# PROJECT CONVERT

**CO**nnected **N**etwork **VE**hicles in **R**eal **T**ime
for network and asset management operations

**Funding for Innovation:**
Connected Vehicle Data

**Project Report:**
April 2019 (re issued July 2020)


Fitzpatrick Advisory

City of Westminster

# Contents

# 1 Introduction and background

## 1.1 Funding for innovation: Connected Vehicle Data competition

Digital transformation is changing the way we travel on our roads and how we provide and maintain our infrastructure.

Connected vehicles have access to the internet/wi-fi and a variety of sensors, which are able to send and receive signals, sense the physical environment around them and interact with other vehicles and the roadside infrastructure. It's estimated that there are already 3 million connected vehicles on UK roads, providing data and receiving information.

The rapid rate of technology deployment in new vehicles will bring further opportunities for better connected vehicles that the UK can exploit to improve the planning and maintenance of our road network.

In 2017 the Department of Transport (DfT) launched a competition to demonstrate connected vehicle use cases and/or applications that could provide real benefit for local authorities.

The competition sought projects which could:

- demonstrate the capability of connected vehicle data;
- improve the quality of road condition and asset management data;
- provide the business case for more widespread deployment across a number of highway authorities;
- enable the development of smart asset strategies based on harvested intelligence; and
- help support innovation within the private sector supply chain.

This Report has been produced by Fitzpatrick Advisory on behalf of Westminster City Council, and is a record of the method and findings of the Project which Westminster subsequently undertook as a result of being successful in the competition.

The Report is intended to be published on their website describing what was done, and why, and what the project outcomes were, it is essentially however a non technical summary of the Project. Requests for more detailed, non confidential, information can be made to Fitzpatrick Advisory at brian@fitzpatrickadvisory.co.uk.

The findings from the work have directly influenced Westminster's approach to understanding the 'ask' of future management of their network, and the tools and techniques which might need to be deployed/developed to optimise resultant benefits. The bid contained the following words from the Director of City Highways:

*"Westminster recognises the importance of digital transformation and the part it is likely to play in the way we not only travel on our roads, but also how we maintain our infrastructure in the future. Westminster has already embraced and embedded technology in its working practices... and we look forward to playing a part in potentially stimulating that transformation in the sphere of Highway infrastructure and maintenance."*

## 1.2 Infrastructure in the City of Westminster

The City of Westminster has an intensively used road and footway network, with around 390km of roads. It is home to 30 tube stations, four mainline railway stations, 150+ bus routes and seven river crossings. Main routes from London's outer and inner ring roads bring commuter vehicles in and out, whilst constant development means lots of construction traffic, also competing for space on the road with taxis, buses, tourist coaches, and growing numbers of cyclists. There are thousands of utilities openings every year in Westminster which influence and impact upon traffic and congestion levels.

This heavy traffic and change poses constant challenges around the maintenance of the network, and also brings inherent security and parking issues, which need to be constantly managed.

Westminster is a particular network in other ways. It is visible to millions of people around the world as home to the UK Parliament, dozens of iconic buildings, shopping destinations and internationally acclaimed theatres and restaurants are instantly globally recognised. In the peak of the tourist season one million pedestrians use Westminster's footways every day.

Asset inventory is difficult to upkeep without consistent and diligent oversight and efficient information flow between platforms and people, and Westminster has a huge obligation, and audience, to 'get things right'.

There is a vast amount of data to help meet the challenge of maintaining the network safely and well. This is collected in a variety of ways and stored and accessed through a number of different proprietary information systems, and manually. Road and footway condition and other pertinent data and information is updated regularly e.g. through manual surveys and inspections, but these are detailed and time consuming, and can become quickly out-dated given the pace of change on the network.

### 1.3 Project CONVERT Bid

Westminster has a unique set of Highways network challenges, but it's data and connectivity issues are shared with most, if not all, local Highways authorities.

In many local Highways authorities, including Westminster, road and footway condition data is routinely collected, every year, and then disposed of, not even fully utilised, in the following year the cycle starts again. This waste of collected data, is an issue.

In addition many of the proprietary platforms used by Highways authorities don't communicate with each other, so there is a constant risk of duplicative effort. Manual oversight and data hygiene has to be consistent and thorough to make sure that consequential decisions are robust.

information processes such as those surrounding the collection of condition data, and thus challenging the conventional means of data collection, would realise benefits and efficiencies, and also pose questions about why things get done the way they get done currently.

As the project was defined, and subsequently undertaken, we worked in close collaboration with Westminster suppliers, appyparking Ltd (Parking solutions and kerbside management), and FM Conway Ltd (Highways and Infrastructure maintainer). It is noted that their help and support to the project has been invaluable.

### 1.4 Objectives of Project CONVERT

The CONVERT title was drawn from the objectives of the research which was to understand the challenges and opportunities of receiving data from COnnected Network VEhicles in Real Time for network and asset management operations.

**Project CONVERT is a research project which seeks to better understand and define the challenges and opportunities for local authorities receiving and using data from connected vehicles in real time, to improve network and asset management operations**

PROJECT CONVERT

Fitzpatrick Advisory City of Westminster appyparking CONWAY

This approach, and the 'disposable data' culture that surrounds it is positively challenged by the potential of real time vehicle connectivity.

The Connected Vehicles data bid provided a timely opportunity for Westminster and other authorities to explore the potential of technology to enable real change in the traditional operating models for roads maintenance.

The vision therefore in which Project CONVERT was set was a future where all of the sources of existing data, with real time information derived from connected vehicles, are fused together to generate one version of the operational 'truth', and enable better and quicker decision making, focused on ever safer and more efficient mobility for our residents and businesses.

We felt our bid offered an opportunity to test conventional custom and practice in the industry, and ask the 'technology, so what'? question.

Our bid proposed re-using digital asset inventory data, previously collected for another purpose, and then comparing and contrasting its utility compared to the existing information flows and processes around Highways maintenance. We hypothesised that digitising

The aims of the project were to:

- assess the technique and benefits of transforming data acquired from in-vehicle laser and cameras into actionable intelligence, and
- provide valuable insights into future asset and network management requirements.

We proposed repurposing previously collected LiDAR (Light Detection and Ranging) data as a proxy for real time condition data received from future connected vehicles.

We wanted to know whether vehicular LiDAR was a suitable means of collecting asset inventory and condition in the future but, more interestingly perhaps, what would be the technical and operational impact of collecting such data?

Highways authorities have adopted asset management philosophies to become more efficient but the current approach does not fully recognise the emerging challenge of how connected vehicles will need to negotiate the network, using signs and markings, and associated traffic regulation information, to understand where they are or where they should be.

### Footway, Cycletrack, Verge

**Bituminous**

Longitudinal Trip
Major Cracking
Major Fretting
Minor Cracking
Minor Fretting
Moderate Local Settlement/Subsidence
Not assessed
Not Defective
Severe Local Settlement/Subsidence
Spot Defects

**Blocked**

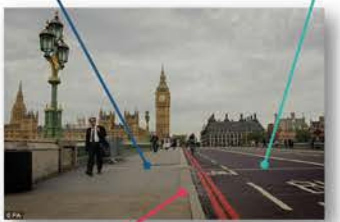
Cracked and Depressed Blocks
Cracked but level Blocks
Depressed or Missing Blocks
Longitudinal Trip
Missing Filler
Not assessed
Not Defective
Spot Defects

**Concrete**

Longitudinal Trip
Major Cracking
Major Scaling/Fretting
Minor Cracking
Minor Scaling/Fretting
Moderate Local Settlement/Subsidence
Not assessed
Not Defective
Severe Local Settlement/Subsidence
Spot Defects

**Flagged**

Cracked and Depressed Flags
Cracked but Level Flags
Depressed Flags (not Cracked)
Longitudinal Trip
Not assessed
Not Defective
Spot Defects



### Kerb

Inadequate Up stand
Kerb Disintegration
Kerb Misalignment
Not assessed
Not Defective

### Carriageway

**Bituminous**

Left Recorded Edge Deterioration Severity 1
Left Recorded Edge Deterioration Severity 2
Moderate Local Settlement/Subsidence
Not assessed
Not Defective
Right Recorded Edge Deterioration Severity 1
Right Recorded Edge Deterioration Severity 2
Severe Local Settlement/Subsidence
Transverse/Reflection Cracking Severity 1
Transverse/Reflection Cracking Severity 2
Wheel Track Major Cracking
Wheel Track Rutting
Whole Carriageway Major Chip Loss
Whole Carriageway Major Cracking
Whole Carriageway Major Fatting
Whole Carriageway Major Fretting
Whole Carriageway Minor Chip Loss
Whole Carriageway Minor Cracking
Whole Carriageway Minor Fatting
Whole Carriageway Minor Fretting

**Blocked**

Cracked but level Blocks
Major Block Deterioration
Minor Block Deterioration
Missing Filler
Not assessed
Not Defective

**Concrete**

Bituminous Patching
Cracking associated with Ironwork
Defective Longitudinal Joint Seal
Defective Surface Dressing
Defective Transverse Joint Seal
Global Settlement
Local Settlement
Longitudinal Joint Cracking
Longitudinal Joint Faulting
Loss of Texture
Major Concrete Surface Deterioration
Major Longitudinal Joint Spalling
Major Single Cracking
Major Transverse Joint Spalling
Minor Concrete Surface Deterioration
Minor Longitudinal Joint Spalling
Minor Single Cracking
Minor Transverse Joint Spalling
Multiple Cracking
Not assessed
Not Defective
Transverse Joint Cracking
Transverse Joint Faulting

Project CONVERT offered an opportunity to provide learning for ourselves and other urban authorities about the best way to transform connected vehicle data into actionable intelligence, and potentially valuable insights into what is required to make sure that vehicles are fully 'compliant' within the network, and also inform the preparations that local Highways authorities and their maintenance service providers will need to make.

# 2 What we did

## 2.1 LiDAR

In a similar way that a bat uses SONAR to measure distance, LiDAR (Light Detection and Ranging) sensors measure distance by continually firing off beams of laser light and recording the time it takes to strike an object or surface and return to the sensor.

By emitting millions of pulses per second, the measurements from the LiDAR sensor build a 'point cloud', a 3D visualisation of the surrounding environment.

LiDAR generates huge 3D maps, which in the future can conceivably be used by vehicles to navigate by. This kind of predictability is exactly what self-driving cars require and the concept has been a significant contributing factor to progress in the industry over the last five years.

## 2.2 Repurposing previous LiDAR survey

As part of its work to do with a smart parking initiative in Westminster, appyparking Ltd had commissioned a LiDAR survey of the Westminster road network and Fitzpatrick Advisory Ltd (working in an asset management advisory capacity with Westminster) were aware of the potential this survey data offered to Westminster's future asset management and smart cities strategy. The Connected Vehicle data competition was an opportunity to explore this potential.

The network had been surveyed using a car mounted 360 degree laser scanner with survey grade panoramic photography at 5m intervals. Both these datasets were combined to form a colourised point cloud. Up to a million pixels were captured for denser imagery and dual Global Navigation Satellite System receivers (GNSS) enabled good locational accuracy to within +/- 30mm.

For this type of LiDAR survey the user (originally appyParking) specified what information was required to be extracted from the point cloud. Point cloud data went through a part manual and part automated extraction process which was able to 'learn' how the required asset types were presented in the point cloud and extract that data, and which also, for example, identified paint on the road related to Traffic Regulations e.g. single yellow line, double yellow line, parking bays etc.

Photographic images went through a sign query image selector, able to crop into any parking and traffic management sign. The cropped signs were then processed within a deep neural network where artificial intelligence translated the images into a text based format to identify what they were.

## 2.3 Areas where LiDAR data was to be compared

We proposed to test and compare the survey data, identifying traffic signs and road markings and other inventory data to be extracted, in 3 different areas of the Westminster Highways network, preferably unchanged since the date of the original LiDAR survey 2017. These areas were selected because they each had distinctly different infrastructure characteristics; where there is a lot of traffic signs and road markings, where there is a conflict of people, cars, buses or other vehicles, and/or where street furniture, parking or vegetation may provide challenges for the 'reading' of LiDAR data.

It was hoped that this approach might uncover potential challenges in the use of LiDAR data which might remain unseen in an urban environment, (LiDAR usage has gone through a steep learning curve in the inter urban Highways environment), and allow lessons to be evidenced and shared should that be the case.

Originally those areas where LiDAR data and extracted assets were to be reviewed and compared were Villiers Street, Marylebone High Street and Grove End Road.

**Villiers Street –** a busy pedestrian and retail street linking Charing Cross main line railway station and Embankment underground station, providing access from the Strand and Trafalgar Square to the River. This narrow street has an underpass and is closed to general traffic although retail deliveries are critical.

**Marylebone High Street –** a mixed use shopping and residential area, with lots of pedestrian and cycling activity, zebra crossings, guard rails, bus routes, deliveries and many potential conflicts; and

**Grove End Road –** a relatively high speed road with significant bus routes.

In the event we were unable to utilise Grove End Road for the comparison, and were not able to attend any other high speed roads, so opted instead for **Vincent Square**, a residential neighbourhood with parking, road condition and signage challenges.

## 2.4 Comparing existing data and information accuracy - ground truthing

Project CONVERT was about exploring the potential of connected vehicles reporting asset condition data in real time. LiDAR data was able to be repurposed, but was it more accurate than the way data is currently collected? Was processing it more efficient, or was it just an additional burden? We needed a structured methodology to be able to draw robust comparisons, and make sure we were comparing the right things, for example like for like asset data. We set out to achieve this by:

*2.4.1 Auditing in-situ traffic signs and road markings with the regulatory environment in key areas.*

Working with appyParking we observed a generally good correlation between the regulatory environment and the captured assets. Where there were anomalies feedback was promptly provided to the maintainer.

*2.4.2 Comparing the LiDAR data with the current network and asset inventory for all assets we currently hold for the 3 selected areas of the network.*

A full inventory list from the CONFIRM asset and works management platform was obtained for each area and compared with the asset inventory extracted from LiDAR.

All of the main asset classes were extracted in the LiDAR survey, with the exception of street lighting. So for the purposes of CONVERT street lighting was not included as an asset class for comparison, although it is worth noting that catenary lighting was captured in Villiers Street. There is absolutely no reason at all to suppose that street lighting condition data is an issue which would prove problematic if being collected from LiDAR or any other device.

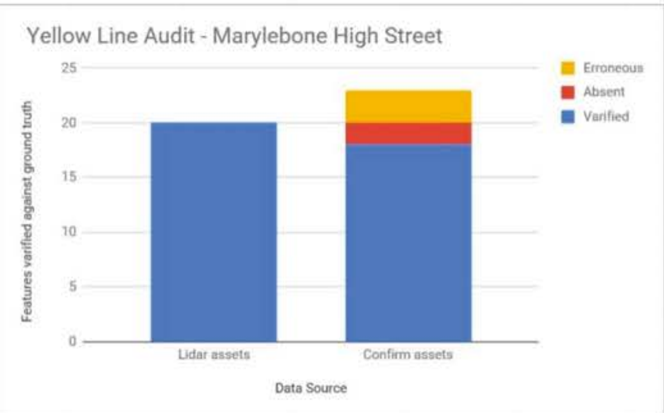
| Assets extracted from the LiDAR survey | | |
|---|---|---|
| Bus shelter | Roundabout | Seating (benches) |
| Bus Stop Sign | Signal controlled junction | Comms Cabinets |
| Dog Bin | Stop and give away | Advertising Boards |
| Litter Bin | Traffic calming | Cycle Racks (all) |
| Car Club Bay | Traffic island | Street Name Plate |
| Disabled Bay | Tram marking | Telegraph Pole |
| Doctor Bay | Waiting restriction | Gullies |
| Footway Parking Bay | Worded and diagrammatic marking | Speed Bumps |
| Limited Waiting Bay | Yellow bar marking | Carriageaway |
| Loading Bay | Yellow box junction marking | All Parking/ CPZ signs |
| Motorcycle Bay | School Markings | Arrow and lane destination |
| Pay & Display Bay | White Bar Markings | Bus markings including bus lanes |
| PrePaid Ticket Bay | Pay and Display ticket machine | Cycle marking |
| Permit Holder Bay | Post Box | Double yellow line |
| Shared Use Bay | Public Telephone Box | Longitudinal line |
| Taxi Rank | Bollards | Pedestrian crossing |
| All Regulatory signs | Guard Rail | Railway level crossing |
| All warning signs | Dropped Kerbs/ Driveways | Road stud |
| Safety Fencing | Footway | Highway Trees (for pavement only) |

## CONFIRM database showing small sample of Highways assets inventory for Marylebone High Street

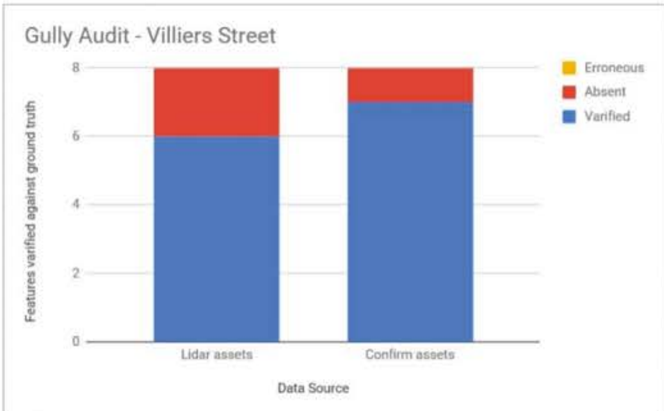
| asset number | Site name | feature_ type_code | easting | northing | bollard style | bollard material | bollard colour | listed | feature_location | feature_type_name |
|---|---|---|---|---|---|---|---|---|---|---|
| 425000 | Marylebone High Street | HWAS | 528361.67 | 182068.23 | | | | | | HW- Anti Skid Surfacing |
| 440075 | Marylebone High Street | HWAS | 0 | 0 | | | | | | HW- Anti Skid Surfacing |
| 425001 | Marylebone High Street | HWAS | 528359.81 | 182075.16 | | | | | | HW- Anti Skid Surfacing |
| 100002 | Marylebone High Street | HWBD | 528349.99 | 182011.52 | City | Cast Iron | Black | Yes | | HW- Bollard |
| 100026 | Marylebone High Street | HWBD | 528349.81 | 182029.07 | City | Cast Iron | Black | Yes | | HW- Bollard |
| 105996 | Marylebone High Street | HWBD | 528327.3 | 181774.19 | Cannon | Cast Iron | Black | Not Applicable | | HW- Bollard |
| 105995 | Marylebone High Street | HWBD | 528339.91 | 181571.92 | City | Steel | Black | Yes | | HW- Bollard |
| 108997 | Marylebone High Street | HWBN | 528333.09 | 181634.26 | | | | | | HW- Litter Bin |
| 440034 | Marylebone High Street | HWCC | 528320.73 | 181768.79 | | | | | O/s 86-87 Marylebone High Street | HW- Carriageway Core |
| 440063 | Marylebone High Street | HWCS | 528311.51 | 181832.78 | | | | | | HW- Cycle Stand |
| 100204 | Marylebone High Street | HWCW | 528346.43 | 181541.89 | | | | | | HW- Carriageway - CW |
| 100205 | Marylebone High Street | HWCW | 528350.94 | 181542.36 | | | | | | HW- Carriageway - CW |
| 100206 | Marylebone High Street | HWCW | 528311.57 | 181884.47 | | | | | | HW- Carriageway - CW |
| 100207 | Marylebone High Street | HWCW | 528313.22 | 181877.38 | | | | | | HW- Carriageway - CW |
| 100208 | Marylebone High Street | HWCW | 528312.7 | 181868.29 | | | | | | HW- Carriageway - CW |
| 100209 | Marylebone High Street | HWCW | 528313.49 | 181854.57 | | | | | | HW- Carriageway - CW |
| 100210 | Marylebone High Street | HWCW | 528317.94 | 181836.7 | | | | | | HW- Carriageway - CW |
| 100211 | Marylebone High Street | HWCW | 528319.32 | 181826.26 | | | | | | HW- Carriageway - CW |
| 405418 | Marylebone High Street | HWCW | 528323.98 | 181776.65 | | | | | | HW- Carriageway - CW |
| 405419 | Marylebone High Street | HWCW | 528320.4 | 181776.52 | | | | | | HW- Carriageway - CW |
| 118897 | Marylebone High Street | HWDK | 528341.27 | 181990.43 | | | | | | HW- Dropped Kerb |
| 440012 | Marylebone High Street | HWFW | 528350.41 | 182025.17 | | | | | | HW- Footway |
| 440013 | Marylebone High Street | HWFW | 528351.45 | 182019.72 | | | | | | HW- Footway |
| 440014 | Marylebone High Street | HWFW | 528351.3 | 182018.95 | | | | | | HW- Footway |
| 440015 | Marylebone High Street | HWFW | 528350.58 | 182016.12 | | | | | | HW- Footway |
| 440016 | Marylebone High Street | HWFW | 528349.28 | 182013.28 | | | | | | HW- Footway |
| 440017 | Marylebone High Street | HWFW | 528361 | 182016.08 | | | | | | HW- Footway |
| 440018 | Marylebone High Street | HWFW | 528346.5 | 182003.86 | | | | | | HW- Footway |
| 440019 | Marylebone High Street | HWFW | 528341.96 | 181992.26 | | | | | | HW- Footway |
| 440020 | Marylebone High Street | HWFW | 528346.42 | 181977.52 | | | | | | HW- Footway |
| 429913 | Marylebone High Street | HWGY | 528353.64 | 182038.04 | | | | | O/P no. 59 Marylebone High Street | HW- Gully |
| 130636 | Marylebone High Street | HWGY | 528317.96 | 181773.19 | | | | | At or outside Fourth Floor 86 Marylebone High Street London W1U 4QW | HW- Gully |
| 130635 | Marylebone High Street | HWGY | 528326.75 | 181772.98 | | | | | At or outside Basement And Ground Floor 32 Marylebone High Street London W1U 4PR | HW- Gully |
| 130622 | Marylebone High Street | HWGY | 528329.8 | 181744.74 | | | | | At or outside 28-29 Marylebone High Street London W1U 4PL | HW- Gully |
| 130633 | Marylebone High Street | HWGY | 528322.9 | 181726.38 | | | | | At or outside Second Floor And Third Floor Maisonette 92 Marylebone High Street London W1U 4RD | HW- Gully |
| 130645 | Marylebone High Street | HWGY | 528332.73 | 181642.55 | | | | | At or outside Basement And Ground Floor 102 - 103 Marylebone High Street London W1U 4RN | HW- Gully |
| 130631 | Marylebone High Street | HWGY | 528340.71 | 181645.38 | | | | | At or outside Basement And Ground Floor 13 - 13A Marylebone High Street London W1U 4NS | HW- Gully |
| 130629 | Marylebone High Street | HWGY | 528332.52 | 181644.74 | | | | | At or Outside 102 Marylebone High Street | HW- Gully |
| 130624 | Marylebone High Street | HWGY | 528336.77 | 181606.34 | | | | | At or outside Basement South And Ground Floor South 110 Marylebone High Street London W1U 4RY | HW- Gully |

*2.4.3 Identifying and updating changes to the inventory, including any unrecorded defects or assets*

In general the level of compliance between the assets captured by LiDAR and those recorded in CONFIRM was good, where there were some difference there were rational reasons usually. The exercise did highlight the need for effective, consistent and continual data hygiene however.




**The yellow line assets for both CONFIRM and the extracted LiDAR assets were audited against the findings from ground truthing. We found all features in the LiDAR assets dataset were verified by ground truthing and no features were missing. The CONFIRM database had two features absent from the dataset when compared to the LiDAR and ground truthing as well as 3 erroneous features that were not present in the ground truth or LiDAR.**




**The absent gully features in the LiDAR assets dataset were present on a pedestrianised end of Villiers Street, we found they were not captured because the survey vehicle could not gain access to the street.**

*2.4.4 Assessing the potential to reduce manual surveys, for condition assessment, and for design of maintenance schemes – checking for degrees of accuracy*

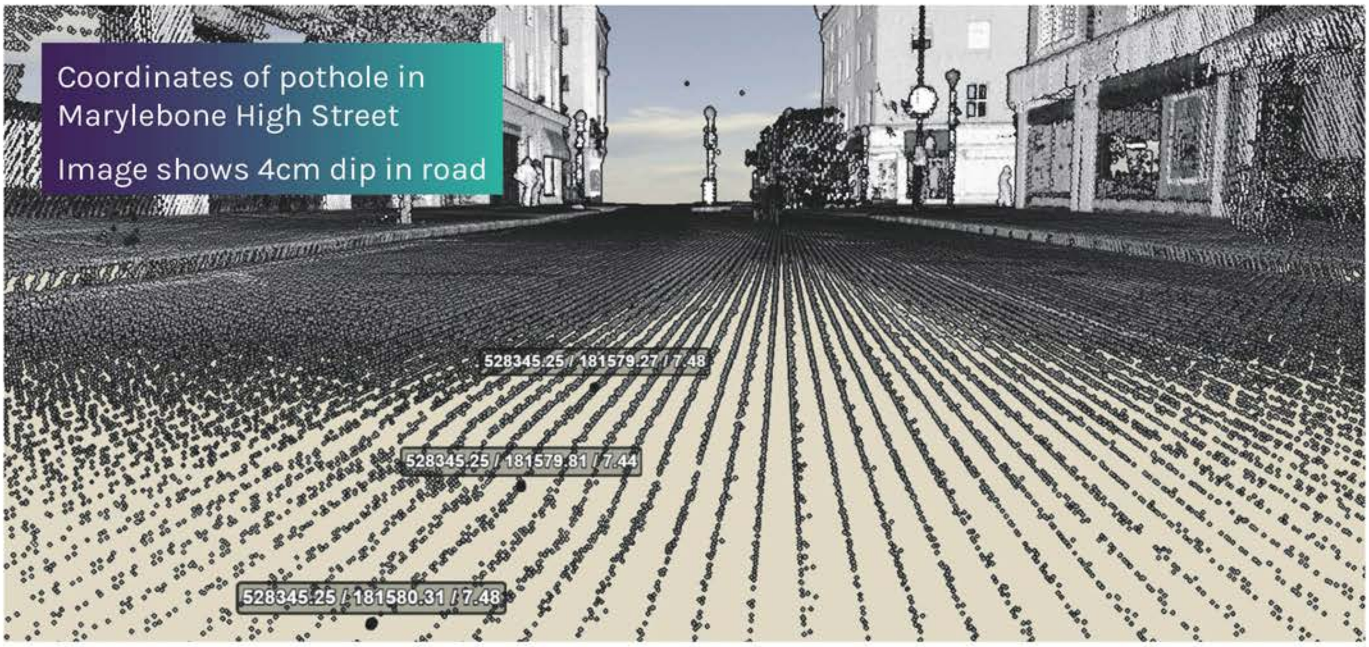
LiDAR is accurate. If defects were being reported from a connected vehicle, it is easy to see what the issue is, and what the resolution might need to be. Combined with other latent data already existing in the Highways department, eg utilities activity, collecting real time condition data from connected vehicles is an extremely powerful and efficient tool.

**Overhead lighting in Villiers Street**

Some of the images below are from Marylebone High Street.

By understanding the accuracy of the LiDAR data, and the effort required to receive, extract, process and utilise it, we had a better understanding of its potential impact and applicability to the way the Highways maintenance agent did its work.

We sat down with FM Conway and considered the potential of real time condition data, received digitally from LiDAR surveys, to reduce the cost and effort of manual surveys of network and asset condition, and the need for topographical surveys to inform the design of maintenance schemes. This understanding was fed into our benefits estimate.


*2.4.5 Understanding data veracity and convergence issues arising from using such data with existing asset management and information platforms, working closely with the maintenance service provider.*

There was broad correlation between the different systems, digital can talk to digital, unfortunately throughout the Highways industry widespread digitisation of the service is lagging behind activity in comparable sectors e.g. construction and rail.

*2.4.6 Understanding the potential impact upon people, platforms, processes and information flow around reactive and planned maintenance*.

Everyone involved in the Project can see the sense in digitising information flows and processes. The cost of investing in new platforms, in training and for suppliers recouping the cost of that investment is not clear in the way maintenance contracts are procured currently. To check our understanding that such sentiment was not peculiarly local to Westminster we conducted a series of interviews with senior representatives from leading organisations in the sector.

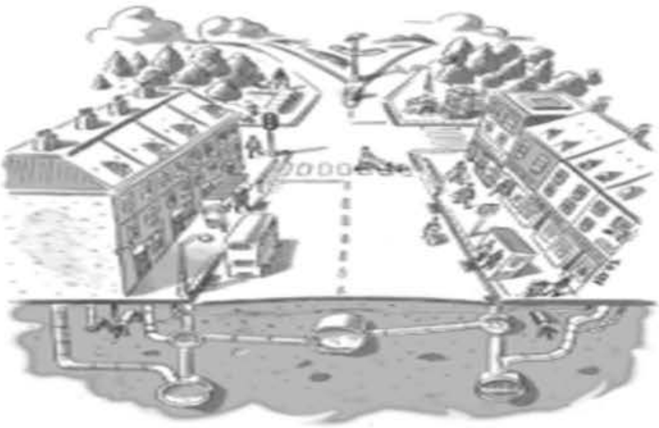
# 3 Industry context for CONVERT

## 3.1 Operating in silo's

CONVERT set out to understand the 'so what' of disruptive technology, in this case the technology of connected vehicles and its potential impact upon Highways maintenance operating models in local authorities.

We found that LiDAR data as a proxy for real time connected vehicle data could unlock a whole lot of process benefit compared to existing practice, but that in many ways the maintenance industry does not appear to have yet fully embraced the change to digital, or even appreciate that it needs to.

We found that Westminster suffers from some problems caused by systemic issues within the industry, in common



with other local Highways authorities in the UK, and that these systemic issues need to be tackled in order for widespread digitisation to be achieved and the subsequent benefits to be properly realised.

All Highways authorities function in vertical operational silo's. This means that the convergence and collation of data and information, horizontal integration, is hard to achieve without a lot of human intervention, filtering and management. The reasons for this include:

- the large number of proprietary information systems and platforms in use in the sector which don't talk to each other;
- a lack of standardisation;
- a lot of data being collected without a clear home or purpose;
- the high cost of data collection and recollection;
- reduced opportunities or incentives for supplier-led innovation in work practice or technology.

- a lack of clear and coherent technical leadership from the engineering institutions which lead or influence the sector, and sometimes even the DfT; and
- inefficient information flows, analogue or digital.

Council focus has historically been on the maintenance needs of individual asset types. CONVERT shows that integrating and digitising the whole service will accelerate consideration of network needs and management, as well as catalysing a more digitised approach to information management generally, cutting through existing silo thinking.

Our research concludes that emergent technology will indeed impact on network operations and asset management in the future, and positively if managed properly.

Officers also examined a range of scenarios relating to the future operation of Westminster's road network in a confidential workshop as part of CONVERT. It considered the capability of the existing network to adapt to spatial changes to it, and of varying demands upon it emerging now and in the future, e.g. provision for Electric Vehicles, and the potential impact of connected and autonomous vehicles on the network, initially identifying a target year for examination, 2035.

Westminster officers looked at the management tools and techniques currently available to them, as considered within CONVERT, and considered their suitability for use in future network management operations and Highways maintenance activities. They considered the rise in consumer technology, the role of apps, and the increase in customer expectation of how their Council should utilise technology for resident and businesses now and in the future.

Officers hypothesised, in a technology focused, relatively neutral, but outcome orientated way about what needed to be 'true' now or in the near future about the way they need to manage or prepare the network and operations to create optimal performance and service in 2035.

CONVERT's conclusions include elements of the workshop findings.

### 3.2 Focus Interviews

We wanted to know whether the way Highways maintenance gets done in Westminster was typical in the industry, or an outlier of best practice. We decided to talk to a range of senior people in the industry to try and better understand the dynamics of the sector and its apparently passive response to disruptive technology 'on the ground'.

From talking to a wide range of maintainers it would appear that many clients are torn between the need for good asset management or good customer service. The industry has got very good at responsiveness, but not necessarily good at longer term or whole life cost thinking, or selling the benefits of it. Digitisation is some way off, even in an authority as forward thinking as Westminster, and so it is by no means an easy transition in what is a relatively low tech industry at the moment, and heavily resource dependent upon manual labour.

In part this is because Highways maintenance, like construction, is an industry traditionally resistant to change, in processes and culture. Some commentators argue that the sector is too comfortable and conservative, because it is dominated by the public sector, which is typically very risk averse.

The industry is also very fragmented, the scale and large number of Highways authorities produces fragmentation, and a lack of consistent capability.

Will the digital revolution only be embraced by maintainers if clients start to mandate and instruct it, and pay for it, or are the benefits of digitisation assumed to be included in the price? Change will need to come from the client, the sector is crying out for positive leadership in the digitisation space.

The CONVERT project raises some significant questions about the impact of technology upon maintainers of the Highway and their capacity to respond and gear up sufficiently, certainly against current procurement methods and current incentivisation.

### 3.3 Digitising the whole value chain

It's clear that connected vehicle data presents a range of potential opportunities for greater efficiency and productivity. It's also clear that the proliferation of processes and systems, the lack of standardisation in the value chain around maintenance, is a significant barrier to achieving those benefits. For the value of connected vehicle data to be fully realised, the whole service and value chain needs to be digitised and integrated. Such integration will catalyse greater innovation and creative thinking, e.g. the development of a platform to digitally integrate all of the data within the service without competing with existing platforms and systems.

## 4 Conclusions

### 4.1 Estimating benefits

The profile of benefits identified from CONVERT is, to a degree, dependent on the extent to which its recommendations are taken forward.

The findings from the work have already directly influenced Westminster's approach to understanding the 'ask' of future management of their network, and the tools and techniques which might need to be deployed/developed to optimise resultant benefits.

As well as some of the outline monetised benefits worked through with the maintainer for CONVERT savings will accrue from digital convergence in maintenance service provider information flows and processes as well. This is obviously harder to measure unless it is mandated.

Project CONVERT highlights the ways in which a local authority can best use acquired data. Envisaging an integrated approach across asset classes and disciplines its feasible that future benefits will be realised through automatic notification of defects or maintenance issues to maintenance teams, with automatic filtering of inconsistencies in data, to derive actionable intelligence for maintenance. The Project CONVERT workshop discussed practical ways in which to bring these theories to real life, possibly in a successor project testing the collection of real time data from equipped vehicles and deploying a customised data host and aggregation engine.

In future LiDAR and camera data in real time can be matched to traffic flows/mobile phone records to derive network occupancy data, and trend analysis, and inform predicted analytics of usage which will in turn inform the longer term maintenance needs of the network.

Being able to automatically predict the needs of the network will allow better responsiveness and management by the maintainer as well as allow more time for consideration of the structural needs of the network, will create the space for innovation in infrastructure design, and the better use of more sustainable materials.

The essential point of CONVERT was not to address specific technology issues, but to understand how any such technology will help drive change into the way things get done. Eg can maintainers use LiDAR data, or other visual data, captured in real time from vehicles on the network, to inform their responses and prioritisation of maintenance activity? Can LiDAR data and its accuracy specifically offer efficiencies for maintenance scheme design and reduce the need for manual topographical survey? Does using LiDAR data, and other similar technology, offer the potential for improved maintenance, greater productivity, and better upkeep of the network and assets on and in it? These were the practical questions which CONVERT sought to help start to answer, and the short answer to all of those questions is yes.

### 4.2 Summary and next steps

In December 2017 the DfT launched a competition which asked local authorities to identify and under-take projects which would:

- demonstrate the capability of connected vehicle data;
- improve the quality of road condition and asset management data;
- provide the business case for more widespread deployment across a number of highway authorities;
- enable the development of smart asset strategies based on harvested intelligence; and
- help support innovation within the private sector supply chain.

CONVERT is the project title for the research project undertaken by Westminster City Council.

The aims of the project were to:

- assess the technique and benefits of transforming data acquired from in-vehicle laser and cameras into actionable intelligence, and
- provide insights into future asset and network management requirements.

Specifically Westminster extracted and re-purposed LiDAR survey data, already captured as part of the DfT Smarter Parking initiative within Westminster's road network, in order to test 7 objectives. Our performance against these objectives is shown below

| Objective | Achieved fully | Achieved partially | Not achieved | Comments |
|---|---|---|---|---|
| 1. Audit in-situ signs and road markings with intended regulatory environment in 3 areas to compare efficacy of LiDAR data to on-street assets, locations, xyz coordinates, and to data stored in WCC platform | Yes | | | Previously collected LiDAR data was re interrogated, and a robust ground-truthing method adopted to compare signs and markings from the LiDAR point cloud data, the assets and geospatial layout on the street, and the traffic regulatory order environment. 56 asset classes were examined consistently across all 3 pilot areas.<br><br>Comparisons were made of existing data sets with changes announced through Traffic Management Orders (TMO's) since the first day of original LiDAR capture. Update of TMO's is labour intensive. An observation is that the process could ideally be digitised and made more accessible, even with Westminster, but that argument is out with the scope of CONVERT. |
| Conclusion | Signs and road markings are generally up to date, (98%) with some signage missing on-street which was either the result of maintainer delay in replacing, or just reflecting the dynamic nature of Westminster's network. LiDAR gave great accuracy of data including height information e.g. road camber, pot hole depth etc. WCC maintenance practices were revised during the pilot scheme to reflect the new Code of Practice. Work is ongoing with the maintainer to make their processes more 'digital' | | | |

| Objective | Achieved fully | Achieved partially | Not achieved | Comments |
|---|---|---|---|---|
| 2. Compare LiDAR data with current inventory | Yes | | | CONFIRM, which was the in-situ works management platform and asset inventory, was interrogated and lists of held assets and locations downloaded. LiDAR picked all of them up, and all well within 10cm tolerance, (the greatest difference measured was 92mm but typically was less than half of that). Compared to the 'ground-truthed' data some geospatial issues were also identified within the existing WCC platform CONFIRM. Some assets and updated condition data was found to be not up to date on the WCC platform. Additionally some asset types were geospatially misrepresented in the WCC platform. |
| Conclusion | Generally the inventory held by Westminster was correct but LiDAR corroborated, and in some cases, improved the inventory and geospatial information held within the WCC platform. Further research into why the geospatial location information was wrong was not possible due to WCC corporately arranging to change its platform halfway through the pilot. This part of the pilot scheme also identified activities not being done optimally by the maintainer, which caused some further investigation into contract scope, and responsiveness, and the performance of the local maintainer. At the same time we contacted and interviewed other Highways maintainers in the area of asset condition update in local authority asset management systems to better understand whether the approach from the local maintainer was typical of industry, generally speaking it is. | | | |
| 3. Identify and update inventory, including unrecorded defects or assets | Yes | | | Key inventory was updated where required, and 3 areas, Villiers Street, Marylebone High Street and Vincent Square, were 'digitally aligned' with relative ease. |
| Conclusion | The passive inventory and condition platform held by WCC is easy to update, and when considering connected vehicles reporting in real time it is relatively simple to see where and how data can be input to it, either continuing manually or via 'edge' layers contributing to a common platform. Thinking ahead, cloud based asset management systems, complementing the real time data collected from connected vehicles, and possibly utilising self-healing mapping techniques, are an obvious development for the future, which might essentially make some of the existing platforms used in the sector less necessary or even redundant. | | | |
| 4. Assess potential to reduce annual manual surveys of network condition and need for design surveys | | Yes | | The savings in annual condition surveys would be initially offset by the cost of an annual LiDAR survey, but dependent upon the approach to reliance on real time data from connected vehicles e.g. an initial dual data approach to develop confidence, and the scope of footway and carriageway network to be assessed, we believe we would realise a minimum £70k per annum benefit by adopting connected vehicles information .<br><br>The benefits from the reduction in confirmatory surveys for maintenance scheme development (geometric, topographical, photo collection etc), and across disciplines i.e. Highways, Street Lighting, Drainage, Public Realm schemes, is now estimated by the maintainer to be in the order of 3-5% per scheme value, conservatively. This exceeds the 1% to 3% savings originally estimated. |

<table>
<tr><th>Objective</th><th>Achieved fully</th><th>Achieved partially</th><th>Not achieved</th><th>Comments</th></tr>
<tr><td>Conclusion</td><td colspan="4">The potential to reduce the effort and cost of annual manual survey effort was proven, but only in part. Technically, geometric and condition data was able to be appraised and used to inform the initial identification of potential maintenance schemes, but not to the detail of the existing UKPMS specification, which currently it could never do since some of the condition data collected via UKPMS is subjective and currently centrally mandated. LiDAR information was also used, in part, alongside conventional confirmation of design information, to compare the cost of design inputs, but its use was restricted to 2 schemes only, again due to activities not being done as agreed with the maintainer. Nonetheless as the process was stepped through the potential is clear, the accuracy of the LiDAR data lends itself to easy transcription into the design, and saves a lot of duplicative effort.</td></tr>
<tr><td>5. Understand data veracity and convergence issues</td><td></td><td>Yes</td><td></td><td>Digital information flows within Westminster are sub optimal, effectively it's still an 'analogue' information and communication process. There is a surfeit of discreet platforms and devices which do not talk to each other, and require human intervention and processing for that information to be able to be turned into actionable information.<br><br>What CONVERT revealed therefore, perhaps surprisingly, was that the technology involved in the pilot (LiDAR) was to a degree irrelevant to the potential success and benefits able to be optimally realised from the collection of real time data, unless the whole service is 'digitised' and able to receive digital data from any source of information or sensor, and officers are sure this is true of most local Highways authorities.<br><br>A workshop which focused upon the service needs looking back from 2035 was held with external advisors and commentators. Westminster identified a number of areas where connected vehicles, and the infrastructure to support them, would need to be better considered, and start to be factored into contractual arrangements, and this is felt to be a real positive aspect of the research by WCC.</td></tr>
<tr><td>Conclusion</td><td colspan="4">The supply side culture in Highways maintenance is relatively low tech, as it is resource driven basically. Activity and scope are heavily influenced by cost and margin considerations. So innovation, and the adoption of techniques to realise the benefits of receipt of real time connected vehicle data, will not be easy to achieve. Unless the contractual, commercial and cultural issues are addressed at the same time as the uptake and use (or re use) of connected vehicle data, benefits will be harder to identify and achieve.<br><br>Westminster wanted to check whether this was a local phenomenon or a wider industry one, so some focus interviews with other players in the industry against a standardised set of questions were undertaken. The collective point of view about why innovation is hard to achieve in this sector, for the cultural issues identified within the focus interviews, is hard to refute. Construction suffers similarly, and initiatives such as Project 13 have been set up to address it, no such initiative currently exists in this sector.<br><br>Westminster is aware that the benefits which will accrue to them from adoption of digital techniques, and the receipt and processing of real time data from connected vehicles, are in part reliant upon the maintainers being part of the solution, and incentivised appropriately to bring innovation into their operations.</td></tr>
<tr><td>6. Understand potential impact upon people, processes and platforms from using connected data</td><td></td><td>Yes</td><td></td><td>Everyone involved in the pilot could see the benefit of becoming more digital, and believe that connected vehicles will be the catalyst for change. Indeed some see connected vehicles as the 'trojan horse' for meaningful change within the local Highways authority sector, and the Highways sector as the 'trojan horse' for change on the way to achieving smarter cities. Again, however, these impacts proved difficult to monetise within the terms of this pilot scheme.</td></tr>
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| Objective | Achieved fully | Achieved partially | Not achieved | Comments |
|---|---|---|---|---|
| Conclusion | The impacts are generally agreed by all players to be positive, but they are difficult to monetise without a specific focus on individual aspects of service provision, and within current contractual practices e.g. some costs are masked by other activities. It will be possible to disaggregate some elements appropriately, but for the cultural reasons stated above, a pilot scheme will need to be much more rigorously mandated by the client, or the maintainer will need to be much more incentivised, to be able to get at that data. | | | |
| 7. Draw and share conclusions, identify scalable opportunities | Yes | | | LiDAR, as a proxy for real time data from connected vehicles, works very well technically. It challenges UKPMS mandated data collection techniques however. It will provide real benefits in design, preliminary and detailed, across a range of disciplines. Westminster reckons the benefits will exceed the 1% to 3% of scheme costs identified in the original bid. Issues around the culture of Highways maintenance, and the contractual incentivisation, and scope of works, will need to be resolved if the maximum benefits from this connectivity are to be realised. |
| Conclusion | CONVERT has already catalysed a range of ancillary and additional activity in Westminster. The immediate benefits described above will be achieved through the improvement and adoption of better contracts and scope, the standardisation of digital processes, the opportunity to do better and quicker design, the achievement of greater productivity, and greater horizontal alignment and visibility of value adding activities in the Highways, maintenance or construction related disciplines in Highways & Transportation.<br><br>Beyond this pilot scheme however, through the aggregation of connected vehicle data and the client being able to receive, process and use such data more intelligently, it is possible to see a wider range of applicable benefits arising.<br><br>4 current concepts now being explored by WCC as a result of the success of CONVERT are:<br>i) The development of 'DASHA©' which will aggregate and be able to show and tell relevant real time data from a range of data sources;<br>ii) The trial and development of 'exception condition reporting' from connected vehicles against 'self-healing' maps;<br>iii) The eventual aggregation, overlay and analysis of a range of different existing data sets across the City, to inform investment and enable better decision making, and<br>iv) The development of a better contractual and incentivisation mechanism for its suppliers, to allow them to begin their own digital journey and for them to bring innovation into their operations, their material solutions, and to be able to partner the Highways authority more effectively. | | | |