Project no. 691735

REPLICATE PROJECT

Renaissance of Places with Innovative Citizenship And Technology

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

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H2020-SCC-2015 Smart Cities and Communities

Innovation Action (IA)

D5.4 E-bikes Deployed in a Corporate Scheme

Due date of deliverable: 31/1/2019

Actual submission date: 30/11/2018

Revision: 31/01/2020

Start date of project: 01/02/2016 Duration: 60 months

Organisation name of lead contractor for this deliverable: Co-wheels

Status (*Draft/Proposal/Accepted/Submitted*): Submitted

Project co-funded by the European Commission within the 7th Framework Programme		
Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Editor/Lead beneficiary :	CO-WHEELS
Internally reviewed by :	ADS

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1. EXECUTIVE SUMMARY

Twelve e-bikes have been successfully delivered as part of the REPLICATE project. A range of different models are being tested alongside different business models for providing and servicing the e-bikes.

The e-bikes have been delivered to a range of organisations that have staff who travel regularly in the area as part of their daily work.

The e-bikes have been designed as a natural extension of the existing car club run by Co-wheels allowing maximum mode choice and flexibility in line with Mobility As A Service principles.

University of Bristol has developed a customised monitoring system for the e-bikes which includes a GPS system as well as access to the diagnostics system which will allow a wide range of data to be analysed on bicycle usage.

The e-bikes use WiFi and Bluetooth as well as a LoRaWAN interfaces. Special compression protocols were developed to ensure this could be done efficiently.

We feel confident that when the monitoring period starts formally these e-bikes will continue to provide important environmental and social benefits as part of the wider range of REPLICATE interventions.

Already, on the environmental side, the e-bikes are showing substantial promise. During a six month period in which up to 10 of the e-bikes were being placed within organisations, they travelled 5224 miles (8,405 km) resulting in an estimated 1.2 tonnes of savings in CO2 so far.

The delivery mechanisms and technology developed a part of REPLICATE has been designed such that it is very scalable. This means that e-bikes can be added in other parts of the city, as well as other locations in the UK and Europe.

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2. REPLICATE

The main objective of REPLICATE project is the development and validation in three lighthouse cities (**San Sebastián** – Spain, **Florence** – Italy and **Bristol** – UK) of a comprehensive and sustainable City Business Model to enhance the transition process to a smart city in the areas of the energy efficiency, sustainable mobility and ICT/Infrastructure. This will accelerate the deployment of innovative technologies, organizational and economic solutions to significantly increase resource and energy efficiency, improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

REPLICATE project aims to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens, and prove the optimal process for replicating successes within cities and across cities.

The Business Models that are being tested through large scale demonstrators at the three cities are approached with an integrated planning through a co-productive vision, involving citizens and cities' stakeholders, providing integrated viable solutions to existing challenges in urban areas and to procure sustainable services. Sustainability of the solutions is fostered in three areas: economic, environmental and transparency in the public management.

In addition, the Model features the replicability of the solutions and their scale up in the entire city and in follower cities, particularly in three follower cities (**Essen** – Germany, **Lausanne** – Switzerland and **Nilüfer**–Turkey) that are involved in the project and therefore, have access to know-how and results achieved on the project so they can apply the developed model. At the moment, there are 2 observer cities, Guangzhou (China) and Bogota (Colombia).

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3. INTRODUCTION

3.1 Relation to Other Project Documents

The definition of the work plan of the REPLICATE project is essential for achieving an effective innovation management system. Apart from the reference documents described below the deliverable has no specific relation to other project documents.

3.2 Reference documents

This document is based in the following projects level documents:

Ref.	Title	Description
REPLICATE Grant Agreement signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	REPLICATE Annex 1 – DoA to the GA	Description of the Action
REPLICATE Consortium agreement signed December 2015 (7th December version)	Consortium Agreement	REPLICATE project – Consortium Agreement
REPLICATE Project Management Plan	D1.1 Project Management Plan (v.1) (29/04/2016)	REPLICATE Project Management Plan
REPLICATE District Management Plans	D1.6 District Management Plan Bristol	REPLICATE District Management Plans
REPLICATE Communication Plan	D11.1 Communication Plan	REPLICATE Communication Plan

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Where there are contradictions, the documents listed above supersede this deliverable. The Grant Agreement is the contract with the European Commission so takes precedence over all other documents.

3.3 Abbreviations list

API	Application Programming Interface
CA	Consortium Agreement
CAN	Controller Area Network
COTS	Commercial Off The Shelf
DoA	Annex I-Description of the Action
EB	E-bike
EC	European Commission
EV	Electric Vehicle
GA	Grant Agreement
GPS	Global Positioning System
H2020	Horizon 2020
LoRaWAN	Long Range Wide Area Network
MQTT	Message Queuing Telemetry Transport
PC	Project Coordinator
PCB	Printed Circuit Board
PL	Pilot Leader
PMP	Project Management Plan
SSH	Secure Shell
STS	Sustainable Travel Solutions
TC	Technical Coordinator
TTN	The Things Network
UOB	University of Bristol

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UWE	University of the West of England
V2X	Vehicle to Everything
WP	Work Package
WPL	Work Package Leader

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4. DELIVERABLE DESCRIPTION

This document provides detail around the e-bikes and their deployment, the bike users, the monitoring of the bikes, the future analysis of their impact, and the business model.

Section 5 explains how the e-bikes have been rolled out as part of REPLICATE.

Section 6 provides technical details of the specification of the e-bikes.

Section 7 describes the details of the e-bike tracking system, showing how it can provide new insights into e-bike usage.

Section 8 covers a number of case studies of e-bikes users, highlighting the benefits that the e-bikes are providing to the community.

Section 9 sets out what is innovative about the REPLICATE e-bike system in Bristol, what social and environmental impacts are expected, what we have learnt in terms of replicability, scalability. This section finishes by looking at business models and the impact on SMEs.

Conclusions are set out in **Section 10**.

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5. ROLL OUT OF E-BIKES

The objective was to place e-bikes in a shared corporate scheme alongside expansion of the car club with electric vehicles (EVs). Initially this was to be a total of 32 bikes presented in bike boxes with internal power supplies and telematics. However, due to issues surrounding the planning application, this method of deployment was not pursued and e-bikes were instead deployed in the manner described below.

Following further research into bike share schemes and after a period of consultation with a range of organisations in the project area, an alternative delivery model was introduced. Given that 87% of bike share users already use sustainable transport modes prior to riding a shared bike (CoMoUK Public Bike Share Users Survey Results 2016) and also that up to 10.5 privately owned vehicles are replaced by each car club car (Annual Survey of Car Clubs 2017/18), Co-wheels decided to reduce the number of bikes being deployed and increase the number of EVs. Information about the EVs can be found in Deliverable 5.5.

The preferred model of delivery was to place 12 electric bikes within public, private and community organisations in the project area, providing a full service and support package. In the original grant proposal, 32 E-bikes were to be delivered and have since had an amendment agreed (AMD 691735-24) to change the proportion of E-bikes (EB) and Electric Vehicles (EV) from 32 EBs/ 6 EVs to 12 EBs/ 11 EVs. Further detail and justification is outlined in Section 9.3: Environmental Impacts.

The criteria we used to determine where to deploy e-bikes targeted people living and/or working in the project area that are making regular short journeys during the working day. These types of journeys are typically made by health professionals and those providing services and support in the community. For this reason, organisations employing people demonstrating this travel behaviour were approached.

Organisations who expressed an interest had a two week trial period with the bikes and then indicated whether they wished to proceed with the scheme and, if so, how many bikes they would be interested in taking.

The following organisations have successfully adopted e-bikes for their staff to use:

(4 bikes) **Bristol City Council (East Central Early Help team)**

(3 bikes) **Bristol Community Health**

(1 bikes) **University Hospitals Bristol**

(1 bikes) **North Bristol NHS Trust (Southmead Hospital)**

(2 bikes) **Barton Hill Settlement**

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(1 bikes) **Bristol Dementia Wellbeing Service**

These organisations are responsible for housing the e-bikes securely and managing the bikes internally. To facilitate the internal management of the e-bikes, Co-wheels has also developed the option for these organisations to place their e-bikes onto the car club booking system although for a number of reasons employees of one organisation can only use the e-bikes related to their own organisation.

The idea is for the organisations to sign up as corporate members of the car club and to invite their employees to join for free under this corporate membership. In addition to lifting any administrative burden, this also opens up other mobility options by providing access to Co-wheels's expanding network of car club vehicles in Bristol and throughout the UK.

The management of all other aspects of the e-bikes is included within the service and support package. This package includes basic quarterly services, a full annual service, maintenance and repairs relating to wear and tear, and emergency call-out support (Mon-Fri 9am – 5pm excluding bank holidays).

To prepare the e-bikes for use, Co-wheels also provides two pannier bags, puncture proof tyres and a D-lock. Helmets and high visibility jackets are not provided with the bikes, although Co-wheels recommends their use.

The e-bikes are insured for theft (providing the rider fully complies with duty of care requirements regarding safe and secure locking procedures when leaving the bike unattended) and technical malfunction and mechanical negligence resulting in an accident. Co-wheels also have the necessary public liability insurance in place in case of injury caused by any act of negligence where they may be at fault.

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6. TECHNICAL SPECIFICATION OF E-BIKES

When choosing suitable e-bikes, it was necessary to consider potential high usage, especially in summer months, with multiple trips per day in all weathers. The e-bikes needed to be robust, easy to manage and suitable for a wide range of users.

Essential requirements included a step-through frame, integral hub gears, a pannier rack, fixed front and rear lights, a fixed handlebar mounted display, hydraulic disc or rim brakes and puncture resistant tyres.

Due to Bristol being a very hilly city, as many different levels of electric assist as possible were also required.

This project has been an opportunity to test different ways of managing the e-bikes – purchase and lease, both of which will be explained in Section 9.5. For this reason, there was also an essential requirement for the bikes to be of reliable quality, easy to maintain and simple to clean.

In total, three different models of electric bike have been used for this project. The technical specifications for these are shown in Figure 6.1.

Bike model	Staiger Sinus BC30f	Raleigh Motus	Giant Entour E+1 Disc
Motor	Bosch Active Line 250W, 36V	Bosch Active Line 250W, 36V	Giant SyncDrive Life, automatic support, 5-mode, 300% tunable support, 60Nm, powered by YAMAHA
Battery	Bosch Battery 400Wh (36V/11Ah)	Bosch Battery 300Wh (36V/8.2Ah)	Giant EnergyPak 400Wh (Panasonic)
Display	Bosch Intuvia multi-function display	Bosch Intuvia multi-function display	Giant RideControl ONE
Gears	Shimano Nexus 7 speed hub gear, twist grip	Shimano Nexus 7 speed hub gear, twist grip	Shimano Deore 9 speed cassette gears, with trigger shifters.

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Brakes	Hydraulic rim	Hydraulic disc	Hydraulic disc
Range per charge	Up to 190km	Up to 180km	Up to 180km

Figure 6.1 – Different e-bike specifications

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7. DESCRIPTION OF TRACKING SYSTEM

7.1 Opportunities for Insight

University of Bristol oversaw monitoring the effectiveness of the electric bike mobility intervention. An important tool for this was the tracking system they developed. They also saw an opportunity to do more, and use the opportunities the e-bikes provide to gain even more profound insight into the way that e-bikes (and bicycles more generally are used).

This opportunity comes from the e-bikes themselves. Whenever trying to monitor the active mobility modes (cycling/walking etc.) one is faced with a number of common problems:

1) what to actually measure (it's not as easy to detect a bicycle through conventional means as it is to detect a car or a bus)

2) on a more practical level how do you power the monitoring hardware (you can get the individual being monitored to charge batteries, but in doing so you introduce a measurement bias into your sample). E-bikes provide an opportunity to overcome both these problems.

E-bikes have a battery, so if that can be used to power the monitoring device then you remove the reliance on the user, as they have to charge the e-bike battery otherwise it won't function.

When it comes to what to measure, the e-bike has an on-board internal control system that is transmitting to an internal network a huge amount of data about the way the user is using the bike. If this can be gathered and added to data such as GPS and accelerometer it can provide an extremely rich picture of not only e-bike use, but cycling more generally.

From an academic perspective, a flexible e-bike mounted platform also provides a chance to experiment with V2X technology more generally.

So, to realise this, much work has been done in developing a monitoring platform that makes the most of all these opportunities.

7.2 Development

The development of the tracking software took place in a number of stages:

- Understanding existing e-bike systems
- Developing hardware to interface with existing systems
- Prototyping
- Production of final trackers

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7.2.1 Understanding existing ebike systems

The initial step in developing a tracking system was to reverse engineer the e-bike control system to understand what was possible and how it could be interfaced with.

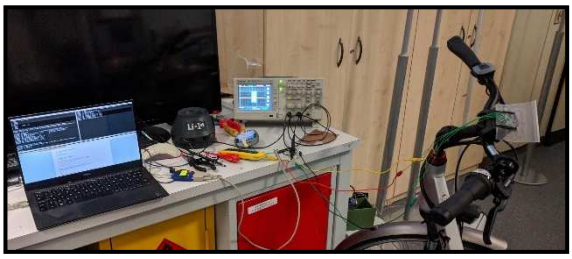
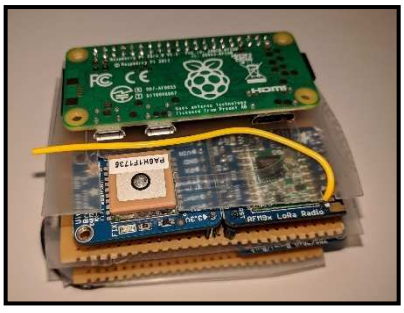


Figure 7.1 - understanding the ebike control systems

7.2.2 Developing hardware to interface with existing systems

Having understood the ebike control systems, we were then able to design the hardware that could draw power from the e-bike and interpret the system's monitoring and control messages.



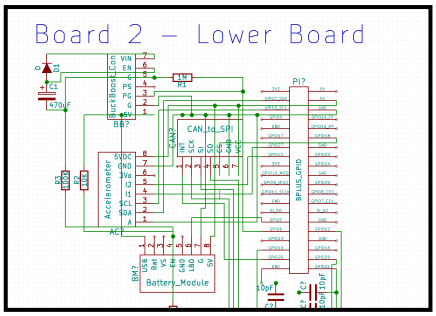


Figure 7.2 – developing hardware to interface with ebike system using Raspberry Pi

7.2.3 Prototyping

Once we had developed the hardware we were able to test the prototype REPLICATE E-bike Mobility Monitoring System. We did this by developing a number of prototypes to test that each element of the design is viable. Through a series of iterations, we made a number of improvements until we developed a final version of the ebike monitoring system.

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Figure 7.3 – prototyping the new systems in real world environments

7.2.4 Production of final trackers

Having developed a number of proof of concepts the 'final' version has been manufactured, and working closely with Co-wheels we have tried to ensure factors such as the installation and maintenance procedures are made as simple as possible to ensure the maximum amount of data possible is collected.

Figure 7.4 – mock-up of design and production ready version

7.3 System Design

Developing monitoring equipment from scratch has been an opportunity to experiment with a range of up-to-the-minute technologies, deploying them in many novel ways.

Rather than using a microcontroller, the monitoring hardware uses a single board computer

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running a full Linux implementation. This provides much more functionality and flexibility and eases the deployment of new software. It also allows a very wide range of applications to be developed for the hardware, and means languages such as python can be used allowing – in the future – some sort of machine learning deployment.

Figure 7.5 shows all the elements of the e-bike system that needed to be connected together to make the monitoring system work.

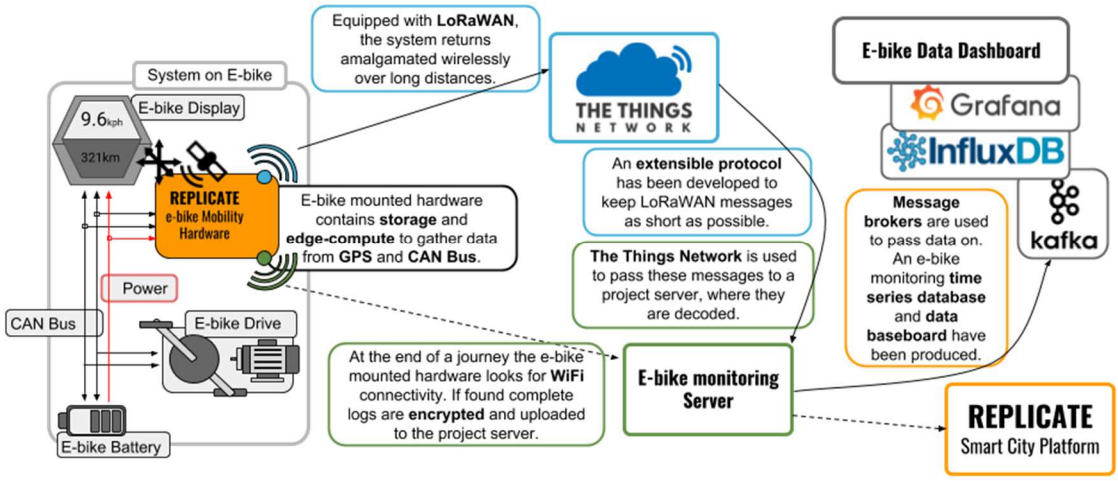

Figure 7.5 – schematic representation of the e-bike monitoring system

A key element of the hardware is how it interfaces with the e-bike. It has two main interfaces, namely the power, which it takes from the power supply designed for the e-bike display, and the CAN bus.

CAN is a serial protocol standard used widely in automotive. The e-bike drive system comprises a number of different components (namely the display, electric drive and battery) and it is through the CAN bus that these communicate. They transfer a huge amount of information about the status of the e-bike and the actions of the user.

Our e-bike monitoring hardware listens to this CAN bus (although does not transmit on it at all) and records all the information that the other participants are broadcasting. This allows the

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monitoring hardware to measure values such as battery status, bike speed, level of electric assist, even down to information about the amount of torque the user is currently delivering.

All this raw data is logged and stored to the hardware's internal storage.

Alongside the CAN bus data the monitoring hardware is also equipped with a GPS unit and accelerometers, and all this data together provides an incredibly rich picture about how the e-bike is being ridden.

As well as WiFi and Bluetooth the hardware also has a LoRaWAN interface and this can be used send short messages (<60 bytes due to limitations in the software) many kilometres. This means that some information about the bikes usage will still be gathered even if the bikes are only rarely within range of a WiFi access point.

The strict limitation on the number of bytes a LoRaWAN message can contain has meant that a novel technique have had to be developed to transmit meaningful data over the LoRaWAN link. If a text based message structure (such as json) were used it would only be possible to send one measurement at a time, and so instead specific salient e-bike related data is encoded in a predefined way and transmitted alongside a predefined flag. For example rather than transmitting the json string '{battery: 100%}' which would be 15 bytes long instead a one byte flag is sent, indicating that the next byte will contain the battery level, encoded into a hex value between 0 and 255. This reduces the message to two bytes.

The software on the monitoring device has been developed to make the addition of new measurements very straight forward, with the e-bike mounted hardware automatically selecting which measurements it can generate based on the CAN messages recently received. Using this sort of encoding structure will mean that, not only will more information be transferred in a single message, but the transmission time itself (which can be quite long with LoRaWAN) will be reduced, which improve transmission success rates on the mobile platform.

Every successful LoRaWAN transmission is passed, by The Things Network, to a project server using MQTT, where it is decoded.

The CAN bus has on it over a 400 messages a second, and LoRaWAN is not capable of handling even a tiny percentage of these. Instead, when the monitoring hardware detects that a journey has come to an end (sensing the e-bike has been turned off), it will look for available WiFi access points.

If an access point is available it will connect to it, and transfer all of the records it has directly

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up the central server. Once successful transmission has been verified the file is deleted from the device to save space. SSH is used as the transport for the transfer, ensuring the security of the transmission and rsync is used to facilitate the synchronisation. If, for whatever reason, the e-bike is not able to transfer data at the end of a journey it will store this data and keep attempting to transfer the data at the end of future journeys.

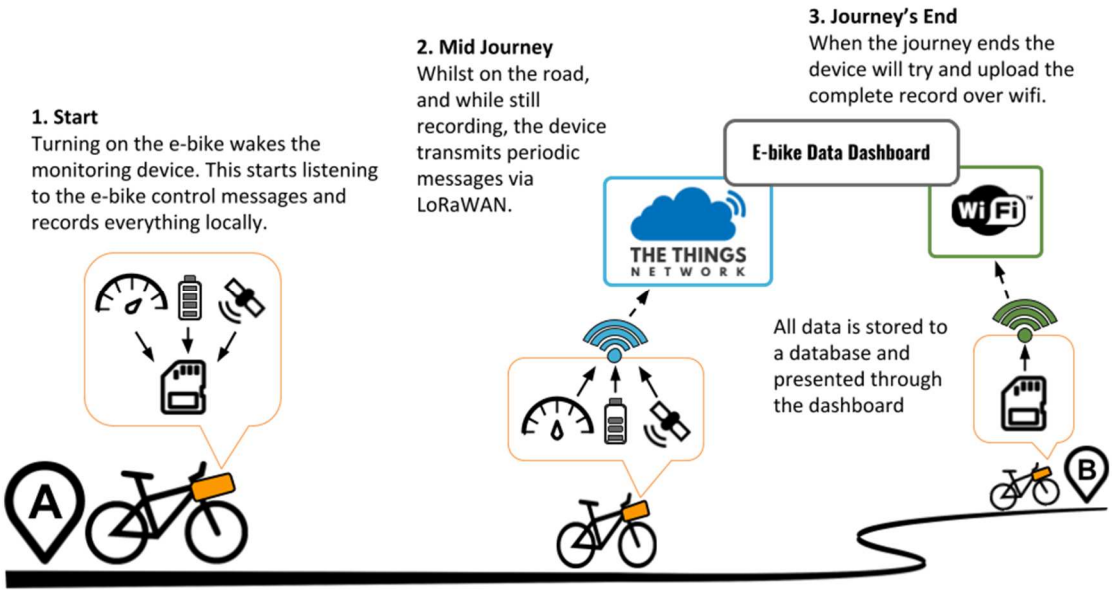

Figure 7.6 – schematic representation of typical e-bike monitoring cycle

The monitoring hardware has an internal battery that is charged while the ebike is on. This allows the monitoring hardware to operate for around 20 minutes after the e-bike has been turned off.

Once on the e-bike monitoring server all data is passed to a message broker so that it can be processed and formatted ready for long term storage in a time series database.

Messages from the The Things Network (TTN) are decoded and pushed directly, while the log file repositories (into which the monitoring devices have uploaded their logs) are checked every ten minutes and if a new log file is found it will be read, decoded and similarly pushed to the database.

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The time series database is then navigable through a graphical web front end.
The system is designed to extensible, and so any other data sinks that also require copies of the data can also be serviced at this stage, as demonstrated by the REPLICATE Smart City Platform in the diagram Figure 7.5.

7.4 Data Dashboard

By combining industry ready open source software (in this case designed originally for data centre management but now largely repurposed for sensor data) we have been able to produce a highly functional backend specifically for the project.

The data is stored in a time series database, to which project partners will be granted access. The database implements a range of standard APIs, allowing researchers, such as those at UWE, to efficiently access and process the data through a wide range of software options. Data can be selected for download based on a large number of criteria, meaning that researchers do not need to transfer very large files much of which is not relevant. Both historic and/or real time data can be received, either by requesting periodic dumps or by subscription to a message broker for a live stream, and a number of different data formats are available in the hope of reducing the amount of effort researchers have to put into pre-processing the data.

Often when analysing data much time is spent simply visualising and understanding what data is available, and so again in an effort to ease the workload of the researcher a data dashboard has been produced. This dashboard provides a powerful yet intuitive web front end through which researchers are able to explore and understand the data. This will hopefully save time and provide a chance to quickly prove and disprove some simple theories. Addition of data to the dashboard is also available to researchers, meaning that if some specific finding or analysis proves extremely useful the output of this could also be added. Some processing could even be automated and done in real time to allow the insights to be more widely distributed.

The dashboard also provides an opportunity for outreach by showing people, especially those that ride the e-bikes, what data is being collected and what that data looks like. Although this has not been yet, it is hoped that e-bike riders and fleet managers will be provided access to the dashboard to allow them easy access to the data and so hopefully improve the way they use the e-bikes.

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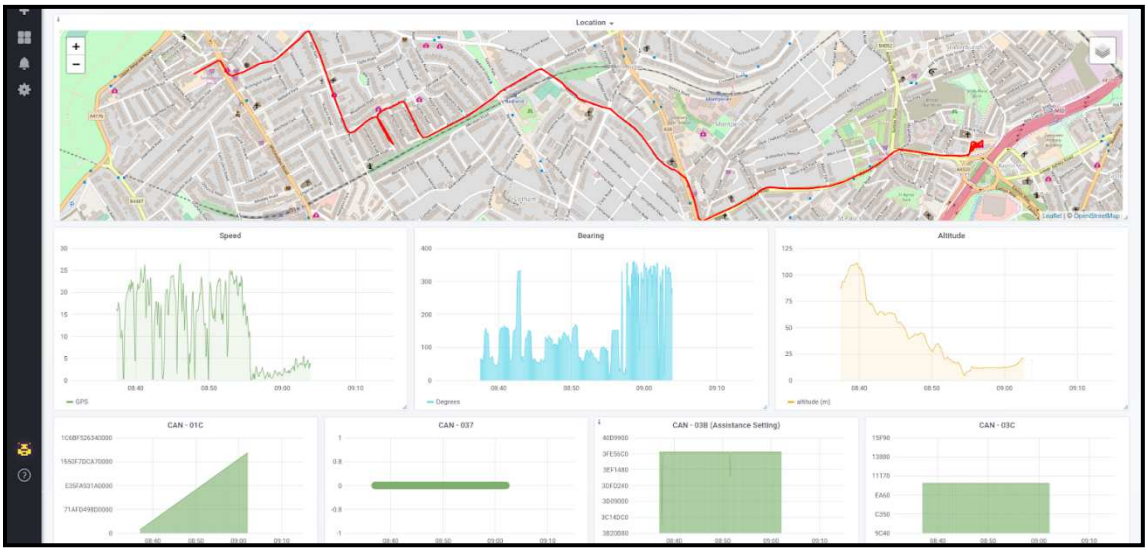

Figure 7.7 –screenshot showing typical data outputs and analysis tools

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8. CASES STUDIES

This sections sets out the experiences of e-bike users through a number of case studies.

Allison

Figure 8.1 E-bike user

Allison is a Dementia Navigator working with Bristol Dementia Wellbeing Service. She has been riding a Co-wheels e-bike since July 2017.

She uses the bike for visiting people in the community and attending meetings. She used to ride her own bike prior to the e-bike arriving but now she uses the e-bike for most of her visits.

"It saves 30% on time and allows me to arrive at visits in a more relaxed fashion", she says.

"I also had a major health issue this year and the e-bike has allowed me to keep using a bike for visits as I would have been unable to manage on my own bike.

"The people I visit enjoy me arriving on the electric bike."

Allison is a champion for the e-bikes within Bristol Dementia Wellbeing Service and encourages her other colleagues to use them.

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Teresa

Teresa is a Community Nurse working for Bristol Community Health. She recently returned to nursing from a career break and her role includes travelling round the city to visit patients who are house bound and otherwise unable to access normal NHS services.

She has been riding an e-bike since April 2017. After her bicycle was stolen from her GP practice, her employer arranged for her to have access to an e-bike so that she could continue her job. She uses the e-bike to attend her patient visits.

"I love the freedom of riding my bike round the city, there are no congestion issues and I always have somewhere to park my bike. Even though the bike is electric and gives you that extra boost, I like to put it in the top gears when riding so that I still get a good amount of exercise every day.

"However, there is nothing more satisfying than placing it in low gears and 'sport mode' when flying up some of the steeper Bristol hills. The patients love the fact that I ride and it's always a great icebreaker when meeting someone for the first time. I even get many comments from passers-by which is great for community relations!"

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9. INNOVATIONS, IMPACTS AND SCALABILITY

9.1 Innovation solution

In line with an aspiration to become a mobility provider, Co-wheels have integrated the electric bikes into their existing car club booking system. The implication of this is that it is possible for members to join the car club and gain access to both the e-bikes and the national network of Co-wheels vehicles, as set out in the Figure 9.1.

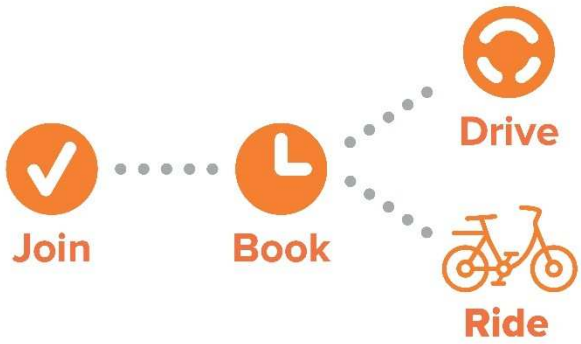

Figure 9.1 – visual representation of e-bike and Electric Vehicle booking system

Provision of the service and support package of the e-bikes has been achieved through a partnership with Sustainable Travel Solutions (STS) in Bristol. To prepare the bikes for deployment, a keen eye has been kept on how to reduce the likelihood of call outs due to avoidable issues such as punctures. In fact, the use of Gecko solid rubber tyres has completely removed punctures as an issue. The benefits of using these tyres are summarized in Figure 9.2.

Compared to good quality	Compared to other	Compared to all bicycle tyres

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pneumatic rubber bicycle tyres	solid/airless bicycle tyres	
• No punctures – total reassurance, whenever and where ever you ride • No pumping up. • Consistent performance, tyres are always the same e.g. you can rely on the ebike battery range remaining constant • Longer life e.g. no more sidewall cracking with tyres left to go flat, no more tyres and tubes binned after puncture and no more leaking valves • Bike hire/share programs can save over 65% on overall tyre purchase & maintenance.	• Real rubber performance • Excellent grip in all weather conditions, wet or dry, sub-zero to 50C • Gecko compounded rubber contains an elastomer network cross-linked with key fillers to build up heat (hysteresis) and so grip and hold the road, (not possible with foamed plastic) • True ride quality – comfort & true road feel • Easy installation (with a hand lever or PNA)	• Sustainable material used – returned tyres will be recycled directly back into new tyre manufacture • Life Cycle assessment study indicates over 70% less damaging to the environment. • UK manufacture • Low tyre manufacturing cost potential • Tyres can be designed for specific requirements e.g. new profiles and unique rubber properties developed. • Gecko uses a patented new cellular rubber technology

Figure 9.2 – comparison of different tyre options

The e-bike monitoring system has been designed with scalability and replicability of deployment in mind. On a manufacturing side, the modular design speeds up the building of each unit, while the use of COTS components reduces the unit cost. We are currently producing PCB layout files, which when finished will speed up manufacturing significantly. The enclosure is 3D printed, again decreasing manufacturing time and decreasing cost.

To make the device easy to deploy with the minimum of training and experience it connects to e-bike without the e-bike being taken apart. This means installation takes <5 minutes and so speeds up maintenance, fault finding and product development. This also reduces the requirement for training which should facilitate any attempts to replicate the monitoring process.

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For the scale up of the back end and communications links, e-bike specific data formats have been developed to compress the transmission of data sent over LoRaWAN. Scalable technologies have been used all along the data pipeline, and work is currently being done to port the pipeline into Openstack, which will automate backend system scale up.

9.2 Social impacts

Formal monitoring has not yet begun, but it is anticipated that the introduction of e-bikes into organisations will promote social inclusion and improve access to sustainable and active transport options by providing access to cars and e-bikes without the expense of ownership. The scheme will also help support modal integration by acting as a catalyst to making more trips by cycling, walking and/or public transport. This in turn will make steps towards locking in behaviour change and cultural change for both individuals and organisations.

UWE will monitor the user experience and travel behaviour impact of the e-bikes. This will be achieved through a combination of online surveys of users, disseminated by their organisations, and qualitative interviews with a smaller sample of volunteers who complete the online surveys. Both methods will also make use of the data collected by the trackers fitted on the e-bikes. The surveys will ask about: the nature of the journeys conducted by e-bike, the ease of use of the e-bikes and the booking system, the ways in which the e-bikes are used and the modes of transport replaced. The qualitative interviews will probe these responses in more detail and explore any wider impacts on the travel behaviour and access to services of the users.

It is planned to conduct three survey waves during the project, and one wave of qualitative interviews

9.3 Environmental impacts

Although formal monitoring has not begun yet, during a six month period in which up to 10 of the e-bikes were being placed within organisations, 5224 miles (8,405 km) of business travel resulting in an estimated 1.2 tonnes of savings in CO2 so far.

Since the bid we have agreed via an amendment (AMD 691735-95) to change the proportion of E-bikes (EB) and Electric Vehicles (EV) from 32 EBs/ 6 EVs to 12 EBs/11 EVs. Using the same

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methodology as in the bid this is expected to be broadly neutral in carbon terms as shown in Figure 9.3.

Initiative	Carbon saving per vehicle per year (tonnes pa)	No. of vehicles	Total carbon savings per year (tonnes pa)
Original proposal: 32 E-bikes and 6 Electric Vehicles			
E-bikes	0.36	32	11.52
Electric Vehicles	1.57	6	9.42
TOTAL			**20.94**
Revised proposal: 12 E-bikes and 11 Electric Vehicles			
E-bikes	0.36	12	4.32
Electric Vehicles	1.57	11	17.27
TOTAL			**21.59**

Figure 9.3 – comparison of predicted environmental benefits for different e-bike and Electric Vehicle ratios

The assumptions for CO2 savings are based on:

- replacing journeys undertaken in staff owned 'grey fleet' with an average emission level of 140g/km covering 7,000 miles/ 11263 km per year.
- Each electric bike is estimated to undertake 2,574 km per year. The CO2 saved is 0.36 tonnes per bike per year

As part of the monitoring we expect to measure primary energy consumption, predict non-renewable proportion of energy consumed and hence produce more detailed estimates of CO2 savings.

9.4 Replication and scalability potential

Here we look at the infrastructure required for an e-bike scheme, define the existing set-up, investigate potential e-bike scheme audiences and their priorities and look at the future sustainability of the e-bike scheme.

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9.4.1 Infrastructure

The original concept for Co-wheels' corporate scheme in Bristol was to present 32 bikes in individual wedge-shaped bike boxes with internal power supplies and telematics. The strategy behind this was to place 'hubs' of these boxes in high profile locations within the project area to facilitate access by corporate users during the working day and by members of the public during evenings and weekends.

To place boxes in these locations would require planning permission to be granted. Suitable locations for a corporate scheme are limited in the project area so pre-application advice was sought from Bristol City Council's Planning Department relating to these. The advice received was that the scheme would be unacceptable on council-owned land due to implications for electricity usage and lost revenue from any car parking spaces taken. Further advice was to explore with land owners the possibility of installing the scheme on private land.

The result of this was to re-visit the method of delivery, which would subsequently become the placement of e-bikes within organisations for their specific use.

9.4.2 Existing schemes

By exploring where this scheme would fit into existing shared electric bike provision in Bristol, the importance of working in partnership was brought into sharp focus.

Travelwest, Bristol City Council's sustainable transport arm, runs a corporate scheme that offers electric bikes for free six month loans to find out whether an electric bike would be a useful asset for staff members.

This scheme was seen as both an enabler and an obstacle for the Co-wheels scheme. On the one hand, by working in partnership with Travelwest it was possible to set up a system of referrals between the two schemes. On the other hand, the fact that this is a scheme that is free at the point of entry could be viewed as a scheme that threatens the sustainability of other schemes through promoting the idea of getting something for nothing. This was especially true when rolling out a scheme in an area with high levels of deprivation and a wide range of social needs.

9.4.3 Audience and their priorities

The main drivers for this bike share scheme relate to improving health and wellbeing, reducing congestion and carbon emissions, and changing transport behaviours. With this in mind, a key consideration is the modes by which potential participants in the scheme are already travelling. CoMoUK (formerly Bikeplus) conduct a bike share users' survey each year and one of the

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findings is that the majority of bike share users (87%) already use sustainable transport modes prior to riding a bike. This learning has three implications. Firstly, the scheme should be targeted at organisations that are historically providing combustion engine vehicles to transport staff around for short journeys in the community. Secondly, it is inevitable that there will be corporate e-bike users that are already riding their own bikes and that there is value in developing e-bike 'champions' within organisations to encourage others to take up riding the e-bikes, given time. Thirdly, it is worth reviewing the size of the scheme initially whilst keeping an eye on future scale up. In the case of the Co-wheels scheme it was agreed that by decreasing the number of e-bikes in Deliverable 5.4 and increasing the number of Electric Vehicles in Deliverable 5.5, there would be a greater demonstrable impact on the project area during the life of the REPLICATE project.

To further understand the audience, a major factor influencing their involvement in the scheme is an understanding of their priorities. The environmental and health benefits of an e-bike share scheme are clear and generally understood by participating organisations. However, in a challenging financial environment where budgets are being cut and spending is being closely monitored to identify savings, it is difficult for organisations to focus on the long term benefits of a scheme that requires some investment in the short term. This is especially true of public sector and community organisations that have increasing demands on budgets that can barely cover existing essential interventions and services. A consequence of this is that where a scheme is fully subsidised, such as the Travelwest corporate e-bike loan scheme, it is an attractive prospect. Where the scheme is attempting to become sustainable for the longer term this presents significant, although not insurmountable, challenges.

9.4.4 Future sustainability of scheme

At the time of writing this report, all 12 of the e-bikes have been deployed within organisations operating within the project area. These bikes have been largely subsidised through the REPLICATE project and the contracts relating to these bikes will be in place until January 2021.

To create a sustainable scheme for the longer term there must be an emphasis on the benefits of the scheme to each organisation, with a strong focus on the cost savings created. The scheme has the potential for significant financial impact related to fleet solutions (e-bikes are cheaper than cars to lease/buy and maintain) and human resources (healthier, happier staff taking fewer sick days and having a higher rate of productivity). Partnered with further evidence from the detailed monitoring of the scheme, there will be a compelling case to be made to participating organisations to continue using e-bikes, and for new organisations to sign up to the scheme.

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Furthermore, by continuing to develop a working relationship with other existing schemes in Bristol, there is the opportunity to become a more established feature of shared e-bike provision in Bristol.

9.5 Economic feasibility

Co-wheels are trialling two versions of a business model for this scheme.

Firstly, there is the ownership model where Co-wheels purchases the bikes and works with a partner organisation to provide the service and support package. For this, Staiger Sinus BC30f electric bikes were purchased through Raleigh UK Ltd with two years warranty. Co-wheels have been working in partnership with Sustainable Travel Solutions Ltd (STS), a Bristol based company specialising in supplying and supporting businesses and public sector organisations with bicycle fleets, for provision of the servicing, maintenance and support for the bikes. As the bikes run on a Bosch system, it was essential that STS were Bosch trained and certified to enable swift diagnosis and resolution of any technical issues relating to the bikes.

To prepare the e-bikes for deployment, puncture proof tyres and cycle panniers are fitted, a D-lock is provided, and a pre-deployment inspection is conducted.

Once deployed, STS provide basic quarterly services, a full annual service, maintenance and repairs relating to wear and tear, and emergency call-out support (Mon-Fri 9am – 5pm excluding bank holidays).

Each bike is replaced with a new bike after two years of use. In the event of a bike being stolen, this has been replaced with a Raleigh Motus e-bike due to its similarity to the Staiger and its faster availability through Raleigh.

Secondly, there is the e-bike lease model where Co-wheels leases the bikes from a 'one stop shop' that provides the full service and support package in addition to the bikes. For this, Co-wheels has been working in partnership with STS, who provide the bikes and the service and support package all together.

The reason for trialling these two models relates to cost and convenience. Figure 9.4 shows the cost comparison, based on a two-year contract.

	Purchase	Lease
Bike cost	£1083.34/ €1,213.34 + VAT	£1995/ € 2,234.40

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		+ VAT
Service & support	£720/ € 806.40 + VAT	Included
Puncture proof tyres	£74.64/ € 83.60 + VAT	Included
D-lock	£30/ € 33.60 + VAT	Included
Panniers	£75 / €84 + VAT	£75 / €84 + VAT
PDI check	£20/ € 22.40 + VAT	Included
Insurance	£120/ € 134.40	Included
Total	**£2122.98 / € 2,377.74 + VAT**	**£2070 /€ 2,318.40 + VAT**

Using official conversion rate of 1.12EUR per 1 GBP for November 2018.

Figure 9.4 – different pricing models for supply and maintenance of e-bikes

In terms of convenience, there is a focus on the relationship with the bike manufacturer. For the purchased model, Co-wheels are working with Raleigh. For the lease model, STS are working with Giant. Specific areas for consideration include efficiency of processes relating to warranty issues and to the provision of spare parts, and familiarity with the product to ensure swift and accurate advice is given.

As part of the monitoring deliverables more details will be provided of operating costs, investment and operating revenue. Assessments will also be made of employment impacts.

9.6 Impact on SMEs

Specific impacts on SMEs that are using the e-bikes as part of the REPLICATE project are yet to be established through the two year monitoring period, but it is anticipated that there will be impacts on staff members using the bikes (health, wellbeing, concentration levels, punctuality etc), as well as on the organisations themselves (reduced spending on transport, reduced pressure on parking, reduced transport administration, fewer staff sick days, reduced carbon footprint, productivity, happier and healthier staff etc).

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As an SME, Co-wheels aspires to be more than a car club, instead developing into a mobility provider providing access to shared cars and shared electric bikes. The REPLICATE project is an opportunity to explore this, although it is still early days. The functionality of placing electric bikes onto the existing car club booking system has been developed, which has the potential to be scaled up across the wider car club operation. The trackers that have been developed by the University of Bristol are a unique solution to the ongoing monitoring of e-bike use, and this stands to provide benefits regarding the growing understanding of how electric bikes are used and the impacts that they can have. Once this is off the ground, Co-wheels will benefit from being able to demonstrate the impact of electric bike schemes for potential clients in the public and the private sector, and for inclusion in bids and tender responses for this type of service. Furthermore, at present, Co-wheels is the only SME that is currently benefitting from this technology.

Similarly, the impact on delivery partners may also become apparent. For example, Sustainable Travel Solutions Ltd, a Bristol SME who provide the service and support package for the REPLICATE bikes, will benefit from extending their track record of working with public sector and community organisations. In turn, Gecko tyres (who make the solid rubber tyres on the bikes) are an emerging enterprise that will be able to provide evidence of the quality of their product as a result of their tyres being used on the bikes.

9.7 Other

Business models could take the form either targeting fleet managers, interested in knowing where their fleet of electric bikes are, or e-bike users interested in optimising the way they use their bike. The amount of data that is gathered even gives the possibility of a personal training angle, where people could have devices fitted to their bike and it could tell them if they are peddling equally with both legs, or getting in the correct gear for hills.

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10. CONCLUSIONS

e-bikes are an important part of the range of measures being tested and deployed throughout the REPLICATE area in order to deliver smart interventions bringing together mobility, energy and ICT.

Developing the e-bike scheme

A wide range of factors have been considered to ensure that the best e-bike system has been deployed. This included allowing for high usage, with multiple trips per day in all weathers. The e-bikes needed to be robust, easy to manage and suitable for a wide range of users. In total, three different models of electric bike have been used for this project.

Our e-bike model targets people living and/or working in the project area that are making regular short journeys during the working day. These types of journeys are typically made by health professionals and those providing services and support in the community.

In line with an aspiration to become a mobility provider, Co-wheels have integrated the e-bikes into their existing car club booking system. The implication of this is that it is possible for members to join the car club and gain access to both the e-bikes and the national network of Co-wheels vehicles.

The scheme has proved very popular with users as demonstrated by a number of case studies.

Developing the e-bike monitoring system

University of Bristol has developed a monitoring system for the e-bikes. To do this they needed to understand the existing e-bike systems, develop hardware to interface with existing systems, prototype the new monitoring system and then develop productions techniques for the production of final trackers.

The e-bike monitoring system has a number of smart aspects including:

- using a single board computer running a full Linux implementation
- listening to the CAN bus to measure values such as bike speed
- the addition of a GPS unit and accelerometers to provide extensive details of e-bike use
- the combination of WiFi, Bluetooth and a LoRaWAN to make data transfer efficient
- development of the software to make the addition of new measurements very straight forward

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By customising industry ready open source software we have been able to produce a highly functional backend specifically for the project. The data is stored in a time series database, to which project partners will be granted access. The database implements a range of standard APIs, allowing researchers to efficiently access and process the data through a wide range of software options. This dashboard provides a powerful yet intuitive web front end through which researchers are able to explore and understand the data.

Monitoring the e-bikes

Formal monitoring has not yet begun, but it is anticipated that the introduction of e-bikes into organisations will promote social inclusion and improve access to sustainable and active transport options by providing access to cars and e-bikes without the expense of ownership. The scheme will also help support modal integration by acting as a catalyst to making more trips by cycling, walking and/or public transport. This in turn will make steps towards locking in behaviour change and cultural change for both individuals and organisations.

UWE will monitor the user experience and travel behaviour impact of the e-bikes. This will be achieved through a combination of online surveys of users and qualitative interviews with a smaller sample of volunteers who complete the online surveys. Both methods will also make use of the data collected by the trackers fitted on the e-bikes.

On the environmental side, the e-bikes are showing substantial promise. During a six month period in which up to 10 of the e-bikes were being placed within organisations, they travelled 5224 miles (8,405 km) resulting in an estimated 1.2 tonnes of savings in CO2 so far.

Promoting SMEs

As an SME, Co-wheels aspires to be more than a car club, instead developing into a mobility provider providing access to shared cars and shared electric bikes. The REPLICATE project is an opportunity to explore this further. Once fully implemented the e-bike scheme combined with the monitoring system will allow Co-wheels to be able to demonstrate the impact of electric bike schemes for potential clients in the public and the private sector, and for inclusion in bids and tender responses for this type of service.

Similarly, the impact on delivery partners may also become apparent. For example, Sustainable Travel Solutions Ltd, a Bristol SME who provide the service and support package for the REPLICATE bikes, will benefit from extending their track record of working with public sector and community organisations. In turn, Gecko tyres (who make the solid rubber tyres on the

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bikes) are an emerging enterprise that will be able to provide evidence of the quality of their product as a result of their tyres being used on the bikes.

Investigating Business Models

Co-wheels are trialling two versions of a business model for this scheme.

1) The ownership model where Co-wheels purchases the bikes and works with a partner organisation to provide the service and support package working with a local company and ensuring that partners are trained to use the new equipment.
2) The e-bike lease model where Co-wheels leases the bikes from a 'one stop shop' that provides the full service and support package in addition to the bikes.

These models will be further investigated as part of the business model work.

Lessons learnt

Looking to the future, the e-bike monitoring system has been designed with scalability and replicability of deployment in mind. On the manufacturing side, the modular design, use of COTS components, 3D printing and PCB layout files will ensure fast and efficient manufacture at significantly reduced cost.

In terms of delivery we have learnt a number of things. Firstly, schemes should be targeted at organisations that are historically providing combustion engine vehicles to transport staff around for short journeys in the community. Secondly, it is inevitable that there will be corporate e-bike users that are already riding their own bikes and there is value in developing e-bike 'champions' within organisations to encourage others to take up riding the e-bikes. Thirdly, it is worth reviewing the size of the scheme initially whilst keeping an eye on future scale up.

To create a sustainable scheme for the longer term there must be an emphasis on the benefits of the scheme to each organisation, with a strong focus on the cost savings created. The scheme has the potential for significant financial impact related to fleet solutions and human resources.

For these reasons we feel confident that REPLICATE has allowed us to develop a strong, effective, sustainable and replicable e-bike business model.