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Evaluation of an Urban Cooperative Mobility Systems

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Abstract

The paper presents the results of the evaluation of the first smart traffic management cooperative systems to be introduced and deployed in the UK. The implementation was first installed as part of the EU COMPASS 4D project between 2012 and 2015 and is being further developed and extended (both in terms of geographic area and in terms of use cases) in a UK DfT (Department for Transport) funded project. The deployment was first extensively evaluated for it's contribution to deliver fuel savings and emissions reductions through selective green light priority. However with the DfT funding the use cases have been extended to vulnerable road user detection and bus management. The short paper (abstract) presented here will be developed into a full paper providing new information never presented before on the evaluation of the Newcastle CITS system.

Keywords: CITS, Energy Efficient Intersection, Smart Traffic Management

Background

COMPASS4D (EC CIP, 2013-2016) deploys cooperative mobility systems in seven European cities, Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona, and Vigo. The systems, which have been developed to improve road safety, increase energy efficiency and reduce congestion for road transport, are:

- Red Light Violation Warning (RLVW) - to reduce the number of red light violations and to minimise the impacts of such violations
- Road Hazard Warning (RHW) - to reduce incidents by means of a system of infrastructure-to-vehicle warnings that raise the driver's attention level and inform them about appropriate behaviour
- Energy Efficient Intersection Service (EEIS) - to reduce energy use and vehicle emissions at signalised intersections

Throughout a 12 month operational phase the services have been piloted by more than 400 different vehicles (buses, heavy goods vehicles, emergency vehicles, taxis, electric vehicles, private cars). The target beneficiaries of COMPASS4D are drivers of buses, emergency vehicles, trucks, taxis, electric vehicles and private cars, as well as fleet operators and traffic managers.

Impact Areas

Six impact areas have been defined, which serve to evaluate COMPASS4D services through assessment of performance indicators:

- Road safety (i.e. accident rates, severity of accidents, severity of injuries)
- Network efficiency (i.e. traffic flows, traffic volumes, travel time, travel time reliability, average vehicle speed, reliability of public transport)
- Environmental impact (i.e. CO_2, NOx, PM10 emissions, fuel consumption)
- Economic sustainability (i.e. maintenance cost, network monitoring, business models for implementation of cooperative systems)
- Traffic network management (i.e. long-term driver behaviour, travel behaviour, compliance, unintended impacts depending on road type, weather conditions, etc.)
- Driver specific metrics (i.e. user acceptance, user experience and compliance, workload and behavioural change)

The analysis is described in simple terms as a two-part question:

- Did the COMPASS4D system make a change?
- Is that change one we desired?

Evaluation of the COMPASS4D Project

Early results reveal that the Speed Advisory system has succeeded in creating the desired change in behaviour. In contrast, whilst the Road Hazard Warning and EEIS are significantly correlated with a behavioural change, it is unclear to what extent this is the change we desire, or its implications on the wider network. Subjective evaluation is taking place through questionnaires and interviews with drivers and other stakeholders. The operational phase, data analysis and evaluation will be concluded in October 2015.

The network-wide Impact of cooperative ITS services is calculated through extrapolation of the impacts of the deployed COMPASS4D services to quantify the benefits to whole networks, cities, and participating organisations. This too seeks to inform the COMPASS4D business model. The provision of network-wide data for different network geometries and demand densities will be useful for evaluating network performance for any European city.

Selected Results from Compass4D Trial

Trial Design

Field Operational Trials (FOT) in Compass4D were designed in alignment with the FESTA V methodology (FOT-NET, 2015). FOTs are an evaluation methodology used to test intelligent transport systems (ITS), specifically their ability to deliver real-world impacts and benefits. To achieve this studies should be designed to evaluate a function, or functions, under normal operating conditions in road traffic environments.

Data Analysis

Analysing the data from the Compass4D system required that there was both a metric to be analysed, a spatial region of interest within which to analyse that metric, and two distinct populations between which the metric could be compared, that is, the baseline and the operational phases.

Due to the size of the dataset, the IDs on each intersection were automatically assigned using a clustering algorithm. The clustering algorithm used the initial plus the final position and heading of the vehicle within the intersection to separate the data sets and "tag" the raw data with the appropriate ID.

To harmonise analysis of the results from each of the pilot sites, a series of Performance Indicators (PI) were created that would allow similar analytical techniques to be used across each pilot site. The majority of the performance indicators were designed to highlight the proposed benefits of the EEIS system or the Speed Advice system, due to the comparative difficulty of creating performance metrics for either the RHW or the RLV use cases. The three most important performance indicators (emissions, duration and number of stops) are presented below. The emissions PI is the total (simulated) emissions across the 500 metre local region of each equipped intersection. The duration PI is the total time taken to enter and exit each intersection whilst the number of stops is the total number of separate "stopping" events. A stopping event is defined as any point where a vehicle drops below five km/hr

Due to the variations in the implementation of the different system across pilot sites such as the difference in data collection or the difference in baseline/operational phase timings (and indeed, what constitutes a baseline or operational phase) the quantitative conclusions are only valid for the particular environment within that pilot site. Results for Verona have been omitted from this paper because the unique nature of the site's objectives means that the results are not comparable to other sites.

Results

Emissions

The effects of the Compass4D EEIS system on the average CO_2 emissions as vehicles pass through RSU equipped intersections for five pilot sites are shown in Table 1. Note that the results for Copenhagen are the total emissions over the entire bus route within the operational area of the Compass4D system.

City	Type	Baseline (gCO_2)	Operational (gCO_2)	% Change
Bordeaux	Light	162	146	-9.88%
	Heavy	928	907	-2.26%
	Heavy (fuel)	222	202	-9.9%
Copenhagen	Bus	5287	4901	-7.30%
Helmond	Heavy	412	396	-3.88%
	Bus	670	674	+0.60%
Newcastle	Heavy	574	563	-1.92%
Vigo	Light	114	114	0.00%
	Bus	651	646	-0.77%

Table (1) The change in emissions between the baseline and operational phase is shown here. The result for Copenhagen is for an entire bus route rather than averaged over a single intersection.

From the data here it can be seen that there appears to be two results within the Compass4D system for the light vehicles. Vigo showed essentially no difference for efficiency within the system, whilst Bordeaux showed a substantial improvement in efficiency (~10%). Data from Thessaloniki, whilst not directly comparable to the data shown here due to spatial characteristics of the equipped network, demonstrated a small improvement in efficiency of 1.7gCO_2/km.

The results for the heavy vehicles appear to be more consistent in emissions reductions with each implementation of the Compass4D system registering an improvement of between 2-4%. The bus data shows the greatest variation ranging from a 7% improvement in emissions for Copenhagen, down to a 2% increase in emissions for Helmond. This comparatively poor (and indeed negative in the case of Helmond) response to the system from buses in Vigo and Helmond is due to a variety of factors.

Duration

The effect of the Compass4D system on the average duration of travel through RSU equipped intersections for five pilot sites is shown here.

City	Type	Baseline (seconds)	Operational (seconds)	% Change
Bordeaux	Light	76.7	74	-3.52%
	Heavy	84.2	78.8	-6.41%
Copenhagen	Bus	875	786	-10.17%
Helmond	Heavy	48.5	46.7	-3.71%
	Bus	35.8	40.5	13.13%
Newcastle	Heavy	47.7	47.4	-0.63%
Vigo	Light	63.8	61.3	-3.92%
	Bus	119	119	0.00%

Table (2) The change in total duration between the baseline and operational phase is shown here. The result for Copenhagen is for an entire bus route rather than averaged over a single intersection.

The data for the total change in duration between the baseline and operational phases for the five pilot sites, shows the same basic pattern of behaviour as that shown within emissions. There is a reduction in total duration across all sites with the exception of Helmond, which sees an increase, and Vigo, which sees no change.

Number of Stops

The effect of the Compass4D system on the average number of stops per vehicle associated with RSU equipped intersections for five pilot sites is shown here.

City	Type	Baseline (No. of Stops)	Operational (No. of Stops)	% Change
Bordeaux	Light	1.14	1.01	-11.40%
	Heavy	1.08	0.953	-11.76%
Copenhagen	Bus	12.6	11.9	-5.56%
Helmond	Heavy	0.405	0.362	-10.62%
	Bus	0.287	0.407	41.81%
Newcastle	Heavy	0.616	0.83	34.74%
Vigo	Light	0.767	0.72	-6.13%
	Bus	2.09	2.09	0.00%

Table (3) The change in the total number of stops between the baseline and operational phase is shown here. The result for Copenhagen is for an entire bus route rather than averaged over a single intersection.

Similarly, the same behavioural pattern is shown here with one anomalous factor in the large increase in stops shown by Newcastle heavy vehicles. Aggregate results collected during this project have shown that an increase in the number of stops should lead to an almost linear increase in the total duration needed to cross the intersection. In Figure 1 the direct relationship between the number of stops and the time to cross an intersection can be observed. This particular data was from the Bordeaux light vehicle set, but similar relationships can be observed in almost all pilot sites and for all vehicle types.

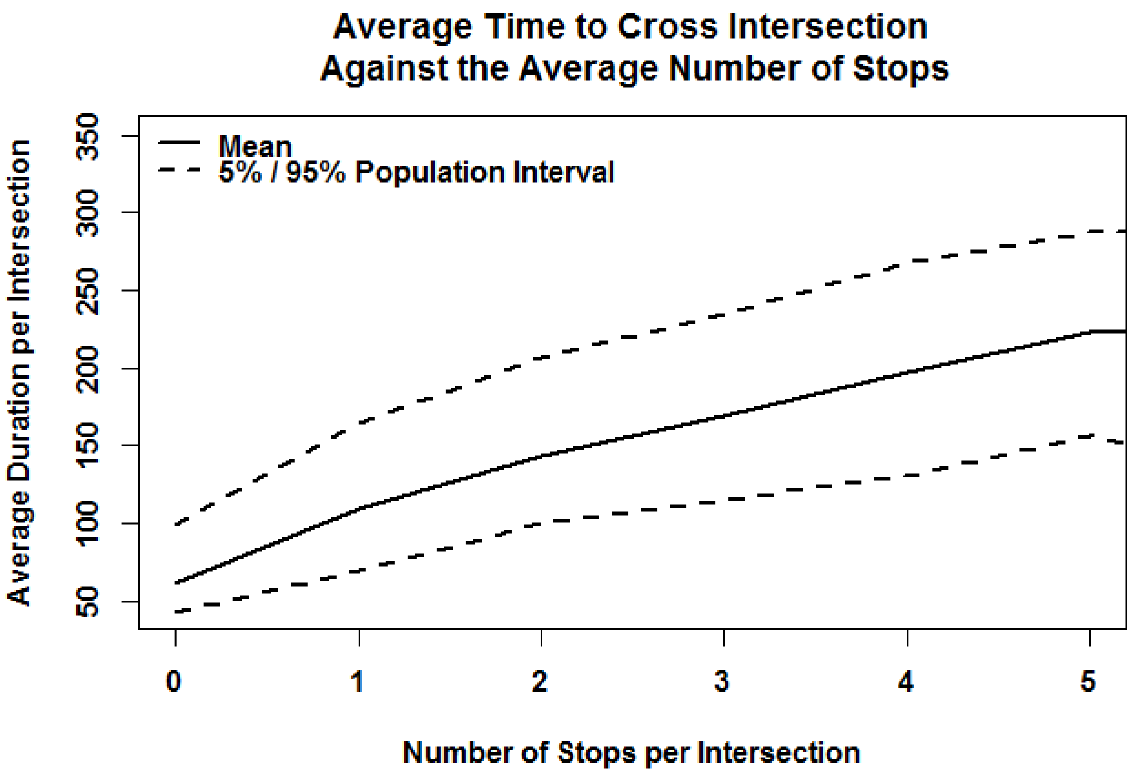

Figure 1 The approximately linear increase in time with the average number of stops per intersection is shown here.

However, for Newcastle the increase in stops was combined with a decrease in the total time to cross an intersection. This is in contrast to other sites where the change in the number of stops was coupled with an identical change (in terms of direction) in the change of duration. This discrepancy in Newcastle can be attributed to two individual intersections which saw a large increase in the number of stops but without the concomitant change in duration. This anomalous result was enough to skew the Newcastle data towards an overall increase in the number of stops without a net increase in duration.

Extending the scope and use cases for Cooperative system in the North East of England

The Cooperative Systems installation in Newcastle is part of a regional ITS strategy to develop the North East of England as a key USP for future transport management. The Urban Traffic Management and Control Centre for Tyne and Wear in association with a large number of regional partners and Newcastle University have committed to develop and roll out cooperative traffic systems as part of a regional smart traffic management project. To part facilitate this the UK DfT (Department for Transport) have invested in an extension to the Compass4D system both in terms of the scale and location of future deployment as well as the development of new case studies, which include vulnerable road user detection, bus management as well as supporting freight management and night-time economy through traffic management to support late night taxi movements.

Summary

The paper has provided some insight into the performance of C-ITS systems through the analysis of results from the coordinated field trails (FOTS) of the Compass4D project. Although this project only considered three use cases it did coordinate the use and data collection of these across its seven sites which has enabled some meaningful cross-comparison and correlations between the sites.

Apart from the new knowledge developed from the evaluation of the three specific use cases in Compass4D the trails indicated what new use cases could be developed with such a C-ITS system. The cities and regions who participated in the Comapss4D project are now utilizing the understanding they now have for the potential of C-ITS to develop innovative use cases that suit their local challenges. In the UK, we have identified that bus priority (to catch up on timetable), evening taxi services, freight and detection of vulnerable road users have all been identified as priorities that will now be integrated and demonstrated in the Newcastle Smart C-ITS corridor in 2016/17. Moreover the research team at Newcastle are exploring how C-ITS can support and enhance vehicle automation by the facilitation of dialogue between the infrastructure and vehicles to initiate certain automated functions, such as speed, eco-driving optima, stay in lane, headway control and ISA as well as focusing on how this intelligent environment and utilizing infrastructure as a service can support older drivers to continue driving safer for longer which is a strategic civic theme of the University in collaboration between TORG and the National Centre for Ageing.

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Disclaimer:

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