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Cooperative Intelligent Transport Systems as a policy tool for mitigating the impacts of climate change in road transport

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Abstract. This paper aims to address the contribution of Cooperative Intelligent Transport Systems (C-ITS) services to the mitigation of climate change impacts in road transport. Climate change is a fact perturbing human activities in various ways. The exacerbation of weather conditions has considerable impacts on transportation, hence indicating transport vulnerability to climate change. Europe is already confronting several changes in the climatic conditions, including increased temperatures, extreme precipitation events, cold waves and sea level rise. Interaction between climate change and road transport is evident in terms of increasing risks for network managers and users, and negatively affecting transport performance major parameters, such as safety, reliability and cost efficiency. The need to limit adverse weather conditions effects to road transport urges to adapt new mitigation policies, which will ensure transport resilience and sustainability. C-ITS services constitute an innovative array of technologies, enabled by digital connectivity among vehicles and between vehicles and transport infrastructure, expected to significantly improve road safety, traffic efficiency and comfort of driving. In this way C-ITS services have the potential to increase the levels of safety for drivers within extreme weather situations, by helping them to take the right decisions and adapt to the traffic situation. The C-MobILE project, funded under the Horizon 2020 programme, envisions a fully safe and efficient road transport without casualties and serious injuries on European roads, by deploying C-ITS services for specific mobility challenges. The project will execute large scale C-ITS deployment activities in eight cities in Europe. The C-ITS services will be provided in bundles, aiming to improve safety and traffic efficiency. The paper includes an extended review of the relevant literature. Then an assessment of the C-MobILE C-ITS services' potential contribution to the mitigation of these effects is presented and assessed.

Keywords: Climate change, extreme weather events, road transport, Cooperative Intelligent Transport Systems.

1 Introduction

Europe is already facing severe impacts of climate change, affecting the full EU territory with regional differences [1]. Changes in the climate system are already having an impact on road transport infrastructure and services in Europe. Adverse weather and road conditions are a considerable cause of an elevated risk of traffic accidents and compromised traffic flow in Europe [1], [2]. Cooperative Intelligent Transport Systems (C-ITS) is an array of technologies, enabling the various elements of the modern surface transportation system to communicate via Vehicle-to-Infrastructure (V2I) or Vehicle-to-Vehicle (V2V) communications, with each other [3]. C-ITS services are expected to contribute to the further reduction of the number of casualties and severity of accidents, through the utilization of warning systems and by influencing drivers' behavior [4].

This paper aims to prove the potential contribution of the C-ITS services, deployed under the framework of the C-MobILE project, to the mitigation of the impacts of climate change in road transport. Firstly, an overview of the various weather phenomena, responsible for road accidents' rise and traffic flow disruption, derived from an extensive literature review, is presented. Then an assessment of the impacts of specific C-ITS services, to be deployed in the C-MobILE framework as well, on road safety and traffic efficiency increase is presented. The impact rates were derived from data collected from the literature review [5].

2 Methodology

First, an extensive literature review was conducted, in order to exhibit the implications of climate change induced adverse weather conditions in road transport. Impact areas highly affected are road safety and traffic efficiency. Then, the perspective of C-ITS services as a policy tool for mitigating such impacts is presented. Literature review data prove that specific C-ITS services, to be deployed as well in large scale in the framework of the C-MobILE project, have the potential to contribute in road safety and traffic efficiency increase.

3 Implications of adverse weather conditions in road transport

Empirical findings and research outputs have shown that road transport services perform worse under adverse and extreme weather conditions. Road transport is almost continuously subjected to meteorological hazards, impacting upon driving conditions, causing accidents and traffic congestion problems. From the viewpoint of the available research, factors contributing to accidents can be grouped into three categories: a) 90% human factors, b) 30% environment, and c) 10% vehicle [6]. Road traffic accidents in the Member States of the European Union claimed about 26.000 lives and left more than 1,3 million people injured in 2014. Data indicate that approximately 12% of the fatalities were caused due to inclement weather conditions [7].

An extended review of the literature shows that inclement weather due to rain is associated with more hazardous driving conditions than wet weather. Reduced friction on the road surface, leading to longer braking distances, and low visibility due to the reflection on wet surfaces, are among the main causes of accidents during rainfall. A significant number of papers display valid results on the correlation between precipitations and increase of traffic crashes. Accident risk during driving on slippery roads is proven to be higher than on dry pavement conditions [8], [9], [10], [11], [12], [13], [14], [15], [16], [18], [19]. Intense precipitation produces also more flooding, affecting the performance of urban transportation networks in terms of delays, detours and trip cancellation. Due to flooding incidents trips are typically cancelled, while the ones occurring take much longer, since drivers are forced to take circuitous routes from origin to destination or stuck in traffic on passable links [19], [20].

Travel during snow events is considered as rather not a safe driving experience, since driving on roads with snow and ice not only extends travel time but also places drivers in a dangerous position. Low friction pavement increases the difficulty of operating and maneuvering a vehicle. Impaired atmospheric visibility limits driver sight distance and restricts driver's ability to judge the unexpected conditions ahead. Several studies indicate that snowfall contributes to high accident rates and decrease of traffic volumes, with snowstorm duration and intensity being the major deteriorating factors [10], [19], [20], [22] [23], [24], [25] [26], [27], [28], [29], [30], [31].

Research findings show that the presence of high winds increases accident risk significantly [31], [32]. Cross winds affecting the exposed sides of a vehicle, are commonly as strong as the vehicle velocity induced air-speed, hence the air pressure acting sideways can be high as the drag force in the driving direction [31]. Wind accidents statistics reveal the frequent appearance of heavy goods vehicles, while private cars hauling any kind of trailers are considered also as of high risk vehicle categories [31].

Fog constitutes an inclement weather event, causing accidents, which tend to result in more severe injuries and involve multiple vehicles [33], [34], [35]. Vision obstruction, occurring mostly during the morning hours in the months of December to February, is the prevalent reason for crashes. Other contributing factors, having direct or indirect effect on the occurrence of fog induced crashes, are speed, lighting conditions, age, area (urban, rural), number of lanes, and presence or absence of sidewalk [35].

4 The C-MobILE project

Coping with climate change requires mitigation and adaptation policies. These two strategies constitute complementary actions [36]. The overall aim of the EU Strategy is to contribute to a more climate-resilient Europe. The C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe) project, funded under Horizon 2020, envisions a fully safe and efficient road transport without casualties and serious injuries on European roads, in particular in complex urban areas and for Vulnerable Road Users (VRUs) [37]. Eight C-ITS equipped cities/ regions are involved in C-MobILE, Barcelona, Bilbao, Bordeaux, Copenhagen, Newcastle, North Brabant Region, Thessaloniki and Vigo, which will be elevated to large-scale deployment locations of sustainable services. This will be achieved by opening up the existing ITS-enabled cities and providing C-ITS services in a seamless, uninterrupted cross-modal and cross-border way [37]. Specific C-ITS services are expected to have certain impacts in road accidents reduction and traffic efficiency increase.

4.1 The C-MobILE C-ITS services' contribution to the mitigation of climate change induced road hazards

Road safety and traffic efficiency constitute impact areas affected mostly by extreme weather events. C-ITS services providing warnings for various road conditions could contribute in avoiding road accidents, as well as in increasing traffic efficiency [38], [39]. Traffic data collection and mobility information provision, addressing in real-time weather impacts on arterial traffic flow (e.g. congestion), could result in travel time savings and reduction of vehicle-hours [39].

Road Works Warning (RWW). Road works warning aims to inform drivers in a timely manner about road works, changes to the road layout and applicable driving regulations. Situations, such as unplanned (ad-hoc) road works and especially emergency repairs due to infrastructure damages caused by extreme weather events, require more attentive driving while approaching and passing the work zone. While approaching the road work zone, drivers having access to the service, receive road works related information, warnings and/ or guidance on an in-vehicle display or smartphone. Instructions typically include reduction of driving velocity, change lanes, or prepare for a steering manoeuvre. The main aim of the service is to improve road safety by reducing the number of collisions [40].

Road Hazard Warning (RHW). Road hazard warning aims to inform drivers in a timely manner of upcoming, and possibly dangerous events and locations. Unawareness of hazardous locations may lead to driving situations with high risk or in the worst case accidents, especially when drivers do not anticipate appropriately to them. The in-vehicle driving assistance information improves the awareness of drivers, increases their attentiveness and allows them to better anticipate to various situations. Situations associated to weather induced hazards comprise of limited visibility, asphalt adhesion, potholes, objects on the road or spilled load, and traffic congestion. Through the provision of timely in-vehicle driving assistance information, i.e. notifications and warnings, on hazardous locations downstream of the current position and in the driving direction of the vehicle, RHW enables drivers to be better prepared for the upcoming hazards and make necessary adjustments and manoeuvres in advance [40].

Emergency Vehicle Warning (EVW). The main objective of Emergency Vehicle Warning is to provide other vehicle drivers with an early warning indication of an emergency vehicle approaching, in order to timely give way to it. Severe weather phenomena, mainly floods and blizzards, constitute the cause of many disaster events, which require an emergency response. At the same time, they affect the way assistance, i.e. the emergency vehicle, will reach the emergency point. EVW enables emergency vehicles to identify themselves and inform other vehicles in the vicinity about their position, direction and speed, even when their siren and light bar may not be audible or visible due to weather conditions. The primary impact of the service is the prevention of possible accidents due to drivers' clumsy behavior, while trying in a hasty manner to give way in an emergency vehicle approaching [40].

In-vehicle Signage (IVS). In-Vehicle Signage is meant to inform drivers via in-vehicle information systems on static and dynamic road signs as indicated on physical road signs and on additional digital displays along the road. Dynamic traffic signs provide travelers with information about special events, such as traffic congestion, accidents, incidents, speed limits, roadwork zones, or road closures, frequently triggered by adverse weather conditions. Both advisory and mandatory road signs are in scope of IVS, while information is retrieved by means of I2V communication. While driving, drivers receive actual IVS related information, warnings and/ or guidance on the in-vehicle display, advising them to adapt driving velocity in line with the road conditions, to change lanes or to prepare for a steering manoeuvre if necessary[40].

Probe Vehicle Data. Probe Vehicle Data is data generated by vehicles, then collected and used as input for operational traffic management, long term tactical/ strategic purposes and for traveler information services. Data broadcasted by vehicles may refer to various implications of inclement weather on the road network, e.g. slippery spots and traffic jams. Such data provide road operators with insight in the traffic situation and surroundings, enabling them to allocate warnings to vehicle drivers, in order to avoid dangerous situations and change the driving behavior (e.g. brake, accelerate, and change routes) [40].

Emergency Brake Light. Emergency Brake Light aims to avoid (fatal) rear-end collisions, which can occur if a vehicle ahead suddenly brakes, especially in dense driving situations or in other hazardous situations, such as decreased visibility or slippery roads. Drivers are not valid estimators of accident risk while driving in adverse weather conditions, and they do not always adjust their driving behavior sufficiently. The underestimation of the slipperiness of a road, for instance, may trigger hard breaking, causing skid related accidents. EBL aims to enable a vehicle to warn all following vehicles of its sudden slowdown, limiting this way the risk of longitudinal collision and improving traffic safety [40].

Slow/ Stationary Vehicle Warning (SSVW). Slow or stationary vehicle warning aims to inform/ alert approaching vehicles of (dangerously) immobilized, stationary or slow vehicles, which impose significant risk. Inclement weather could force a vehicle's immobilization, e.g. accidents, vehicle problems, emergency vehicles. The service focuses on providing timely in-car driving assistance information on a stationary vehicle, offering drivers an extra time to react appropriately, and hence contributing to accidents' decrease [40].

Warning System for Pedestrians (WSP). Warning system for pedestrian aims to detect risky situations (e.g. road crossing) involving pedestrians, allowing the possibility to warn vehicle drivers. Visibility obstruction due to fog, mist, haze, snowfall or freezing drizzle impedes drivers' detection skills, limiting the chances to spot the behavior of a VRU, i.e. pedestrian or cyclist, in the vicinity of the vehicle. The service seeks to track whether dangerous scenarios may occur, in order to notify the driver timely. The expected impact is the provision of comfortable driving, as well as the enhancement of traffic safety, as a result of avoided accidents [40].

Motorcycle Approaching Indication (MAI). Motorcycle approaching indication warns the driver of an approaching/ passing motorcycle (the scope can be extended to cover as well VRUs). Adverse weather conditions are among the most common causes of motorcycle accidents, especially collisions with passenger vehicles, as most vehicle drivers don not notice motorcycles on the roadways due to limited visibility. The objective of the service is to provide timely in-vehicle driving assistance information on an approaching motorized or powered two-wheeler in the driving direction of the vehicle, in order to reduce the risk of an accident [40].

The following table presents average values of data collected from the literature review [5], depicting road safety and traffic efficiency related impacts of C-ITS services on individual vehicles when installed across different vehicles and road types at EU level.

Table 1. Average values of C-ITS services' impacts on road safety and traffic efficiency increase

C-ITS Services	Impact area				
	Road safety				Traffic efficiency
	Fatalities	Severe injuries	Slight injuries	Material damages	Average speed
RWW	-3,4%	-3,4%	-3,4%	-3,4%	+2%
RHW	-4,1%	-4,2%	-4,2%	-4,2%	
EVW	-0,8%	-0,8%	-0,8%	-0,8%	
IVS	-6,9%	-3,9%	-3,9%	-3,9%	
PVD	-2,6%	-3,7%	-3,7%	-3,7%	
EBL	-2,7%	-2,5%	-2,5%	-2,5%	
SSWV	-1,9%	-0,7%	-0,7%	-0,7%	
WSP	-1,8%	-1,9%	-1,9%	-1,9%	
MAI	-3,8%	-3,8%	-3,8%	-3,8%	

5 Conclusions

In this paper the contribution of the C-MobILE C-ITS services to the mitigation of climate change impacts in road transport is presented. Firstly, climate change induced extreme weather events, impacting upon road transport, are thoroughly presented. Precipitation, snow, wind and fog constitute the main weather-related hazards, affecting harshly road safety and traffic efficiency. Subsequently, the C-ITS services to be deployed within the framework of the C-MobILE project, and which could potentially act as factors reducing accidents and increasing traffic flow, are described. The most prominent C-ITS services, having the greatest impact in road safety and traffic efficiency, are Road Hazard Warning and In-vehicle Signage. Overall, it is demonstrated that the C-ITS services deployment constitutes a mitigation measure, which could establish a resilient transport system, able to anticipate climate changes and cope with them.

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