aiming at assisting, improving and easing the driving task. Although safety and driver convenience have been the main motivators behind their development, the reduction of the negative environmental effects of traffic in terms of reduced fuel consumption and related emissions is also among the prime priorities of some VACS or results as a by-product of an improved vehicle operation.

VACS are expected to revolutionise the features and capabilities of individual vehicles within the next decades in favour of the safety and convenience of their users, i.e. their drivers and passengers. However, simulation investigations as well as relevant Field Operational Tests (FOTs) indicate that some VACS can also affect, in a positive or negative way, the traffic flow