Big Data, Technology and Transport: The State of Play

A Sustainable Built Environment National Research Centre (SBEnrc)

Final Industry Report

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Preface

The Sustainable Built Environment National Research Centre (SBEnrc), the successor to Australia's Cooperative Research Centre (CRC) for Construction Innovation, is committed to making a leading contribution to innovation across the Australian built environment industry. We are dedicated to working collaboratively with industry and government to develop and apply practical research outcomes that improve industry practice and enhance our nation's competitiveness. We encourage you to draw on the results of this applied research to deliver tangible outcomes for your operations. By working together, we can transform our industry through enhanced and sustainable business processes, environmental performance and productivity.

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Synopsis

Traffic congestion and disaster response are key issues facing transport planners and managers around the world with many now asking if there are promising technologies emerging that are offering new solutions. For instance, in the US alone the cost of congestion was estimated to be over $120 billion in 2012. Australia's capital cities were estimated to have a combined congestion cost of $16 billion in 2015, which is expected to increase to $37 billion by 2030.[1]

The rapidly growing level of technology enablement of vehicles and urban infrastructure, combined with the growing ability to analyse larger and larger data sets, presents a significant opportunity for transport planning, design, and operation in the future. However, like many emerging technology areas, there is both great interest and great hype around 'Big Data'.

Building on two academic reports,[2] the purpose of this industry report is to provide a clear summary of how real value can be developed with evidence of actual implementation. It is clear that despite the opportunities of Big Data not yet being fully realised it presents a valuable tool for transport planners and managers around the world.

Acknowledgments

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Big Data, Technology and Transport

Key Findings

Using data to improve the management of transport networks is nothing new, but our research suggests that the coming decades will see a massive shift in how we generate and harness data that will completely change the game. Those that can quickly identify and access the important data and use it to enhance decision making will find it a very powerful tool; however, it has some complexity that is yet to be unravelled.

For transport managers, efficient data access and use has the potential to enhance the ability to digitally simulate transport planning options, inform the greater utilisation of existing infrastructure and modal interconnections, and significantly improve disaster and emergency responses. However, after these early wins comes the real value, being able to predict issues or bottlenecks before they occur. Given the right data and software this can be done by comparing historical records to real time data streams to see if current conditions are shaping up in a similar way to conditions associated with past issues, such as congestion hot spots.

When the term ‘Big Data’ is used, it typically means data sets that are so large they cannot be analysed using current methods. To get an idea of the scale we are talking about, consider that a study by transport researchers in Tokyo, that had access to GPS data from over 18,000 taxis across the city, generated some 360 million items of data per second.

Given the scale of Big Data, this then calls for new computer-based data analysis software, referred to as ‘Big Data Analytics’. For example, this report will discuss software called ‘Hadoop’ that is able to analyse data on many servers at once to run traffic scenarios and has been shown to be able to carry out collision analysis on 2.4 billion vehicles in just ten seconds. The report also shows that there are now software companies offering such services with the company ‘HERE’ professing to be able to collect data from over 2 billion traffic probes per day and compare it to historical data to predict traffic congestion issues.

It is not news that there is more and more data available about the transport network and its users. Data has long been collected on traffic counts, average vehicle speed, weather conditions, and traffic signalling. This data forms a valuable database of historical conditions; however, what is more interesting is the promise of new types of data that will become available very soon, such as data streamed directly between vehicles and infrastructure.

What is even more interesting, is how the plethora of data generated by our ever digitising society can be harnessed for transport management, such as from social media, destination information and whatever is trending locally. In this report we show how in the UK, computers search twitter feeds for transport keywords, and in Seoul, social media traffic is mapped during disasters to quickly identify trouble spots.

So the big question becomes, how can Big Data be harnessed to enhance transport management in our ever growing cities? This report seeks to shed light on this important question.

Key Recommendations

Strategy related

- Be clear on exactly what you want to achieve from data analysis, such as trends, and ensure systems are tailored to this outcome and store only what is absolutely needed to avoid ballooning storage needs.
- Ensure existing data is harnessed fully using emerging analytics platforms and then carefully review new data options to ensure they have strong utility before setting up systems to receive and analyse them.
- Find out what software platforms other road agencies are using and see if there is potential for sharing. Consider the development of multi-jurisdictional legislation or standards around data generated by vehicles to ensure compatibility with transport agencies' digital platforms.
- Identify currently held assumptions around the availability and utility of data and ensure that strategies to incorporate greater data collection and analysis are ground-truthed with international best practice.
- Consider the development of specific policies to ensure privacy concerns associated with Big Data are appropriately handled, such as mandating that all data is de-identified and only derived trends and patterns can be stored once real-time data is received.

Data related

- Identify all current forms of data collection, access and assessment and ensure that the data with high utility is digitally integrated rather than being manually imputed between software.
- Ensure that in the case that sensors are added to the network they are located at high priority locations in the network and are able to communicate with the selected data platforms.
- Decide on the format, language and syntax of data and ensure historic datasets are formatted accordingly. Create protocols for the verification of data from secure third party providers or unsecured public sources, especially in the case of the deployment of first responders.
- Decide between cloud-based or local storage for data and analytics. Cloud-based may be cheaper; however, it can present security and privacy issues. In-memory systems are more expensive but are more secure and faster.
- Keep an eye on advances in sensors and analytics performance along with the availability of new datasets or datastreams that may have strong utility for transport agencies.

Software related

- Consider selecting a third party or an in-house data analytics platform. Third party platforms can be expensive and closed. Although in-house platforms will require customisation and capacity building they can be more secure and faster than offsite platforms.
- Ensure software platforms can integrate private, mass transport and social data to both undertake predictive analysis and run simulations on the network to inform optimal use of existing infrastructure to defer capital expenditure and maintenance.

The Question of Big Data and Transport Systems

Introduction

There are multiple definitions of 'Big Data'. Most commonly, the term is used to broadly characterise data sets so large they cannot be stored and analysed by traditional methods. Large volumes of data are now available from a growing number of sources, many with unique formats, languages and configurations. However, this is only one dimension of the complexity of Big Data. The velocity at which data is received and the variety of information available adds to the challenge of creating value. It is these three characteristics (referred to as the three V's – Volume, Velocity and Variety) that distinguish Big Data from other forms of data.

The emergence of Big Data has largely been the result of a decrease in the cost of sensory and observational technologies in conjunction with mass digitisation of systems and processes around the globe. Combined with vast amounts of historical information, real time data from sensor networks and computer simulations is now creating an immense resource to be harnessed by transport agencies.

Not only can data be used to observe direct traffic related phenomena to inform management techniques such as streamlining traffic signal timings and ramp metering, but the broader availability of data in our urban environments opens up new opportunities to inform transport related behaviours and investments. Because of the large volumes of information produced, Big Data requires new forms of analysis in order to produce meaningful results. The term 'Big Data Analytics' is used to describe the processing of multiple massive data sets to extract useful information that can be visualised, say by a traffic management or disaster management control centre.

Big Data provides the promise of going beyond what could be referred to as 'Small Data' – data such as traffic counts, average speed, temperature conditions and traffic light signal durations – to include consideration of literally hundreds of data sources that stand to inform congestion and disaster management efforts. Examples of these include data streamed directly from vehicles, data about car parking, data about public transport, data on social events that may affect traffic, meteorological data, sensors on transport infrastructure indicating damage, and social media communications during disasters.

Given the economic and social impacts of congestion and disasters it is critical that related data sources are harnessed. Using data to reduce peak-time congestion, for instance, can not only improve the traveller experience but defer capital investment in expanded infrastructure.

What value can Big Data actually create?

The use of data to inform transportation is not a new phenomenon; traffic systems have long produced streams of observational and sensory information. However, there is a growing array of additional data that can be used to deliver multiple benefits to both traveller and transport system managers.

Such a focus not only allows for the current transport network to be better managed, it provides a unique opportunity to seamlessly interconnect various transport networks and modes to provide the optimal mobility solution for our growing cities. For instance, efforts to reduce congestion, especially the effective integration with mass transit options, can lead to a number of benefits, such as:

- Enhanced liveability of cities due to less lost time in congestion and health related issues.
- Faster, cheaper journeys that reduce wear and tear on vehicles and the road network.
- Attracting businesses to cities by providing better and more efficient connected mobility.
- Reduced environmental impacts such as air pollution and greenhouse gas emissions.
- Easing the stress on the city transport budget and maximising the benefit of expensive transport assets.

For example, by using road sensors and GPS data from the city's 1,000 buses, the Dublin City Council mapped real-time bus locations. Some 1.2 million people now have access to journey information updated every 60 seconds to find the fastest route for their travel, moving more efficiently through the network of roads, tramways and bus routes.[3]

What forms can Big Data be found in?

Data is highly varied and can be thought of as being in one of three broad categories:

1. *Highly structured datasets*: This type of dataset originates from technology implemented to address well-defined problems (e.g. data from automatic toll road payment transponders for the use in processing toll road payments, or data from intersection sensors on traffic flows and time-of-day usage of the road network).

2. *Unstructured datasets*: This type of dataset is produced from any interaction between road users and digital infrastructure. Given the explosion in the use of mobile phones, personal computers, sensors, cameras and devices, there is huge (yet largely untapped) potential to harness these data streams to inform congestion, which moves transport management into the realm of Big Data.

3. *Data from seemingly unrelated sources*: There is an array of data that has not previously been considered as related to transport, but may in fact provide a valuable source of intelligence. Such data may provide insights into the behaviour and functioning of the transport system; such as the price of parking at particular public carparks, the level of fines for illegal parking, the number of people walking more than 1 kilometre to public transport and real-time weather conditions. If this data is available, it typically needs to be manually inputted from other sources by traffic control centre operators. For instance in Singapore, software is used to estimate 10 minutes ahead of time when and where it will rain and directs taxi drivers to these locations in anticipation of additional fares.

What types of Big Data can be used?

Currently, access to data is not a concern as there are a multitude of data sources available which produce a wealth of information. However, it may be the case that additional data sets that are currently not freely available may be more valuable than those that are currently openly available. The challenge is to harness the data by processing and interpreting it both at the higher levels of trends and scenarios and at the lower levels related to day-to-day management. Transport management systems can review historic databases and compare this to real-time data from a range of sources including those currently available and those anticipated to be available in the near future (See Figure 1).

Historic data available

Existing databases of transport related data can be used to inform possible future conditions. For example, in 2016 Main Roads Western Australia developed a tool called NetPReS (Network Performance Report System), which integrates data from multiple sources to report road network performance in terms of multiple indicators. The tool is currently limited to historical performance but is expected to be expanded in to real-time performance analysis.

Currently available data

A growing number of cities are beginning to integrate data collected from both traditional and emerging sources. For instance, the 'Twitraffic' application used in the UK shows that social media can be used effectively as a way to diagnose and identify traffic congestion.[4] The app searches Twitter for keywords such as 'traffic' and 'accident', and can identify incidents an average of seven minutes faster than the transport monitoring system. In the case of public transport, the provision of real-time traffic conditions and accurate wait-time estimations greatly improves customer perceptions of service effectiveness.

Further to the data currently available, it is anticipated that numerous additional data streams will be available for transport management in the near future, generated by vehicles and infrastructure.

Anticipated future data availability

Vehicles (including private vehicles, public transport, and freight vehicles) are increasingly acting as mobile sensors and computers which can both produce and receive data.

Imagine your bus knowing where all the cars are around it and how fast they are going in order to identify the optimal speed to both navigate traffic and provide the smoothest ride for passengers. Imagine your car knowing that another vehicle that you cannot see is racing towards your intersection and is likely to run the red light and hit you, but your car tells you to stop. This data is termed 'Vehicle-to-Vehicle' (V2V) and will revolutionise safety and route selection in the coming decades.

Likewise infrastructure like motorways, bridges, traffic signals, bus stops and train stations can be sending and receiving data to and from various vehicles. This is termed 'Vehicle-to-Infrastructure' (V2I) which can bypass third party data from mobile telephones to communicate directly with the vehicle to allow real time transport monitoring and management, while enhancing predictive capacities.

Then there is 'Vehicle-to-Everything' (V2X) that combines V2V and V2I and also communicates with mobile phones. V2X can tell you how long a bus trip would have taken you, tap into wireless networks to find out occupancy rates at car parks you typically park in (and even how safe they are), and check the driving history of the person in front of you to see if they are a safe driver to suggest how close you should be driving behind them.

How can Big Data be of use?

The analysis of real-time and historic data can act to mitigate and prevent key bottlenecks in transport systems, allowing transport infrastructure investment to be postponed by opening up the bottlenecks and deferring the need for additional infrastructure in order to reduce pressure on transport systems.

Predictions of future traffic conditions

As is described further in this report, historic data can be used to inform predictions of near-future transport conditions by comparing past commuter behaviour with real-time data. While the ability to predict potential traffic conditions is still in its early stages, there are promising examples that suggest this is feasible. For instance, the 'JamBayes' software by Microsoft uses historic datasets, weather reports, and real time datastreams to predict congestion 30 minutes in advance of an unexpected incident, based on current conditions. To curtail road congestion before the congestion becomes severe, management systems need to be able to communicate directly with traffic lights and other traffic control systems when real-time congestion pre-cursors match historical information on congestion events.

Simulation of planning options

The depth of data becoming available, both historic and real time, allows data mining programs to identify correlations and convergent traveller preferences across multiple platforms such as surveillance cameras, phones, metro cards and sensors. This can aid in the development of transport demand projections that take into account multiple modes of transport (private vehicles, public transport, cycling, etc.), forming a big picture overview of expected travel patterns that can inform long term transport planning and infrastructure investment.

Such an approach can allow the simulation of various transport planning options in order to quantify the improvements delivered by suggested upgrades and integrated modal options. This can allow city planners to optimise future transport corridors to best meet the needs of commuters. Research in this field is relatively new, but is promising, with Singapore using historical datasets to inform plans for transport corridors and public transport routes. However, such simulations can be further enhanced by considering the interaction of transport options and land-uses.

Figure 1: Examples of data types related to transport and congestion management

How can we analyse Big Data?

Due to the volume, velocity and variety of modern data streams there are inherent challenges in the analysis and harnessing of this information. In particular, the different data formats and languages in which data is stored may lead to difficulties in processing using data mining algorithms. However, the potential rewards are that transport systems can be planned, designed and managed based on actual passenger and transport system use behaviour, as opposed to reported behaviours and preferences which may not present the whole picture.

Looking further than the data related directly to transport, however, opens a new realm of potential. This analysis requires programs and technologies that extract value from what our research team refer to as the 'Datasphere'. This is data that may seemingly be disconnected from transportation but, when assessed, shows correlations that would otherwise be hidden. Effectively harnessing such data can provide significant benefits due to the development of temporal, spatial and historical correlations between key factors. In fact, it is in this ability that the true potential of Big Data exists.

In basic terms, 'Big Analytics' is software that sifts through information and identifies the key data sources and interrelations. It is again early days with a growing number of software companies attempting this task. This report outlines three examples of Big Data analytics software (Table 1), namely:

- Apache Hadoop, an open source data collection and analysis platform.
- Spark, a Hadoop extension with improved processing performance.
- SAP HANA, a licensed, customisable software proven effective in collecting and analysing Big Data.

<table>
<tr><th>Hadoop with MapReduce</th><th>Hadoop with Spark</th><th>SAP HANA</th></tr>
<tr><td>Open-source</td><td>Open-source</td><td>Closed-source</td></tr>
<tr><td>Disk memory, which uses batch processing where data is stored and then processed at specific intervals</td><td colspan="2">In memory, allowing real-time continuous processing of incoming data</td></tr>
<tr><td>No support</td><td>No support</td><td>Hardware support</td></tr>
<tr><td colspan="2">Machine learning capability has to be specifically programmed into the platform</td><td>In-built machine learning capability for better predictive ability</td></tr>
</table>

Table 1: Comparison of emerging Big Data analytic software platforms

Apache Hadoop

Hadoop distributes data collections across multiple nodes within a cluster of servers, meaning custom hardware does not need to be bought or maintained. The software can be connected to traffic monitoring equipment such as city checkpoints, video monitoring, traffic flow detection, signal systems and devices to provide the city with a Big Data storage system with high throughput and fault tolerance. This allows for a fast and efficient dynamic monitoring system that enables vehicle track analysis and searching, fake plate number analysis, vehicle control and traffic violation data storage. The system has been shown to be capable of carrying out collision analysis on 2.4 billion vehicles in just ten seconds.

Spark

Spark is a data-processing tool which operates on the data distributed using Hadoop in order to overcome some of the limitations, allowing much faster processing times. As both Hadoop and Spark are open-source, modifications can be made in order to customise it to a user-specific application. Companies are also building their own data analytics software based on these.

A case study undertaken in India illustrates the power of the Hadoop/Spark platform. In the trial, data such as vehicle speed, vehicle counts and the time taken for the vehicle to pass by the sensor area, was processed in order to see if the severity of traffic congestion could be predicted. The study found that whereas the existing system took a significant amount of time to undertake such computations, Spark was able to predict traffic conditions in less than a second.[5]

SAP HANA

SAP HANA provides an all-in-one platform which has been proven to be effective in handling the data required to analyse traffic congestion. Being run through cloud-based or in-house servers makes SAP HANA versatile and cost effective. The platform also excels at delivering deeper insight from Big Data and the Internet of Things due to its strong machine learning capabilities. However, this platform is not open source and licensing must be purchased or rented. SAP HANA provides support, especially with hardware, and can help set up a Big Data system quicker than using an open source platform.

Both Japan and China have used SAP HANA to reduce congestion on city roads. The Nomura Research Institute (NRI) conducted an experiment using GPS data from 18,000 taxis located in Tokyo.[6] Using the platform, they managed to process approximately 360-million items of data per second. In Nanjing, China, SAP HANA has been used to process 100 million points of data, including GPS and traffic sensors per day. The software then gives a rating to the roads in the city which is used by city management and accessed by over 800,000 members of the public.[7]

Options to Harness Big Data to Inform Congestion Management

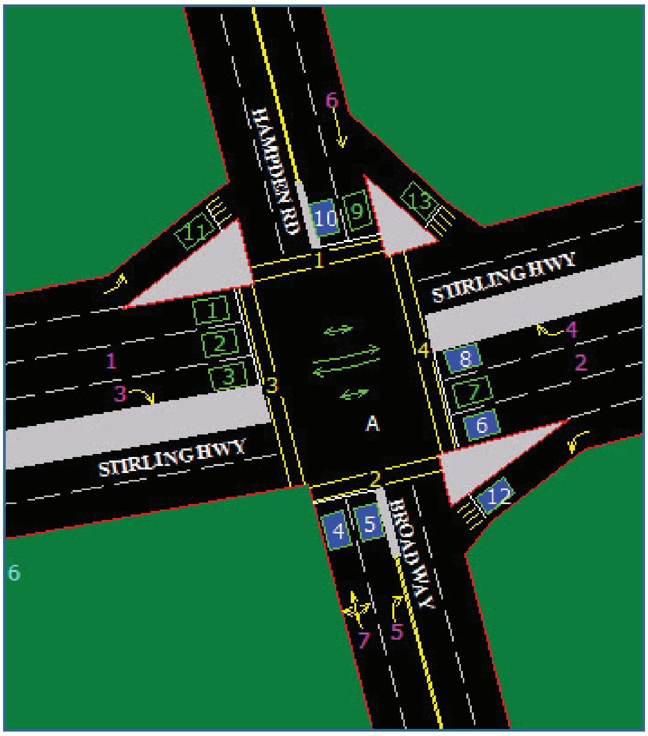
Real-time congestion management

Many congestion management systems currently use real-time data, albeit from a limited set of traditional 'small data' sources. Multiple types of software exist which respond quickly to real-time changes in traffic volume, traffic movement demands and direction of travel. Two main types of software currently used in Australia to inform traffic control systems are 'SCATS' and 'STREAMS'.

SCATS

SCATS 'Sydney Co-ordinated Adaptive Traffic System', is used in most capital cities and monitors real-time traffic signals and vehicle volumes to coordinate adjacent traffic signals to reduce traffic congestion and optimise traffic flow (with the option for user intervention by control system operators), See Figure 2.

Figure 2: Sample of SCATS user interface



The use of SCATS has been shown to correspond to a reduction in overall travel times, vehicle stops, fuel consumption and waiting times at red traffic signals.[8]

STREAMS

STREAMS uses real-time transport data and integrates CCTV, variable message signs and vehicle detectors to produce a map-based, browser-style intelligent transport system (ITS) interface for transport network management. Despite being an example of small data, STREAMS can model transport network infrastructure in real-time and manage ITS devices. While STREAMS is primarily designed to reduce traffic congestion, VicRoads reports that the installation of this system also delivered a 30 per cent reduction in motorway accidents. The STREAMS system also delivered economic benefits of $94,000 per day, travel time savings of 42 per cent during peak periods, and an 11 per cent reduction in greenhouse gas emissions.[9]

While real-time congestion mitigation techniques have been implemented extensively across multiple cities and countries, any real-time strategy only has a limited scope to improve traffic conditions. This is primarily because it is already too late to avoid the congestion once it has been observed. Real-time mitigation strategies are often based around deterring additional traffic from moving towards the area, through traffic signals or responsive road tolls, but neither strategy eliminates the existing congestion. As such, there is great interest in predictive strategies which seek to curtail traffic jams or emergency situations before they occur.

Predictive congestion management

The question is now being raised as to whether the use of Big Data can effectively predict traffic conditions, and the short answer is ‘yes’, but not perfectly, and not just yet. The long answer is that although the rapidly emerging sources of data may contain the necessary information to predict travel patterns and identify problem areas, the tools required to process this data to extract the useful information and correlate it to historical data in order to create a well-informed prediction of future conditions are in the early stages of development.

In order to better improve congestion prediction models, aggregated traffic flow variables (e.g. which assume vehicle speed to be equal to the speed limit) can be replaced with real-time data in order to create a more realistic model. Early application of such data collection has been achieved in Tokyo with the use of the ‘Zenryoku Annai!’ software application that receives approximately 360 million data packages every second from traffic sensors, satellite navigation systems, mobile location data, and taxi GPS location data to achieve “*near instantaneous response times*”.[10]

However, even with such a process, no prediction will be perfect given traffic conditions are also influenced by non-linear factors such as vehicle collisions caused by abrupt changes in traffic conditions and dynamics, mechanical failure, or driver error. Even a perfectly safe vehicle under perfect geometric and environmental conditions may still crash due to sudden changes in road dynamics, interruptions to the normal flow of traffic, or a distraction or disruption inside the vehicle.

There are currently a number of ‘Big Data Analytics’ traffic prediction systems in development. An early mover in this space is the global company ‘HERE’ that processes information collected from over 2 billion traffic probes per day and compares it to historical data, since 2011, using algorithms to generate predictions of road traffic congestion issues.[11] Microsoft has also developed various software to predict traffic conditions, with some software platforms taking into account unexpected traffic conditions, and have achieved promising results.

The ‘Midtown in Motion’ project in New York City uses software to compare real time data from microwave sensors and transit cards with historic records to predict congestion hot spots and adjust traffic light timings to improve vehicle flow which has achieved a 10 per cent improvement in vehicle travel speeds.[12]

Public transport planning and deployment

Public transport systems are increasingly equipped with automated data collection systems, which can be harnessed along with other data streams to provide insight into passenger demand and identify optimal public transport networks, routes and connections. The potential to blend in numerous datasets and streams related to why travellers are using transport services, such as shopping times, public events and climate conditions, can create a more sophisticated understanding of factors that affect patronage. Analysis of such data can provide information on passenger needs and behaviour, as well as provide an assessment of system performance and real-time conditions.

The two key data sources of interest for public transport networks are:

1. Automated Vehicle Location (AVL) data, provided by mobile phones.
2. Automated Passenger Counting (APC) data, provided by smart cards (metro cards), surveillance systems (i.e. video cameras), Wi-Fi and Bluetooth trackers, and sensors connected to assets, signals and switches.

Currently, both forms of data are used for system performance evaluation. However, neither data source has been used extensively in system planning and development, making such data a largely underused resource. If harnessed, these and other forms of data can inform projections of passenger volumes, which are essential in the effective prediction of future demand and can act to enable the design and optimisation of networks.

Furthermore, the analysis of such data sources can replace lengthy, costly and often overstated surveys on travel habit and stated preferences. Algorithms can directly construct travel demand based on observed travel patterns and provide a basis for public transport planning. This can include tactical planning (a mid-term plan that involves service frequency, timetabling, and vehicle and crew scheduling) and strategic planning (a long-term plan concerned with overall network and service design such as passenger stop positioning, and line topology and capacity). Combined with traffic data this can provide a powerful tool to inform the integration of transport modes to provide travellers with the mobility option that best harnesses the existing network.

Options to Harness Big Data to Assist in Disaster and Emergency Response

As dynamic systems, transport networks are subject to unexpected events while operating, potentially leading to disruptions in services, severe congestion and loss of life. There are two main types of unexpected events, namely:

1. Man-made events such as vehicle crashes and roadworks which cause traffic congestion due to lanes or entire roadways being blocked.

2. Natural disasters or extreme weather events such as bushfires, storms and cyclones, which can cause damage to the transport network resulting in congestivon or even blocking access.[13] (Refer to SBEnrc Project 1.35: Transport Network Resilience: Disaster Logistics and Infrastructure Vulnerability)

This second type is of key interest to transport authorities, especially with the Fifth Assessment Report of the Intergovernmental Panel on Climate Change predicting that climate change will increase the 'frequency and severity' of natural disasters in the future. In general, the level of resilience should be proportional to the intensity of use of that transport corridor, as well as the availability of alternative routes. Critical highways, bridges and railways must be identified and prioritised for strengthening in order to protect 'points of failure' in transport networks.

A 2014 Transport Resilience Review by the UK transport authorities defines transport resilience as ensuring that systems are able to withstand the impacts of emergencies, operate in the face of these events and recover promptly.[14]

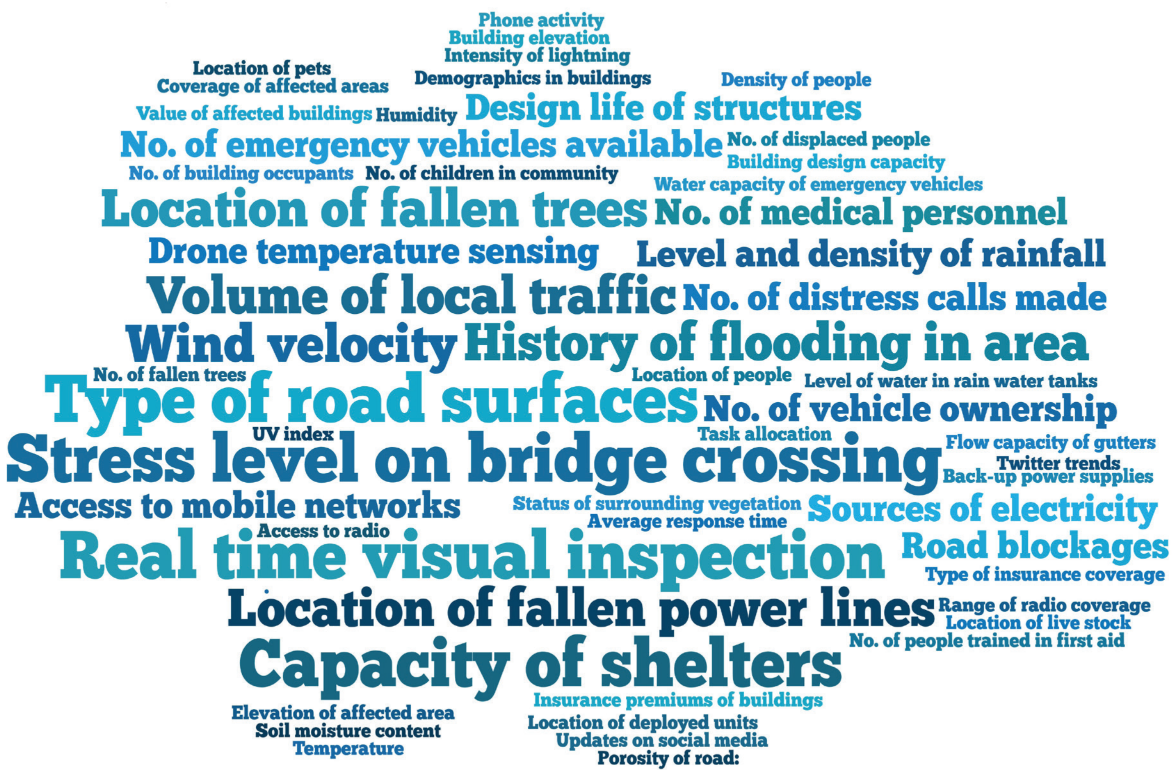


Figure 3: Examples of data types related to disaster and emergency response

There are four main phases of disaster management:

1. Prevention,
2. Preparedness,
3. Response, and
4. Recovery

Thre are also two major sources of Big Data:

1. Dedicated sensor networks (e.g. earthquake detection sensors, tilt sensors and pavement integrity sensors) and
2. Multi-purpose sensor networks (e.g. social media, smartphones and technology-enabled vehicles).

The availability of such data presents a significant opportunity to aid in disaster management through the integration of multiple emergency-sensing platforms and response systems, to both predict and respond to emergencies (See Figure 3).

The New South Wales Special Emergency Services (NSWSES) have proposed a system that could be processed using SAP HANA and allows for sharing of real-time information in order to enhance the response of emergency services. While NSWSES is focused on emergency services deployment, the platform and structure can be tailored to suit specific, transport-based requirements.

Emergency response systems

A range of data collection technologies and devices can be used to produce real time high-resolution information to inform the deployment of emergency services and route the public to safety. These can include the use of tilt sensors on trees, poles and other infrastructure that is likely to interfere with traffic flow in the case of a disaster to provide real time appreciation of the potential routes that are blocked.

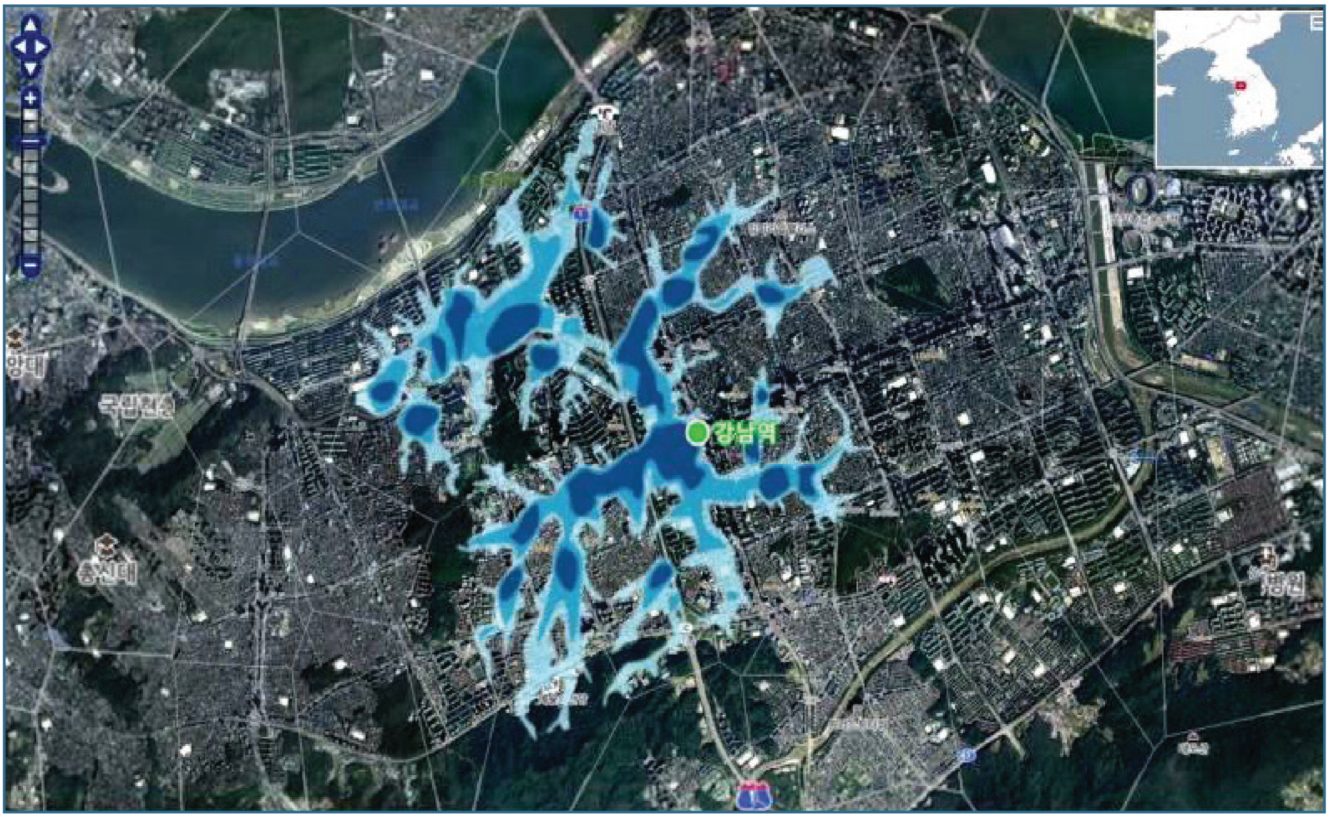


Figure 4: The 'Smart Big Board' mapping social media data flows during a disaster in Korea

Drones can also be used to assess the damage and quickly identify accessible routes much sooner than land-based reconnaissance.

Rio de Janeiro is an early leader in terms of integrating disaster sensing and management technologies. The city's Traffic Control Centre receives footage from over 900 video cameras that is combined with 120 layers of associated data including data related to weather, emergency services, traffic conditions and utilities. The system has decreased the response time to natural disaster related emergencies in the city by 30 per cent.[15] Based on the premise that increased social media activity in particular areas during a disaster can correlate to areas of greatest need for assistance, researchers in Korea have designed a process to identify such areas (See Figure 4).[16]

The Queensland government and Transmax's Emergency Vehicle Priority (EVP) solution allows emergency vehicles to travel more quickly and safely. The EVP system uses the location of the emergency vehicle and the flow of surrounding traffic to estimate the vehicle's time of arrival at intersections. Using this information, EVP pre-emptively changes traffic lights to green before arrival to ensure the emergency vehicle can continue through without having to slow down. This system has been found to reduce the travel time for emergency vehicles by 10-18 per cent.

The exciting implications of Big Data are only beginning to be realised, especially in Australia, which predominantly draws on real-time, for-purpose emergency detection data. Harnessing and analysing additional streams of data, such as social media and drones, can inform mitigation techniques which enable first responders to:

- Identify areas which need the most urgent relief immediately after the disaster and coordinate crisis responders and logistics.
- Provide guidance to the public to avoid hazards, including the provision of safe transport pathways away from the danger.
- Aid in recovery activities such as safety confirmation, materials logistics, volunteer coordination and provision of relief supplies.

Over time, such data can populate a databases to allow future evaluation of the effectiveness of the emergency management response and identifying optimal response strategies.

Emergency management

In a similar way to predictive congestion management, real-time data from a variety of transport, seismic and weather-related sources can be compared to historical data sets in order to inform predictions of the likelihood and severity of emergencies. This can be done by identifying the sets of conditions associated with past events and monitoring current conditions to see if they begin to form similar patterns.

Such an approach can be used to identify at-risk areas to inform communities well in advance of the disaster when conditions appear to be similar to those of historic events. For instance, the Rio de Janeiro Traffic Control Centre uses data analysis software to compare historic and real-time data to identify patterns and trends to predict where incidents are likely to occur.

In Western Australia, more than 5,000 bushfires occurred within the twelve months after July 2013. There is currently a detection system in place in the state called the Aurora Bushfire Detection System, which uses data to predict at-risk areas for bushfires and relays this information back to the public via the government's website. The Aurora system calculates the direction and intensity of the bushfire using several data sets: threat analysis data, time since last burn, forecast weather, drought factors and fire hotspots.

The information processed by the system enables Aurora to determine whether there is likely to be any impact on any surroundings whilst also enabling a message to be sent to any residents that may need to evacuate, with transport agencies involved in ensuring access is provided.

On the other side of the country, Victoria is currently in the process of implementing the Resilient Information Systems for Emergency Response (RISER), which draws in data from weather monitoring networks, cloud-sourced information, social media, and drones.

RISER's new weather monitoring networks collect a detailed set of data outlining the temperature, radiation, wind speed and direction, soil moisture and humidity to predict not only the likelihood of any bushfires occurring but also the destructiveness.

There is huge scope for the development of truly integrated disaster management systems which will act to improve transport resilience in the face of emergencies and unexpected events. This is especially the case in Australia, which is in the early stages of developing the potential of growing sources of data to inform disaster management.

With data exploding across a dizzying array of platforms, and the promise of high-resolution information which can accelerate disaster recovery, many cities across the world are beginning the shift to multi-platform data in order to respond effectively and efficiently to disasters and unexpected events.

Ultimately, harnessing multi-platform data to create a more robust and resilient transport and communications network will allow communities to be better prepared for emergencies, respond rapidly and recover swiftly afterwards.

Visit the SBEnrc YouTube channel for a short film on this project

The Future of Technology Enabled Transport

It is anticipated that in the near future rather than relying on mobile phone data from passengers in vehicles, the vehicles themselves will produce, process and react to datastreams. Initially, vehicles will receive data such as existing and anticipated traffic conditions, optimal routes to a given destination, locations of other vehicles (especially those not visible to the driver), optimal average speeds to reach green lights, average overtaking waiting time on freeways, location and duration of roadworks and closures, incident alerts and timings, potential areas of congestion from public events and even instructions to the vehicle to create open corridors around emergency services and public transport vehicles.

For instance, Audi's traffic light information system released on select 2017 Audi Q7 and A4 models will inform drivers of the timings until traffic lights change to green to allow drivers to either slow down on approach or turn the vehicle off while waiting. Third party applications such as the 'EnLighten' application provide similar information to motorists, harnessing traffic signal timings to provide travel speed recommendations, and is now being installed in BMW vehicles.

However, this is just the beginning, with a plethora of data becoming available that stands to inform transport options, including:

- Information on vehicles that can influence how they are treated by other vehicles on the road, such as: the level of technology enablement; the driving history of the vehicle; the level of insurance it carries; the number of crashes it has been involved in; and whether it has been found to have been operated under intoxication.
- Information on public transport such as: the location of stations suitable to access the destination and the anticipated wait time; the vacancy rate and cost of park and ride; the punctuality and availability of seats on busses and trains; interchange information if you need to change; and most valuably, the real-time comparison of alternative modes with continued driving considering cost, time and security.
- Information on car parking such as: opening hours and levels of vacancy of car parking structures; levels of vandalism; cleanliness of stairwells; types of insurance offered; the level of personal safety; and the average wait time, cost and duration of street parking (perhaps with the ability to reserve a street or structure carpark).

Vehicles that have these capabilities are referred to as 'connected vehicles' and will increasingly access data generated by other vehicles ('Vehicle to Vehicle' or 'V2V') and urban infrastructure 'Vehicle to Infrastructure' or 'V2I'). A number of car manufacturers are now testing V2V prototypes with Toyota announcing in 2016 it will increase its V2V enabled fleet test size to 5,000 vehicles. However, data compatibility is proving to be a challenge for the industry, such as the Mercedes E-Class being only capable of communicating with other E-Class models.

In order to streamline efforts, the United States Department of Transport propose to require that all new light vehicles from 2021 have V2V technologies with a standard V2V frequency to allow communication across makes and models. In Australia, the frequency of 5.9GHz has been allocated to transport information systems.

Slow progress on harmonisation of technology standards internationally has delayed implementation and adoption of connected vehicles in Australia. Transport Certification Australia and Austroads are also working on a system to ensure the security, robustness and credibility of what is being referred to as ‘Cooperative Intelligent Transport Systems’ (C-ITS). Testing of connected vehicles has commenced in New South Wales, which has implemented a C-ITS testbed in Illawarra for 60 participating heavy vehicles fitted with V2V and V2I technology which broadcasts on the 5.9GHz radio spectrum.

A range of additional value can be created when we move to ‘Vehicle to Everything’ or ‘V2X’ to inform the traveller of information that is not necessarily directly transport-related, such as: the location of your favourite coffee vendor between the car park and your destination; the level of undercover walk ways to your destination in rain events; the chance that the recent football match will cause delays; the level of greenery on the walk to your location; or the location of your favourite shops or vendors in relation to alternative parking options.

So what about driverless cars? Vehicle manufacturers around the world are in a race to embed greater levels of technology into vehicles. Some even have the goal of producing vehicles that do not require drivers. Whether this goal is achieved or not, or in fact if it’s even a preferable outcome given concerns that it may lead to increased congestion, the majority of safety and traffic management related benefits can be achieved whether or not the driver takes their hands off the wheel. As such, driverless vehicles have not been a focus of this report.

Main Roads Western Australia Traffic Control Centre, Perth, Australia

Privacy Concerns

There is no doubt that the exponential growth in the generation of data will trigger significant changes to the transport industry. However, there are rising concerns around the adequacy of regulations ensuring privacy.

Even data that is said to be 'anonymous' may still be linked to specific individual sources if cross-referenced with other sources of related data, especially as much of the data is currently shared with private companies with little accountability.

Not only do traffic management centres have to tackle this issue, they also have to decide on whether secondary data that they have not collected themselves is reliable enough, such as that from social media. For instance, such data may require verification using other data sources such as sensors and camera footage or still-shots before say directing response teams in the case of an emergency.

In smaller datasets, IT managers can manually move data between tiers, giving them a measure of control; however, as the dataset grows exponentially, auto-tiering is likely to become increasingly necessary. As auto-tiering does not keep track of where the data is stored, unauthorised access to data stores is less easy to detect and data breaches may occur. Thus, new mechanisms must be developed to prevent data theft and maintain the 24/7 availability.

In Australia, Privacy Act 1988 regulates and protects personal information, including the Australian Privacy Principles which define the standards, rights and obligations in relation to handling and assessing personal information. According to the Privacy Act, organisations must take reasonable steps to implement practices, procedures and systems that protect personal information. These organisations must also be able to deal with privacy related complaints.

Griffith University's Big Data and Smart Analytics Lab, Nathan Campus, Brisbane, Australia

Conclusions

As vast amounts of data continue to emerge across a huge array of platforms this presents a valuable opportunity for transport planners, designers and operators. The interrogation of such data compared with previous conditions has the potential to not only streamline transport options but also predict and prevent congestion and blockages. This data can additionally inform the seamless integration of various modes of transport for travellers.

Although Big Data can provide key information to evaluate, plan and improve transport systems, the key challenge in its utilisation is the fact that the extensive volume of information requires multiple modes of data analysis and processing. Because so much information is available, software and programs must be developed which can sift out irrelevant information and focus on key features of the data which will provide necessary inputs into transport prediction patterns.

However, due to the scale of data, data variety and rapid frequent changes, it is a challenging task to integrate, visualise, analyse and respond to queries. Current data analytics systems provide limited analysis capabilities with long response times of several minutes, which is an impediment for real-time data analytics.

Recently, in-memory computing techniques have been found to achieve significantly higher efficiencies, with remarkably quicker processing speeds. Multiple IT firms are actively working in this field, with researchers currently investigating new methods to improve processor speed and responsiveness.

Further, when using Big Data for future transport volume projections, highly specialised and accurately calibrated data mining programs must be used in order to develop accurate and robust projections, because the sheer volume of information available makes analysis difficult.

The algorithms and projections developed using Big Data must also be properly calibrated against real-life transport volume scenarios in order to ensure that the projected system performance is sufficiently accurate.

These challenges must be overcome in the future in order for Big Data to be accurately, effectively and efficiently harnessed for congestion management and emergency response. Yet as a whole, what transport planners stand to win is far greater than what they could lose.

In particular, enhanced systems for managing transport and the timely prediction of when bottlenecks will occur will allow transport planners to devise methods to prevent congestion in these areas. This and other options for using such data can effectively defer capital investment in transport system expansion by better utilisation of current systems.

References

1. Bureau of Infrastructure, Transport and Regional Economics (2015) Traffic and Congestion Cost Trends for Australian Capital Cities, Commonwealth of Australia, Canberra, Australia.
2. SBEnrc (2017) Mining the Datasphere: Big Data, Technologies, and Transportation – Congestion Management: A Sustainable Built Environment National Research Centre (SBEnrc) Academic Report, Curtin University and Griffith University, Australia; and SBEnrc (2017) Mining the Datasphere: Big Data, Technologies, and Transportation – Disaster Management: A Sustainable Built Environment National Research Centre (SBEnrc) Academic Report, Curtin University and Griffith University, Australia.
3. Berst, J. (2013) Smart Mobility: Dublin Uses Real-Time Data to Reduce Congestion, Smart Cities Council, Virginia, USA, May 18.
4. GeoConnexion (2016) Twitraffic: The Power of Twitter for Real-time Traffic Information, GeoConnexion.
5. Prathilothamai, M. Lakshmi, A.M. and Viswanthan, D. (2016) Cost Effective Road Traffic Prediction Model using Apache Spark, Indian Journal of Science and Technology, Vol. 9, No. 17.
6. Intel (2011) Not limited to ERP applications alone, the Intel® Xeon® processor E7 family also provides new business opportunities via in-memory technology, Intel.
7. Chen, S. (2016) Smart Traffic: an IOT Solution for Measuring, Discovering, Predicting and Analyzing the Real-time Congestion, SAP HANA Innovation Award Winner 2016, Sap Hana.
8. NSW Transport Roads and Maritime Services (2015) How SCATS Works, New South Wales Government, Sydney, Australia.
9. Victorian Auditor-General's Office (2010) Using ICT to Improve Traffic Management, Victorian Government, Melbourne, Australia.
10. Mullich, J. (2013) Drivers Avoid Traffic Jams with Big Data and Analytics, Bloomberg L.P., New York, USA.
11. Highway Engineering Australia (2015) Big Data: The Key to Unlocking the Future of Traffic, tTansport and Infrastructure, HEA , vol. 47, no. 2, pp. 40-41.
12. Solomonow S., Mosquera, N. (2012) NYC DOT Announces Expansion of Midtown Congestion Management System, Receives National Transportation Award, New York City Department of Transport, New York, USA.
13. SBEnrc (2016) A Stakeholder Engagement Approach to Enhancing Transport Network Resilience in Australia: A Sustainable Built Environment National Research Centre (SBEnrc) Industry Report, Curtin University, and Griffith University, Australia.
14. OGL (2014) Transport Resilience Review: A Review of the Resilience of the Transport Network to Extreme Weather Events, Department of Transport, London, UK.
15. Berst, J. (2013) Why Rio's Citywide Control Centre has become World Famous, Smart Cities Council, Virginia, USA.
16. Choi, S., Bae, B. (2015) The Real-Time Monitoring System of Social Big Data for Disaster Management, Computer Science and its Applications, Springer Berlin Heidelberg, Germany, pp 809-815.

Sustainable Built Environment National Research Centre

SBEnrc Overview

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. The Centre is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas.

Among the SBEnrc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

This research would not have been possible without the ongoing support of our core industry, government and research partners.

SBEnrc Core Partners

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