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Quantifying the impact of a real world cooperative-ITS deployment across multiple cities

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ABSTRACT

Cooperative Intelligent Transport Systems (C-ITS) - Connected Vehicle technology in the USA - where vehicle and roadside infrastructure communicates to deliver more intelligent traffic management, is one of a range of ITS technologies emerging as a key component in pursuit of the wider objectives of improved urban mobility. This paper presents the Compass4D project, which deployed a C-ITS system in seven European cities and coordinated the common evaluation of the technology for three services focusing specifically on safety and environmental objectives under real-world driving conditions.

The significance of the Compass4D deployments and results provides some of the first evidence of the effectiveness of C-ITS in real world conditions. Both light and heavy vehicles showed efficiency savings of 2–6%. Equipped buses exhibited a variety of results with one pilot site showing a reduction of greater than 200gCO_2 per bus route per trip whilst other buses showed an increase in total emissions.

The paper presents results from both field trials and microscopic simulation studies (to understand the network- or city-wide impacts of the technology). It discusses the results in detail before outlining the potential for further deployment in terms of the impact on energy efficiency and environmental objectives. Government and road operators will benefit from the results to gain an understanding of the potential impact of services given specific deployment characteristics.

1. Introduction

Cities in both the developed and developing worlds are under pressure to balance public and private demand for mobility against finite spatial, financial and infrastructural resources, whilst ensuring safety and environmental targets are met.

In the EU-28, passenger transport (passenger km) has grown at 1.0% per annum since 1995, whilst freight transport (tonne km) has grown at 1.1% per annum. Trends in road fatalities are downwards (c.f. 57,000 in 2000 vs. 25,500 in 2016), but the vision of a further 50% reduction in fatalities over 2009 levels by 2020 (EC, 2010) is challenging. Similarly, whilst CO_2 emissions are declining (c.f. 5.1GT CO_2e in 2000 vs 4.5GT CO_2e in 2013) (EC, 2015), the aim of a further 60% reduction in transport greenhouse gas emissions by 2050 (EC, 2011) is ambitious. Health issues surrounding continued exposure to local air pollution and noise have also come to the fore, with nitrogen dioxide levels in urban areas a particular cause for concern (Moldanova et al., 2011).

Amelioration of safety and environmental concerns in road transport can be partially achieved through provision of new, or expansion of existing, infrastructure. However, these are expensive solutions. Attention has turned to Cooperative Intelligent Transport Systems (C-ITS), which offer the potential to increase the efficiency of existing urban infrastructure by improving network

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capacity, whilst simultaneously providing safety and environmental benefits, and reducing fuel and energy demand (Jandrisits et al., 2015). The 2008 'Action Plan for the Deployment of Intelligent Transport Systems in Europe' (EC, 2008) and subsequent Directive on ITS deployment (OJEU, 2010) recognise the role C-ITS has to play in overcoming the limitations of traditional infrastructure, and seek to ensure their coordinated and consistent deployment.

Through targeted C-ITS measures aimed at specific users or vehicles, cities can potentially achieve policy targets, adding value to the road network, whilst reinforcing or encouraging desired behaviours amongst both motorised and non-motorised users. Packages of measures allow a city to become smarter in its overall provision of mobility services.

In this paper, selected findings from the European Commission's Compass4D ("*Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment*") project are presented. Compass4D deployed C-ITS in real-world urban environments and quantified the impacts. Through the results and key findings, it is possible to determine how urban mobility policy could benefit from either selective or wide-scale deployment.

1.1. Background to C-ITS

C-ITS enable direct communication between vehicles, roadside infrastructure and traffic control centres (Jandrisits et al., 2015). The technology, which can communicate vehicle-to-vehicle (V2V) and infrastructure-to-vehicle (I2V) - collectively known as V2X (vehicle-to-anything) – enables traffic management centres to receive precise and comprehensive information from vehicles about traffic situations. This allows a targeted approach to managing flows through a network, for example the ability to deliver signal priority for different types of vehicle. Furthermore, C-ITS can inform drivers about traffic events, such as traffic light phases, current traffic situations and danger zones (Jandrisits et al., 2015; Katsaros et al., 2011), enabling drivers to make informed route choices and implement more efficient driving behaviour. This can potentially result in safety benefits, greater energy efficiency, and a decrease in CO_2 emissions. Drivers not equipped with C-ITS systems may also potentially benefit from its effects, by experiencing fewer unnecessary changes in speed, or a reduction in start-up delays at junctions (Preuk et al., 2016). Conversely, non-equipped drivers may also be disturbed by 'out-of-the-ordinary' behaviour of equipped vehicles in certain circumstances, e.g. long, slow coasting to traffic signals (Rittger et al., 2015).

Early C-ITS research took place in laboratory conditions using traffic micro-simulation and concentrated on algorithmic development (e.g. Tielert et al., 2010; Katsaros et al., 2011; Guler et al., 2014; Kamalanathsharma and Rakha, 2014). Although much simulation work has been performed in isolation, micro-simulation studies have also played a role in setting bounds on the expected impacts of C-ITS systems, as well as ascertaining network-wide effects or critical threshold penetration rates of equipment.

With the majority of the enabling technology already standardised in Europe by ETSI TC ITS (vehicle), CEN TC 278 WG16 (roadside infrastructure), and IEEE 802.11 p/ITS G5 (communications) (Festag, 2014; Lonc and Cincilla, 2016), field operational tests (FOTs) can be implemented to test C-ITS in real-world conditions (Barnard et al., 2011, 2015). A FOT is "a study undertaken to evaluate a function, or functions, under normal operating conditions in road traffic environments typically encountered by the participants using study design so as to identify real world effect and benefits" (FOT-NET, 2015). Thus, drivers use their vehicles under normal conditions with data collected concerning the behaviour of the vehicle, the system, and the drivers themselves, as well as the interactions between them.

A major planned deployment is the European C-ITS corridor, a smart-road deployment project involving road authorities in The Netherlands, Germany, and Austria (Katsaros et al., 2011; Guler et al., 2014). However, the Compass4D FOT deployments (2013–15) provided an early indication of the potential impact of C-ITS technology in real-world driving conditions, and these are the focus of this paper.

1.2. Previous studies

The services offered by Compass4D build on a pedigree of C-ITS studies from Europe, the United States and Japan (Table 1). These have examined the impacts of C-ITS through limited FOTs or simulation studies. Studies have focused on particular types of vehicle or operations using those vehicles on sections of road, typically urban highways. Work has targeted either technology demonstrations of V2X communication, or applications addressing a single policy goal, such as improving safety or increasing energy efficiency, but not necessarily both.

Previous studies have reported Green Light Optimal Speed Advisory (GLOSA) in isolation as being able to reduce CO_2 emissions and fuel consumption by approximately 13% (Eckhoff et al., 2013). Very similar results were reported for the adoption of a dynamic eco-driving system for highway traffic (Barth and Boriboonsomsin, 2009). These values are also in line with the identified benefits from the C-ITS systems in Table 1 for the FREILOT (Blanco et al., 2012) and COSMO (Volvo Group, 2013) project applications.

It is noted that suggested benefits from simulations, studies limited to few vehicles, or on a particular type of road (e.g. highways), may indicate greater efficiency results than those achievable across a real-world urban network (Tielert et al., 2010; Schuricht et al., 2011; Xia et al., 2013). It is also considered unlikely that a combined C-ITS system, such as Compass4D, will yield benefits that are precisely a linear combination of the benefits as suggested for individual components. Nor might it be expected that all vehicle types would share similar benefits in all conditions. Such considerations helped inform the methodology applied in the Compass4D FOTs.

1.3. An overview of compass4D and ITS services

Compass4D collaborated with European cities to facilitate the sustainable deployment of C-ITS. Engaging directly with road