Information Sharing Proof of Concept

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This report describes an investigation of whether there are tangible benefits to the physical transport infrastructure from the better sharing of data. The investigation builds on the STRIDE project, an *Internet of Things* Technology Strategy Board project, looking at the collation of disparate data via an information hub to produce enhanced information sources for re-use, and applies this to physical infrastructure in the Cambridgeshire A14 corridor as a test of its wider applicability. The possible benefits extend both to better use of existing assets and to better-informed drivers. Both technology, and human issues concerned with governance, privacy and cooperation are considered in the report.

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Appendices (on http://www.damtp.cam.ac.uk/user/pvl/APPENDICES/)

The work was undertaken by BT Research and Innovation and Cambridgeshire County Council, with additional contributions from Atkins, Cloud Amber, Neul and Steria. It was coordinated by Peter Landshoff, Professor Emeritus at Cambridge University.

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1 Summary of key findings and recommendations

- It is important to make better use of information to increase the effective capacity of the road system, so as to avoid the environmental and monetary costs of laying more tarmac.
- The road system should be treated as a single entity even though many organisations have responsibility for it[1]. (No journey begins or ends on a Highways Agency road.)
- The potential for conflicting and inconsistent actions by different stakeholders will always be present but one can aim to reduce this by making sure that people make decisions based on the best available information.
- Where possible, information should be transferred electronically rather than person to person, so that it is made available rapidly and to all that need it. This is best achieved through the use of data hubs and, as far as possible, by machine-to-machine processes. Each organisation connected to a hub decides what information it is willing to share and who is allowed to see it.
- There should be a web site for easy discovery of both commercial and open data, with minimal metadata descriptions of them.
- There is an urgent need to provide more, and more expeditious, exchange of information among those involved in the handling of incidents – the police, Highways Agency traffic officers, fire service etc. In particular it is important to bring in the knowledge of local authorities on the appropriateness and availability at the time of previously-agreed diversion routes.
- A set of scenarios should be modelled for each strategic route, so as to inform the best diversion strategy when an incident occurs.
- It is important to avoid the need for numerous local negotiations, and therefore to decide at national level[2]
    - the system architecture, data formats, procedures and protocols
    - which agencies should participate
    - what different agencies should be able to see
    - how to bring together networks with different security restrictions
- As part of this, there is a need for all agencies, especially public sector, to clearly define their key objectives and needs so that data and information services can be designed or adapted to meet these purposes.
- The low level of information infrastructure on local authority roads compared with Highways Agency roads needs addressing, and steps should be taken to overcome the problems resulting from the unavailability of local authority staff

[1] This is in line with the Department for Transport's *Action for Roads* policy, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/212590/action-for-roads.pdf

[2] The Cabinet Office project MAIT (Multi-Agency Information Transfer), http://mait.org.uk/, is appropriate for this. It now includes a previous project DEIT (Direct Electronic Incident Transfer).

out of hours when an incident occurs.

- It should be mandatory for those undertaking road works to transmit electronically to the road authority concerned notification immediately after they have begun and ended.
- More work needs doing on the most appropriate technologies to replace obsolescent methods of monitoring traffic flows, such as MIDAS loops, and particularly technologies that can be applied effectively and cheaply to local authority roads.
- More work needs doing on the most appropriate technologies to give drivers continually-updated information about the road system, particularly warnings about incidents and their expected clear-up times. Variable-message signs are too widely-spaced and all too often display information that is not relevant to a particular driver.
- The route to universal adoption of such new technologies, and the means to cope with their inevitable obsolescence, needs careful planning. New systems will need to run in parallel for several years with existing ones. There must be debates on privacy issues, and the benefits from people cooperating should be publicised.

2 Approach and scope

The general approach of the study is to treat the road network as a single entity with multiple domains of control[1]. The Cambridgeshire part of the A14, which is highly congested, was used as a laboratory, but the findings are applicable to the whole of the UK road system. Specific issues that were addressed include

- Examining the existing information and data architecture, and business process, and identifying where changes could be made to make better use of them to manage the road system
- Engaging with the various stakeholder organisations and understanding what their existing processes are and how they consider they could undertake their role better
- Evaluation of other potential information sources: sensors and social media.
- Analysing the management of incidents to see whether the duration and effect of an incident could be reduced by the better sharing and use of available information.
- Better sharing and processing of diverse data sources to enable motorists to make more informed decisions – ‘how does a driver know what is happening at the front when they join the back of a queue?’
- Making existing transport models more effective by enabling results of actual incidents and events to be dynamically fed into models instead of updates being provided as one-off events each few years

The main issues with the use of information are not just the development of better technologies, but persuading people of the need to collaborate and creating governance processes to handle questions such as privacy and data ownership. A great deal of data is already available; the challenge is to bring it together in a way that makes it available for re-use in a way that enables others to makes best use of it.

3 Background

The study is under the umbrella of East of England Transport Information (EETI), a collaboration that began in 2009 at the instigation of the Department for Transport. Among its active public-sector partners are

Cambridgeshire County Council
Essex County Council
Suffolk County Council
Department for Transport
Highways Agency.

BT Research and Innovation is key to the collaboration, and there is active involvement also from a number of freight organisations.

EETI's central aim is to make more effective use of the road network, without laying more tarmac, in particular to

- Reduce congestion
- Reduce transportation costs

Experience with information-technology projects has been that it is mistake to try to do too much at the outset. Therefore EETI's general strategy has been to start with something simple and localised (initially the eastern half of the A14) and then gradually add in more functions and extend the area – first to the whole region, ultimately the whole country. A key aim is to prove that there are incremental steps to wide deployment, with each step kept small and simple.

A particular focus of the work of EETI has been on the better handling of incidents. Work carried out by EETI in 2009-10 showed that

- There is an urgent need to provide better communication and exchange of information among those involved – the police, Highways Agency traffic officers, fire service etc
- In particular it is important to bring in the knowledge of local authorities on the appropriateness and availability on the day of using previously-agreed diversion routes.

The study makes use of the output from a project funded by the Technology Strategy Board as part of its *Internet of Things* activities and led by BT, named STRIDE[3]. It began in April 2013 and it included the creation of an information hub that allows the input of every kind of information, from a variety of sources, so that it can readily be made available to all those with a need to know or those who create applications to use the data.

[3] STRIDE (Smart Transport Internet of Things Data Ecosystem): http://www.stride-project.com/tag/transport/

The study reported here was funded by the Department for Transport to build on these initiatives and to explore the benefits of implementing the EETI recommendations and also the outputs of the STRIDE project.

4 Key principles

Managing road networks involves considering the infrastructure, the traffic that moves on it and the people and goods that are conveyed in the vehicles. There are therefore a large number of independent stakeholders, each with their own organisational objectives, processes and systems. A traditional IT approach would be to try and define an optimised process between these organisations. This is highly complex, time-consuming and difficult to manage, partly due to the potentially conflicting priorities of the organisations involved. This proof of concept has taken as key premise a different approach. Namely, a more effective overall solution can be achieved by enabling each of the involved organisations to make improvements to their own processes.

The key principles underlying the study are therefore:

1. Organisations and individuals are able to make more effective and efficient decisions if they have immediate access to the information they require
2. Much of the required information is already available; however it is typically locked into separate systems.
3. Decision makers are the best judges of which information they do and do not need. Decoupling information provision from information usage will simplify the cost and speed of integrating organisations.
4. In line with the government's Open Data principles[4] making information available will create an environment for innovation, enabling entrepreneurs to develop new services and applications that support the wider roads and communities ecosystems.
5. Where possible, information should be transferred electronically rather than person to person over the phone.

5 Information hub

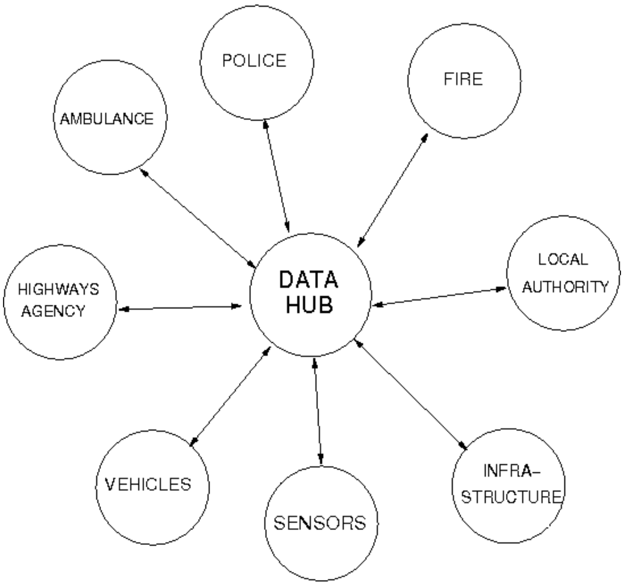
A central element to this architecture is the information hub, which is built on the *Internet of Things*[5] principle and whose purpose is to facilitate the rapid exchange of continually-updated information, via a publish and subscribe regime, among all those concerned with managing an incident, as well as giving information to road users to allow them to make informed decisions on whether to try to avoid the incident.

The role of the information hub is to make it relatively simple to set up and exchange information with a number of other interested parties. Traditionally this has been a complex, costly and time-consuming activity, with individual agreements having to be put in place between each pair of cooperating organisations. An information hub helps address this by requiring organisations to establish only a single connection to

[4] *Open Data – Unleashing the Potential*, Cabinet Office, June 2012, http://www.cabinetoffice.gov.uk/resource-library/open-data-white-paper-unleashing-potential

[5] https://connect.innovateuk.org/web/internet-of-things

the hub. The hub then takes on the responsibility of managing the information flow to other appropriate partner organisations, with each deciding what



information it is willing to share and specifically who is allowed to see it. Subject to these permissions, organisations can then choose which elements of the information they wish to extract to help them with their processes. The hub must ensure that the confidentiality and security policies for the information supplied are explicit, agreed and delivered.

Projects such as DEIT[2] (Direct Electronic Information Transfer) have already started along this route, showing how hub architectures can help with the specific issue of reducing the cost of connecting organisations together. The difference with the approach being followed in this study is that DEIT essentially requires the information provider to direct information to allowed information consumers – the decision to share information sits with the information provider. The model described here makes it more of a joint responsibility.

Details of how the hub is used to manage information are given in Appendix A.

6 Management of incidents

A key part of the study was to understand what additional information organisations need, and in what time frame, to enable them to improve their part of the overall management of incidents and consequential congestion.

Discussions with the Cambridgeshire police revealed that when they arrive at an incident they tap details into a hand-held device. They then spend up to 10 minutes phoning Fire and Ambulance, and so the police suggested that there is an obvious need to set up automatic exchanges of information via a hub. The study set out to prove this concept, to seek evidence that where data and knowledge are shared and combined in an intelligent and efficient manner there are tangible, beneficial outcomes for the physical transport infrastructure, for example by improving the effectiveness of diversion routes.

Negotiations with both the Cambridgeshire police and fire services, and to some extent also with the East of England Ambulance Service, turned out to be time-consuming and complex. A particular concern to the police is the confidentiality of personal data, such as people's names or car registration details. It was eventually agreed that the police control room system should have a direct connection to the data hub, but that only certain of its data fields should be fed into it. At the time of writing, this is still awaiting Home Office approval.

When the outputs from the proof of concept are deployed more widely, decisions about cooperation among the three emergency services will need to be taken at national level. Ideally, all emergency service control rooms should be designed so that they can easily interface with each other and with appropriate information hubs in such a way that data confidentiality is secure.

A meeting in Cambridge on 13 March 2014 brought together officers from the Cambridgeshire and Suffolk police forces, the Highways Agency Regional Control Centre, Cambridgeshire County Council Highways Management Centre, the Department for Transport and BT. The meeting reviewed the process for managing incidents and confirmed the need greatly to improve the automatic sharing of information. Among the detailed points made were:

- It is important to sort out at national level what different agencies should be able to see (at present it tends to be all or nothing) and how to bring together networks with different security restrictions.
- The responsibilities of different agencies in the case of an incident need documenting. At present there is wasteful effort because the default is to assume, often correctly, that others have not taken necessary actions.
- The arrival of connected cars increases the urgency to supply information to individuals that is both relevant to them and more understandable. A particular problem is with specifying location: "Junction 23" means little to most road users or to local authorities.
- Incidents on local-authority roads are generally handled much less efficiently than on Highways Agency roads. There is wide variation among local authorities, between having 24-hour control centres to having none at all. Not all local authorities even have a single phone number that the police or the Highways Agency can call in case of need.

We attended a cold debrief about an oil spill on the M11 in September 2013, which was described as a particularly difficult incident. The incident lasted 13 hours, though that it would do so was not apparent at the start. Present at the debrief were Essex police, Highways Agency and Amey (which took over from Skanska as contractor to the Highways Agency on 1 April 2014). Among the points made were:

- Airwave[6] has problems. Not only is it expensive, it is complicated to use because it has several channels, each for different purposes and with different ownerships.

[6] http://www.cambridgewireless.co.uk/directory/orgprofile/default.aspx?objid=36227

- Conference calls between all the parties, including the media, were a great help. Automating the exchange of information would be valuable.
- Identifying what was happening on stretches of the road between cameras was a problem, though it was helped by photos tweeted by drivers.
- Closure of the Essex control room at 7 pm did not help. It would have been useful also to use the Cambridgeshire variable-message sign system, but it was not yet available. It was agreed to recommend that the Highways Agency should have access to local authority variable-message signs out of hours.
- It is up to the contractor to decide how to restore the road. This usually works but can sometimes cause tension if police or Highways Agency think it should be done differently. Procuring specialist equipment can be difficult: locating the nearest may need several calls and none might be available nearby. The Highways Agency's new asset support contracts are financially driven and limit what is available on standby.
- Data technology should help allocate more efficiently both resources and who does what.
- The police are good now at freeing lanes as quickly as possible, though forensics still take priority in the case of a crime scene.

More details of our work on the management of incidents may be found in Appendix B.

7 Information sources

To improve the visibility of the network outside the strategic road system requires more data from third parties, or additional sensors. A step change should be anticipated in the number of sensors on the road system and attention must be paid to associated systems, such as street lighting, that may have use for traffic flow detection or data collection.

Sensors must be added cost effectively, to provide sufficient detail, coverage and accuracy. For example, today

- GPS location is increasingly available on smart phones so, with user consent, a smart app could provide location data. Even with out this, tracking through mobile phone cell identification is now good enough to help inform decision making.
- Satellite navigation units identify the specific road but at present only a small number are networked for real-time use. Satellite navigation companies sell this data but it can be costly and can be limited in how it can be used.
- Fleet-management companies use satellite navigation, so they know the specific road a vehicle is on and they have a network connection, but the data set may be very small and of limited value if the fleet is primarily on the strategic network rather than smaller roads.

The existing sensors on the strategic network have non-trivial installation requirements. They are typically mains powered and are close to network connection points; to replicate this onto more of the UK road network would be prohibitively expensive. We looked at the options for collecting information cost effectively from new sources; those studied were traffic sensors and social media.

The work on traffic sensors was split into two parts, a paper-based evaluation and a later field trial to test selected sensors in real world scenarios – optical fibre, and wireless devices based on Bluetooth and Wi-Fi. The object was to assess whether different sensors can cost-effectively provide information that will help both the local authority and road users. We concluded that a fibre sensor can potentially cover a large number of roads from a central location, but more work needs doing to conclude that this is a practical means to detect traffic. Wireless detection methods are promising, but to achieve the necessary accuracy it may be necessary to combine wireless data with other vehicle-counter data. Details are in Appendix C. More work is needed to evaluate wireless detection against existing vehicle detectors and to assess ways to reduce running costs while allowing enough information to be transmitted to management centres.

The purpose of the analysis of social media was to understand whether information sources such as twitter can be mined for valuable information. Interviews with the organisations involved in managing incidents indicated that some tweets, especially those containing pictures, can provide them with valuable information. We have created an automated filter that can deliver a stream of traffic-relevant information. Our experiments showed that our approach gives an accuracy for traffic-relevant tweets of approximately 90%, at the expense of some loss of accuracy for non-traffic-relevant tweets. This compares very favourably with other known approaches. In most real-world applications, it is the accurate identification of relevant tweets that is most important. Thus the loss of accuracy for non-relevant tweets is less critical. Further information is in Appendix D. More work is needed to determine if and how social media data can add significant value in traffic management.

8 Direct communication with vehicles

This activity looked at information interchange between vehicles and the information hub. The aim of this work was to explore the use of new machine-to-machine technologies, along with novel wireless connectivity solutions, to demonstrate innovative ways to gather and distribute information. The study looked at what information can be provided from the hub to the vehicle, whether information can be cost-effectively provided from vehicles about road conditions, whether machine-to-machine protocols can be used to transfer data in small packets (to minimise the network costs), and whether TV White Space can be used as a low-cost carrier network for this information.

We investigated how much data is needed to provide a core transport information service to and from vehicles, and what a wireless network solution architecture might look like. We developed a smartphone-based application, built upon existing work from the STRIDE[3] project, that can send and receive relevant data to and from vehicles, and a message protocol that can send this information with a limited amount of data. We then created a demonstrator based on this application, plus an information distribution component with the capability to route different information to different devices, based on the source of information or the location of a device.

Part of the STRIDE project was to use smartphone acceleration monitors, GPS capability and other smartphone sensors, to analyse drivers' behaviour, and we have extended this to provide information about traffic flows. If a sufficient number of drivers can be incentivised to install the smartphone application, this should be a good method to gain information about traffic flows on poorly-instrumented local authority roads.

Finally, we demonstrated the use of TV White Space to send and receive small data packets (time, location, direction and speed within 40 characters) to and from a moving vehicle along the A14 over unlicensed spectrum. However, there are outstanding issues such as the regulatory environment and the so-far limited number of vendors; therefore there is still a large degree of uncertainty around the best radio solution to use. The most suitable protocol for machine-to-machine applications appears to be Weightless[7], though it is lacking in major industry players support for chips and devices, and there are issues over real-world coverage ranges, size of antenna needed at the terminals and cost of power amplifiers. Also it is not optimised for mobility management and fast handover between cells.

Details of this work are in Appendix E. Further trials should be carried out using standard cellular-phone communications, to determine for example what information should be sent to vehicles. And more work needs doing, in consultation with Ofcom, on issues related to spectrum, antenna and transmitter power.

9 Network modelling

The purpose of this work was to set out the current extent to which the geometry and theoretical capacity of the A14 corridor can be assessed and mapped, using available data sources to understand the current usage and operational characteristics. The study focused on two specific incidents on the road network in 2011 and 2012. Low sample sizes and breadth of data for specific days in the past made it difficult to obtain a full view of all of the impacts of an incident, although the traffic model was configured to represent the metrics that are available.

It was concluded that there are a number of areas along alternative routes in the corridor that have low levels of residual capacity, and that it is these pinchpoints that determine the capacity of the whole diversion route. This indicates that even if the motorist had greater knowledge and ability to divert, the quality of the routes then available to them would not necessarily be high. There are also specific areas along the A14 itself that have low levels of residual capacity and therefore are likely to react more significantly to any incident along that particular length of road.

While a number of data sources are available, the data which they hold for defining the level and pattern of diversion due to an incident are limited. For example, the sample size of the TrafficMaster data on any specific incident day is comparatively small, and there are a limited number of traffic count sites that cover historical days including those of an incident. Currently, only the long-term Highways Agency Traffic Information Database for the A14 and A428 is used in analysing flow changes due to an incident, which leaves uncertainty in the level of diversion onto other alternatives.

This analysis has shown that between 30% and 35% of the traffic that diverts from the A14 due to an incident, or is held within a queue on the A14, diverts to the A428

[7] http://www.weightless.org/

corridor at Caxton Gibbet. This level of direct A428 transfer increases closer to Cambridge, indicating that there is also some diversion taking place through more minor routes between the A14 and A428. It can be seen that there is also higher flow on the A14 after an incident than is typical for that time of day, and that this is potentially representative of the level of traffic that is held in a queue on this route.

The ability of adjacent roads in the corridor to absorb additional traffic that has been diverted from the A14 due to an incident was analysed. A number of areas of low residual capacity were highlighted that have the potential to exhibit increased delay if an incident occurs on the A14 and traffic diverts onto these alternative routes. Initial analysis has highlighted that there are limited options for providing temporary or permanent alternative arrangements at these key pinchpoints. While improvements to specific movements could potentially be made, this would come at the detriment to other movements and road users.

The levels of residual capacity in key routes parallel to the corridor are restricted by these key pinchpoints. Analysis has shown that the level of available capacity on each of these routes is restricted to between 500 and 1000 Passenger Car Equivalents[8] per hour across the day, indicating that the primary alternative routes to the A14 would be unable to operate effectively should all of the A14 traffic attempt to divert due to an incident. This demonstrates that if a more effective methodology of communicating an incident to the public is developed and more people are able to divert, this diverted traffic is still likely to be faced with a low-quality route and hence it is import that such eventualities are well managed.

The impact of roadworks on the network during the time of the incidents was analysed; they had little to no impact.

Further information about the modelling exercise may be found in Appendix F, including a recommended strategy for its enhancement.

10 Advances in technology

Consideration should be given to how new technologies can challenge well-established practices. For example, automated information distribution could enable new approaches to identification and allocation of available resources, such vehicle-recovery contractors, or repairs on the local-authority network.

A meeting in Cambridge on 26 March 2014 brought together experts in technology and in transport to discuss how developments in technology will change the way that the road system is managed and how information is conveyed to drivers. The discussion focused on Highways Agency roads. Some of the points made were:

- Motorways are well serviced, but not A roads. The challenge is how to improve the latter without large capital investment.
- A possible solution is to put wireless infrastructure onto roads. An assessment would have to be made of how much bandwidth would be needed and what would be the smallest useful data package to transmit into vehicles.
- In-vehicle equipment should not only give information to the driver; it should also encourage adjustment to driving to make better use of road space. The

[8] http://en.wikipedia.org/wiki/Passenger_car_equivalent

transition period with partial vehicle/ driver communications coverage is a challenge; one cannot rely on people having latest smartphones.

- It was suggested that floating-vehicle information, which already largely exists, might replace loops for signal control.
- A policy and governance framework is needed to prevent data silos being created, perhaps by creating a data market.
- Autonomous vehicles and road trains are potentially important, but fragmentation[9] is an issue, and who has the responsibility and carries the risk?
- Parking spaces should be instrumented, and people informed with the same technology used for public transport information.
- More attention should be given to prevent drivers falling asleep. This becomes the more important as the number of elderly drivers increases. An issue is the business case for safety improvement.
- As the time needed for the gathering and analysis of data decreases, real-time network modelling will become increasingly important for network management, if it can be demonstrated to make a difference.
- Data should be used to review the success, or otherwise, of past decisions.

A further meeting on 30 May 2014 paid particular attention to the problems with local authority roads. Among the points that were made were:

- Local authorities need better information to help them make good decisions. But they have very little recurrent spend money, so in particular there is a need for cheap connectivity.
- More intermediaries are needed to aggregate data and turn them into services, particularly for local authorities. But they should not have to deal separately with the different local authorities.
- A market place should be created for those who have data to sell.
- There should be a web site for easy discovery of both commercial and open data, with minimal metadata descriptions of them[10].
- Work should be done to uncover and overcome the obstacles to sharing best practice – governance, intellectual property protection etc. Business models should be created to help different organisations work together.
- Sensor points should be set up where a variety of devices can be plugged in.
- On average cars are only about 25% occupied. There should be a study of what makes people comfortable to share journeys, and whether getting better information would make them readier to use public transport.

It was pointed out that most of these issues are relevant not just for transport.

More complete notes of the meetings are in Appendix G.

[9] See, for example a talk by Martin Green, http://www.cambridgewireless.co.uk/Presentation/Martin-Green15.05.14.pdf

[10] This recommendation is not new: see http://www.escience.cam.ac.uk/projects/transport/ntdffinalreport.pdf