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Smart Motorway Innovation for Achieving Greater Safety and Hard Shoulder Management

Nicola Callaghan
Glasgow Caledonian University

Thomas Avery
University of Greenwich

Mark Mulville
Dublin Institute of Technology, mark.mulville@dit.ie

"SMART" MOTORWAY INNOVATION FOR ACHIEVING GREATER SAFETY AND HARD SHOULDER MANAGEMENT

Nicola Callaghan[1], Thomas Avery[2] and Mark Mulville[3]

[1] *School of Engineering and Built Environment, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, UK*

[2] *Department of Built Environment, University of Greenwich, Park Row, London SE10 9LS, UK*

[3] *School of Surveying and Construction Management, Dublin Institute of Technology, Aungier Street, Dublin 2, Ireland.*

"Smart" motorways are becoming more prevalent through technology-driven approaches such as active traffic management (ATM) systems, hard shoulder management (HSM) control systems and digital enforcement cameras. Such technologies are able to monitor and respond to fluctuating traffic conditions by altering the speed limit to smooth traffic flow, activate warning signs to alert users of hazards up ahead and permit the use of the hard shoulder, either permanently or at peak times. This paper investigates smart motorways as a way of reducing congestion achieving greater road safety and improving hard shoulder management. This research is one of the first which deals specifically with the topic of smart motorways, where much of the focus to date has been on smart cities alone. A questionnaire approach was undertaken with 124 members of the public relating to their knowledge of smart motorways. The results indicate that user knowledge of smart motorways was lacking in some areas and that there is an inclination to wilfully ignore some of the "smart" rules of the road which contrary to the intention of smart motorways, may increase the safety risk and CO_2 emissions.

Key words: innovation, management, smart motorways, sustainable infrastructure

INTRODUCTION

The term "smart motorway" is a concept that utilises technologies and procedures such as sensors, cameras and digital displays to monitor and respond to fluctuating traffic conditions. An ATM system is often used to dictate the speed of approaching vehicles and allow the hard shoulder to be used as a running lane either permanently or during busy periods (UK Government, 2016). The use of smart motorways as a way of increasing motorway capacity is a relatively new concept implemented by Highways England (HE). While current HE studies demonstrate improved journey time and reliability (Highways England, 2016a), smart motorways have also been met with some criticism; particularly relating to user safety and increased Carbon Dioxide (CO_2) emissions (UK Government, 2016). Although some research on the impact of smart motorways has been previously carried out (Highway Agency 2016; Unwin *et al*., 2011), the varying research and arguments for and against these schemes has never been formulated into one coherent assessment. In 2016, The Transport Committee launched an

[1] nca2@gcu.ac.uk

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inquiry into how policy on all-lane running should evolve. The report highlighted a gap in knowledge of the extent to which road users understand and comply with signs of smart motorways, and the changes that are needed in driver education and behaviour (Road Safety GB, 2015). As a result, this paper makes an original contribution by gathering data on the level of public knowledge of using smart motorways which could be used to inform future infrastructure management policy.

LITERATURE REVIEW

Management of Smart Motorways

The successful management of smart motorway schemes often relies on the use of an "accelerated programme" which can limit their construction period to less than two years, compared to approximately ten years for a traditional road widening project (Walker and Threlfall, 2016). This can be achieved due to concurrent working, standardisation of solutions and the lack of land purchase requirements as well as a "productisation" approach being taken to deliver the extra capacity required in the most cost and time-effective manner possible. However, according to the Automobile Association (2017) ATM systems are not the answer everywhere and more robust, traditional widening with hard shoulders is still needed on some overloaded sections of motorway. A pilot study of the M42 ATM project was found to be over-engineered, too resource intensive and technology reliant (Birdsall, 2014). Where smart motorways have been introduced, a principle of "design once, use many times" has been developed into best practice (Walker and Threlfall, 2016). However, this approach requires flexibility of project teams due to ongoing adaptation and innovation of best practice. Lean deployment in the supply chain is actively encouraged, with time on site limited as much as possible to reduce disruption for users (Chen *et al*., 2012). As such, work is front-loaded at the design stage and efforts made to make the product more efficient before taking it to the roadside. Smart motorways also promote early contractor involvement and NEC target contracts, which emphasises collaborative partnering and uses a pain/gain scenario (Chen *et al*., 2012; Walker and Threlfall, 2016).

Sustainable Infrastructure

Road transport is a significant source of environmental concern, accounting for nearly 20% of total greenhouse gas emissions (EEA, 2007). It is therefore the objective of many national Governments that motorways should be managed in a way that is sustainable in terms of a low carbon future (Department of Transport (2007). Smart motorway schemes are one example of a technological solution that is being introduced in many countries internationally (Highways England 2016b). Environmentally, any addition of capacity is going to present some challenges, such as increased air and noise pollution (Walker and Threlfall, 2016). However, evidence from existing smart motorway schemes suggests no significant increase in these areas, which could be partially due to the reduction in speed and smoother flow of traffic resulting in lower emissions (Walker and Threlfall, 2016). According to Ladyman (2017) cars travelling below or above the optimal speed range for minimising CO_2 output (approximately between 30mph and 55mph) produce significantly more CO_2 than when they are used at optimal speed. In addition, Unwin *et al*., (2009) states that one of the key environmental benefits from implementing smart motorways is that the scheme makes best use out of the existing road space when compared to traditional widening schemes which results in less impact on the environment during the construction phase.

Quality of Life, Accessibility and Social Well-Being

It may be argued that transportation facilities and networks have the power to shape development, influence property values, and determine a neighbourhood's character and quality of life (The Center for Transportation and the Environment, CTE, 2008). Consequently, the transportation industry has long been concerned with gaining an improved understanding of how transportation investments and policies influence community development. According to CTE (2008) innovative transportation projects help to improve accessibility to people, places and services which could improve social well-being. For example, changes in accessibility to sites, where interaction occurs that both builds and allows people to access social capital, can lead to changes in social cohesion. However, there are concerns over the interface between these motorways and the passing neighbourhoods. According to Picardi (2014), very often vehicles speed by bedroom windows, front gardens and even school playgrounds separated only by the width of a pavement. Furthermore, the never-ending "hum" of motorway traffic is rarely mitigated and these long stretches of black asphalt raise the temperature of their local environment by absorbing radiation and contributing to a microclimate known as the urban heat island effect, a phenomenon that adversely impacts the atmosphere and energy consumption (Picardi, 2014).

Journey Time and Congestion

In 2014, a smart motorway system on the M25 was introduced. For a six month period following the introduction of the scheme the journey times were assessed using data collated from a satellite navigation database and compared to data held prior to its introduction (Highways England, 2016a). A reduction in average journey time across each time of the week and in each journey time percentile was identified, suggesting that the introduction of smart motorway schemes can reduce average journey times. More specifically, it showed that 50% of journey times were more reliable when an "all lane running smart motorway" was introduced. Addressing this percentile range is significant because it addresses the journey time reliability of an "average day" rather than days where significantly increased or reduced traffic due to incidents or events has occurred. However, one criticism of smart motorways is that increased journey reliability is not necessarily a benefit and could lead to "peak contraction" whereby more journeys would occur in a smaller time frame such as rush hour due to the improvement to journey reliability (UK Government, 2016) which could counteract any reductions in traffic congestion. Another potential shortfall of such research is the reliance on data from a satellite navigation database of journeys which have the ability to re-route a journey to avoid congestion (The Automobile Association, 2015). As congestion begins to build, drivers may be diverted off the smart motorway and later re-join after the congested area. This may appear in the results as two relatively quick journeys on the smart motorway as opposed to one longer journey through congestion. Multiple occurrences of this may skew the results favourably to the ability of smart motorways to reduce journey times.

Public Perception of Safety

The perception of the general public seems to be opposed to converting hard shoulders into extra motorway lanes. For example, 59% of AA members state that they would feel more nervous driving on a motorway without a hard shoulder and 85% of members state that hard shoulders make the motorway safer (The Automobile Association, 2015). Walker and Threlfall (2016), on the other hand, suggest that smart motorways improve speed compliance and are therefore safer through the use of overhead mandatory speed limits, driver information, CCTV coverage and enforcement. However, particular

questions have been raised regarding the use of the hard shoulder as a running lane by services that traditionally made use of it to reach their destination more quickly, such as the police or ambulance services. This is emphasised by Cambridge (2016) who states that some drivers refer to the lay-bys which have replaced hard shoulders as “death zones”. Thomas (2016) also suggests that HGV drivers from overseas are unaware of how smart motorways work, and often take breaks in the lay-bys. Additional concerns range from insufficient lighting and signage informing drivers of the new layout, refuge areas being too far apart and a lack of communication between HE and the emergency services (Dunn, 2016).

Parliamentary Objections

The House of Commons Transport Committee (2016) published a report claiming that the conversion of the hard shoulder into a running lane was a “radical change” and an “unacceptable price to pay” for journey improvements. Whilst accepting that the network needs updating to prevent unmanageable congestion by 2040, the House of Commons Transport Committee (2016) argues that there are major concerns over the safety of converting the hard shoulder into a running lane. The cause of concern is due to 28% of those surveyed feeling that the M25 was less safe following the conversion to an all lane running smart motorway. However, perceived safety and actual safety are two different things (Loewenstein et al., 2001). Furthermore, while 28% of those surveyed felt less safe, 72% felt equally safe or safer. The House of Commons Transport Committee (2016) accepts that all lane running schemes increase capacity.

However, it may be argued that this is a “short term solution” with regards to the net effect on journey times. For example, as congestion is reduced, people tend to travel greater distances which results in the same average journey times as before the scheme was introduced (Thomson, 1968). Instead, it is suggested by Winston and Mannering (2014) that more emphasis should be placed on technological advances as a cost effective way to increase network capacity. This is potentially an argument for the introduction of smart motorways, as these utilise the latest technology in an effort to control traffic flow and this investment will serve as a catalyst for improvement and advancement. According to Metz (2016) "you can't out build congestion"; instead it is suggested that further innovation and investment in technology advancement is the only long-term solution. Consideration of technological advancement becomes even more important as cars evolve, which is likely to include "accelerating autonomous driving technology, advances in artificial intelligence, sensors, cameras, radar and data analytics" (Silver, 2017) which can transform not only how road users drive but also overcome some of the potential drawbacks of smart motorways. This argument is underpinned by Power (2016) who states that any new vehicles will require the ability to communicate, both with other cars and with the passing infrastructure.

METHOD

Sampling and Data Collection Approach

This research analysed opinions in order to explain the current knowledge and behaviours of members of the public in order to assess the use of smart motorways. A questionnaire technique was selected to primarily gain an understanding of the underlying views of motorway drivers. A questionnaire was identified as the most appropriate method to draw valid conclusions from targeting a large and varied sample (Sue and Ritter, 2007). The questionnaire was created using Google Forms and distributed via email to respondents of varying ages (between 18 and 65 years), backgrounds and professions,

who were known to the research team (including past employers, colleagues, friends and relatives). The decision to end the questionnaire after only three days was determined by the high response rate, where 124 questionnaires were returned which upholds the normal statistical distribution rule.

Questions Asked

The questionnaire was divided into three sections. The first section collected general background information about the participant including age range; time since the participant passed their driving test; how often the participant drives and how often the participant drives on a smart motorway. Conclusions could then be drawn on how the performance of smart motorways may change over time or as they become more commonplace or how new/experienced drivers should be further advised on their use.

Section two included multiple choice questions to identify the participant's level of the knowledge and understanding of smart motorways. Questions included; what does the red "X" above the lane indicate; whilst driving on a smart motorway, if your vehicle experiences difficulties e.g., a warning light appears, what should you do and; when should you use the refuge area.

The final section was designed to ascertain if the participant was likely to intentionally disregard the rules of the road, which provided a distinction between a lack of understanding and lack of discipline. Questions asked such as; do you ever choose to ignore the displayed speed limit were subsequently followed up asking why, again using a multiple choice technique. Respondents were typically asked to select an answer from six options (including a "don’t know" response).

Analysis Technique

The survey was carried out on an anonymous basis which was imperative as it required road users to potentially admit to wrong doing (Stangor, 2014). One of the benefits of using Google Forms was that all of the responses were collated onto a single spreadsheet. Simple coding was used for each multiple choice option followed by calculating basic response frequencies and percentages. However, further statistical analysis would have allowed for stronger conclusions to be made.

DISCUSSION OF RESULTS

Level of Knowledge

The results show that 61.3% of those surveyed were aware of what is meant by the term "smart motorway". This is indicative and serves as a barometer of how successful the HE and UK Government have been at informing the population about smart motorways. Although it is an indicator of the awareness of the population, it is not an indicator of the ability of the population to use a smart motorway as it is intended. According to The Royal Academy of Engineering (2012), the majority of smart infrastructure systems use a feedback loop which collects data, processes it and presents it in a way to help a human operator make a decision. As a result, road users play a crucial role in successfully completing this loop, which can only be achieved with increased levels of user knowledge.

Of those surveyed, 89.5% understood that the refuge areas are only to be used in an emergency when there is no hard shoulder. However, this contradicts research carried out by the RAC which revealed that 52% of respondents did not know what an emergency refuge area was (RAC, 2017). One of the criticisms of smart motorways relates to them being unsafe because of the potential for a car to be stopped in a live lane (Dunn, 2016).

Moreover, the research by the RAC (2017) states that 64% of respondents did not know what to do after stopping. If the refuge area is perceived as something that should never be used (3.2% of those surveyed thought this) or as something to be used for a break (4% of those surveyed thought this), then there is an increased possibility of a car becoming stopped in a live lane. This is due to a driver either refusing to use a refuge area in an emergency, or being unable to because it is fully occupied with those who believe it can be used to take a break. Of those surveyed, 71% understood that the hard shoulder should be used only when directed to. Therefore, it may be argued that the safety of smart motorways could be hindered due to a lack of understanding regarding use of the refuge area. However, HE (Highways England, 2016a) state that smart motorways have no adverse effect on safety. The challenge here lies in establishing the various positive attributes of smart motorways from a safety, infrastructural and technological perspective (Smart Transportation Alliance, 2015). Furthermore, internationally recognised best practices should be followed when maintaining, upgrading and modernising existing infrastructures (Smart Transportation Alliance, 2015). This also aligns with that of Walker and Threlfall (2016) who emphasises the importance of a collaborative approach in reducing road mortality and injury rates.

The results indicate that there is a relatively significant lack of knowledge surrounding key aspects of smart motorways. This lack of knowledge could indicate that value may be added with relevant education and the publication of further guidance related to driving on smart motorways. However, this assumes that drivers would use the smart motorway as intended if they properly understood how to.

Driver Behaviour

The discipline of drivers on smart motorway tends to vary depending on which rule is being proposed. The vast majority of drivers never choose to ignore the red "X" which identifies that a lane should not be driven in. However, 47.6% of those surveyed admitted to ignoring the speed limit at least some of the time. In addition, “motorists across the UK have faced up to £526 million in fines, after 210,538 drivers have been caught exceeding the limit, which can drop from 70mph to speeds of just 20mph, with more variable speed zones planned across the UK as part of so-called smart motorway schemes” (Rodger, 2017). This willingness to ignore a rule that is fundamental to one of the main benefits of a smart motorway, suggests a strong possibility that overall performance is being hindered. This aligns with the results of the UK Government (2016) which states that “poor compliance with Red X signals is a grave concern that not only puts motorists at risk, but also places vehicle recovery operators, emergency services, and traffic officers in harm’s way”. This highlights the wider implications of non-compliance of smart motorway instructions.

Furthermore, 15.3% of those surveyed admitted to ignoring the hard shoulder when it is being displayed as a running lane at least some of the time. The use of the hard shoulder as a running lane is a fundamental part of smart motorways as it is the method of increasing capacity without widening. The reasoning given for the refusing to obey the speed limit implies that the majority of drivers do this consistently when certain criteria are met. For example “the traffic is not sufficient to warrant a reduced speed limit” was the reason given by 52.5% of those who admitted to ignoring the speed limit. This was followed by 29% who said that they ignored the speed limit "to keep up with the flow of speeding traffic". The results show that there is a proportion of drivers that willingly choose to ignore the rules of the road. It is therefore suggested that an improved performance of smart motorways may require increased enforcement of the rules of the

road. This suggestion is further justified by some of the reasoning that participants gave for ignoring the speed limit as 11.9% of participants who admitted to ignoring the speed limit did so because speed limit was not enforced.

General Observations

It was observed that those aged between 21 and 39 were more likely to ignore the rules which are important to the performance of a smart motorway.

When the participants were categorised in terms of the length of time since they passed their driving test, a negative trend between this and their level of knowledge of smart motorway. This could imply that the design of smart motorways is not very intuitive for drivers with significant experience driving on standard motorways prior to their existence. It could also imply that there is a level of complacency within drivers with regard to taking on new driving rules which increases over time subsequent to passing ones driving test. It is suggested that drivers should not be considered as homogeneous and that a multi-faceted approach is needed going forward. This is also supported by the Transport Committee (2016) who states that the HE should target their awareness campaigns at "different groups, including disabled, elderly, novice, or drivers of any gender".

CONCLUSIONS

The published literature on smart motorways emphasised improvements in both journey times and journey reliability but there is currently a lack of information on the reduction of CO_2 emissions.

Although some perceived benefits of a more reliable journey time were identified, it also raised the question of "peak contraction" which arguably counteracts any reductions in traffic congestion. One of the most important considerations raised by the research is that of user's safety, particularly, with regards to the use of the hard shoulder. With regards to user compliance on smart motorways, the results showed that a significant proportion of the drivers surveyed willingly choose to ignore the rules of the road. It is therefore suggested that an improved performance of smart motorways may be brought about by increased enforcement.

It was identified that knowledge of how to drive on smart motorways tends to decrease as the time since passing ones driving test increases. It can therefore be assumed this trend is related to the intuitiveness of the design of smart motorways, a complacency that drivers acquire over time or a combination of the two. A link between the frequencies of driving of the participants and their knowledge of / behaviour on smart motorways was not observed, however the sample size for those who said they drove rarely or very rarely was very small. As a result, a more quantitative classification would enable a more scientific conclusion. Instead, this research has identified the level of public knowledge surrounding the use of smart motorways. By continuing to improve the skills and attitudes of drivers, the UK Government has the opportunity to improve traffic congestion and safety standards and further reduce the personal cost to people affected by road collisions.

Future Research

Future research is needed to determine the relationship between how many road users fail to use the hard shoulder as they should, and the performance of the smart motorway to establish more accurately the impact that a lack of knowledge or discipline has on performance. Furthermore, additional monitoring of smart motorways is required in order to determine their tangible benefits (such as cost savings).

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