NIC Project UKPNEN03 Deliverable D1

High Level Design and Specification of the Three Trials

August 2019

Optimise Prime

HITACHI Inspire the Next
Uber
Scottish & Southern Electricity Networks
centrica
Royal Mail
UK Power Networks

Table of acronyms & glossary

The acronyms and terms used throughout this document are clarified below.

Table 1 – Table of acronyms

Acronym	Full form
3P-DP	Third Party Data Provider
ANM	Active Network Management
API	Application Programming Interface
BEV	Battery Electric Vehicle
BRP	Balance Responsible Party
CPU	Central Processing Unit
DAI	Data, Analytics & Innovation
DB	Depot Based
DC	Direct Current
DDoS	Distributed Denial of Service
DNO	Distribution Network Operator
EHV	Extra High Voltage
ETL	Extract, Transform, Load
EV	Electric Vehicle
EV-CPC	Electric Vehicle Charge Point Controller
FSP	Full Submission Pro-forma
GB	Great Britain
GBP	British Pound Sterling
GDPR	General Data Protection Regulation (Regulation (EU) 2016/679)
HEC	Hitachi Enterprise Cloud
HV	High Voltage
IaaS	Infrastructure-as-a-Service
ICE	Internal Combustion Engine
IT	Information Technology
kVA	Kilo-volt-ampere
kW	Kilowatt
kWh	Kilowatt hour
LCN	Low Carbon Networks
LCT	Low Carbon Technology (e.g. solar photovoltaics, battery storage)
LEM	Local Energy Market
LPN	London Power Networks plc
LV	Low Voltage
MoSCoW	Must have, Should have, Could have, Won't have
MPP	Massively Parallel Processing
MV	Medium Voltage
MVP	Minimum Viable Product
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
NTP	Network Time Protocol
OLA	Operational-Level Agreement
OP	Optimise Prime
PaaS	Platform-as-a-Service

Acronym	Full form
PHV	Private Hire Vehicle
PS-DP	Partner Systems Data Provider
QA	Quality Assurance
RAM	Random Access Memory
RP	Responsible Party
R2H	Return to Home
SoC	State of Charge
SLA	Service-Level Agreement
SPN	South Eastern Power Networks plc
SSEN	Scottish & Southern Electricity Networks
SSL/TSL	Secure Sockets Layer/Transport Layer Security
SSV	Shared Services
TCO	Total Cost of Ownership
TfL	Transport for London
TOA	Trials Operational Applications
ToU	Time of Use
UK	United Kingdom
ULEZ	Ultra Low Emissions Zone
USEF	Universal Smart Energy Framework
USP	Universal Service Platform
UTC	Universal Time Coordinated
V2G	Vehicle to Grid
V2X	Vehicle to other use (e.g. grid or building)
VPC	Virtual Private Cloud
VPN	Virtual Private Network
WD	Weekday
WE	Weekend
WS	Workstream

Table 2 – Glossary of terms

Term	Definition
Un-managed charging	Charging of an EV at the rate set by the connection until it reaches full charge or is disconnected.
Smart charging	Charging via a smart-charger equipped with two-way communication, enabling charging habits to be adaptive.
Aggregator managed charging	Smart charging is controlled by an aggregator to meet their specific objectives.
Depot managed charging	Smart charging is controlled by/on behalf of the depot operator in to meet their specific objectives and adhere to connection agreement constraints.
Flexibility	The ability to respond dynamically to a signal provided by the DNO to increase or decrease the power exchanged with the network, compared to an initial planned behaviour.

Executive summary

Optimise Prime is an industry-led electric vehicle innovation and demonstration project that brings together partners from leading technology, energy, transport and financing organisations, including Hitachi Vantara, UK Power Networks, Centrica, Royal Mail, Uber, Scottish & Southern Electricity Networks, Hitachi Europe and Hitachi Capital.

The project will gather data from up to 3,000 EVs driven for commercial purposes through three trials. Optimise Prime will also implement a range of technical and commercial solutions with the aim of accelerating the transition to electric for commercial fleet operators while helping GB's distribution networks plan and prepare for the mass adoption of EVs. Through cross-industry collaboration and co-creation, the project aims to ensure security of electricity supply while saving money for electricity customers, helping the UK meet its clean air and climate change objectives.

This report forms the first Optimise Prime deliverable, D1, providing a comprehensive overview of the high level design of the three project trials and the specification of the systems that will enable the trials. The three trials are described in Table 1.

Table 3 – The three Optimise Prime trials

Trial	Description
Home Charging (WS1)	Collecting data from return-to-home commercial EVs, this trial will analyse data on these commercial loads that are normally invisible to the distribution network operator and will test the provision of flexibility services from these vehicles.
Depot Charging (WS2)	Studying the network impact of the electrification of depots and delivery vehicles. The project will implement depot planning and optimisation systems, together with a new type of profiled connection, aimed at better utilising existing network infrastructure to support growth in EV charging.
Mixed Charging (WS3)	Taking journey data from Uber private hire EVs and analysing this alongside network data to predict the increasing charging demand from this growing and rapidly electrifying sector. This trial will identify how the distribution networks can accommodate this demand at the lowest cost for the electricity customer.

The main report introduces the three trial use cases and scenarios, providing details of the high-level requirements, broken down into a series of objectives and sub-objectives of each trial. The appendix provides a catalogue of the activities that will be pursued by the project in order to reach the objectives. The report goes on to present a high-level solution architecture for the technology that will enable the project to meet its objectives.

This report should prove valuable to any DNO considering how to plan for the future growth of commercial EVs. Although some aspects of the trial design are specific to Optimise Prime and its partners, the principles and objectives are applicable to all DNOs and to vehicle fleets planning a transition to ultra-low carbon vehicles.

Table 4 shows the requirements of Deliverable D1 set out in the Project Direction, and where each item can be found within this report.

Table 4 – Contents of Deliverable D1

Deliverable D1 : High Level design and specification of the three trials	
Evidence item	**Relevant section of the report**
Report outlining the:	
Requirements	The high-level requirements of the trials are described in section 3.1, this is further detailed for each objective throughout section 3
Use cases	The three use cases are described in section 2.1
Scenarios	Section 2.2.2 describes the charging scenarios that will be compared through the trials, together with the wider trials methodology.
Technologies	Section 5 details the solution architecture and technologies that will be used to deliver the trials
Locations	Section 6 describes the locational boundaries of the trials and, for the depot trials, the specific locations selected for the first phase of trials. This section also reports progress made in securing vehicles to participate in the trials.
for WS 1 (Home Charging), WS 2 (Depot Charging) and WS 3 (Mixed Charging)	In each of the above sections, the terms Home, Depot and Mixed have been used to differentiate between the three trials.

Optimise Prime is committed to sharing the project's outcomes as widely as possible. The project will continue to engage with a wide group of stakeholders throughout the fleet, PHV, technology and energy industries through a programme of events, reports, and the project website www.optimise-prime.com.

1 Background & purpose

This report, the first deliverable of the Network Innovation Competition funded Optimise Prime project, provides the output of the work completed in the first six months to design the trials and specify the technical solution that will be implemented in order to conduct the trials.

1.1 Introduction to Optimise Prime

Optimise Prime is an industry-led EV innovation and demonstration project that brings together partners from leading technology, energy, transport and financing organisations, including Hitachi Vantara, UK Power Networks, Centrica, Royal Mail, Uber, Scottish & Southern Electricity Networks, Hitachi Europe and Hitachi Capital. The role of each partner is described in Table 5.

Table 5 – Project Partners

Partner	Description	Project Role
	Electricity Distribution Network Operator (DNO) covering three licenced distribution networks in South East England, the East of England and London. The three networks cover an area of 30,000 square kilometres and over eight million customers.	London Power Networks is the project's funding licensee. UK Power Networks provide networks expertise and will develop new connections methodologies.
	Hitachi is a leading global technology group committed to bringing about social innovation. Three Hitachi companies are project partners. Hitachi Vantara, Hitachi Europe, and Hitachi Capital.	Hitachi will lead the project, providing overall project management, energy and fleet expertise and project IT platforms. Hitachi will also develop tools for the depot trials.
	The electricity DNO covering the north of the Central Belt of Scotland and Central Southern England.	Supporting experiments within the Central Southern England region, ensuring wider applicability of methods.
	Royal Mail provides postal delivery and courier services throughout the UK. It manages the largest vehicle fleet in the UK with over 48,000 vehicles based at 1,700 delivery offices.	Royal Mail will electrify depots and operate EVs. Project tools will be tested in the depots and data from the vehicles will be captured
	Uber is the fastest growing private hire vehicle (PHV) operator in the UK. Over 70,000 partner-drivers use the app in the UK, with the majority in and around London.	Uber will provide journey details from EV Private Hire Vehicles operating in London for the mixed trial.
	Centrica is UK based international energy and services company that supplies electricity, gas and related services to businesses and consumers.	The British Gas commercial vehicle fleet will participate in the trial. Centrica will also provide charging and aggregation solutions for the home trial.

Data from up to 3,000 EVs driven for commercial purposes within London and the South East of England will be gathered and analysed. Optimise Prime will also implement a range of technical and commercial solutions with the aim of accelerating the transition to electric for commercial fleet operators while helping GB's distribution networks plan and prepare for the mass adoption of EVs. Through cross-industry collaboration and co-creation, the project aims to ensure security of energy supply while saving money for electricity customers, helping the UK meet its clean air and climate change objectives.

Optimise Prime aims to be the first of its kind, paving the way to the development of cost-effective strategies to minimise the impact of commercial EVs on the distribution network. Commercial EVs are defined as vehicles used for business purposes, including the transport of passengers and goods. Compared to vehicles used for domestic purposes, commercial EVs will have a much greater impact on the electricity network. The additional impact of commercial depot-based EVs results from two factors: co-location of multiple EVs at a single depot location, and higher energy demand per vehicle resulting from higher daily mileages and payloads. The latter is also a factor when commercial EVs are charged at domestic locations.

Two DNO groups (UK Power Networks, Scottish & Southern Electricity Networks) across four licence areas are involved in the project. The consortium includes two of the largest UK commercial fleets and a major Private Hire Vehicle (PHV) operator. The project aims to involve around 3,000 vehicles. This scale will allow the industry to robustly test different approaches to reducing the impact of vehicle electrification on distribution networks, in advance of mass adoption throughout the 2020s. This will also help understand the impact of a wide range of variables, including different network constraints, typical mileage and driving style, traffic characteristics, location (urban, sub-urban, rural) and availability of public "top-up" charging on the feasibility of electrification of commercial vehicle fleets.

By studying this diversity, the learnings generated by the project will be applicable to the whole of GB. Optimise Prime will deliver invaluable insights by using data-driven forecasting tools designed to allow networks to proactively plan upgrades. In addition, this project will create a detailed understanding of the amount of flexibility that commercial EVs can provide to the network through smart charging. Finally, a site planning tool will allow Royal Mail to request profiled connections from the DNO. Taken together, these form a set of innovative capabilities that allow for greater network utilisation.

Optimise Prime will seek to answer three core questions relating to the electrification of commercial fleets and PHVs:

1. How do we quantify and minimise the network impact of commercial EVs?

We will gain a comprehensive and quantified understanding of the demand that commercial EVs will place on the network, and the variation between fleet and vehicle types. We will achieve this through large-scale field trials where we will capture and analyse significant volumes of vehicle telematics and network data. This data will enable the creation and validation of practical models that can be used to better exploit existing network capacity, optimise investment and enable the electrification of fleets as quickly and cheaply as possible.

2. What is the value proposition for smart solutions for EV fleets and PHV operators?

We will gain an understanding of the opportunities that exist to reduce the load on the network through the better use of data, planning tools and smart charging. Additionally, we will consider and trial the business models that are necessary to enable these opportunities. We will achieve this by developing technical and market solutions, and then using them in field trials to gather robust evidence and assess their effectiveness.

3. What infrastructure (network, charging and IT) is needed to enable the EV transition?

We will understand how best to optimise the utilisation of infrastructure to reduce the load on the network. This will be achieved through the collection, analysis and modelling of depot-based (DB), return-to-home (R2H) fleet and PHV journey data. Answering these questions will enable network operators to quantify savings which can be achieved through reinforcement deferral and avoidance while facilitating the transition to low carbon transport. The trial will also assess the journey data to understand the charging and associated IT infrastructure requirements and implications for depot and fleet managers to be able to operate a commercial EV fleet successfully.

1.2 Purpose and structure of this report

The purpose of this report is to outline the requirements, use cases, scenarios, technologies and locations for the three Optimise Prime trials:

- WS 1 (Home charging),
- WS 2 (Depot charging), and
- WS 3 (Mixed charging)

This report is intended to be used by project stakeholders to gain understanding of the trials' methods and by future projects to learn from Optimise Prime.

Section 2 introduces the three use cases associated with the trials and gives an overview of the methodology that has been followed to design the trials.

Section 3 explains the objectives that have been developed for the project's trials. These are then broken down into the specific sub-objectives that will be tested in each trial. Further details of the activities and experiments that will form part of trial can be found in the appendices.

Section 4 provides a specification of the data that will be required in order to run each trial, identifying where the data will be sourced.

Section 5 describes the high-level architecture of the IT systems that will be used to capture, store and analyse the data and perform the experiments.

Section 6 details practical aspects of trial planning, including the plan, details of locations and vehicles that will be involved in the trial.

Section 7 explains the key lessons that have been learnt from the planning process.

Section 8 details some of the lessons learnt from other innovation projects and how these lessons have been used in the planning of the trials.

Section 9 summarises the key conclusions and details next steps for the project following the high-level planning of the trials.

1.3 Trials & methods overview

The three trials were set out in the Full Submission Pro-forma (FSP) and are described in Table 6. The trials broadly align with the fleets or three project partners, although additional participants may be invited to each trial in order to supplement the partners' vehicles if required.

Table 6 – Optimise Prime trials

Trial Number	Name	Partner	Description
1	Home Charging	British Gas Maintenance[1]	A field study of charging behaviour and flexibility with a return to home fleet.
2	Depot Charging	Royal Mail Delivery	A field study of charging behaviour and flexibility with a depot-based fleet. Additionally, the testing of profiled connections.
3	Mixed Charging	Uber PHV operator	A study based on analysis of journey data from electric PHVs.

The use cases are described in more detail in the next section. As stated in the FSP, two methods will be tested through the trials. They are summarised in Table 7 below.

Table 7 – Optimise Prime methods

Method 1 **Smart demand response for commercial EVs on domestic connections**	Currently the additional peak demand would trigger reactive network reinforcement with the costs being entirely socialised as domestic and non-domestic use is blended together. In Optimise Prime we aim to separate the commercial loads to make them visible, testing demand response approaches with commercial EVs charging at domestic premises to identify and quantify the available charging flexibility.
Method 2 **Depot energy optimisation and planning tools for profiled connections**	Currently depots request a connection based on 'worst case' estimated peak demand, often triggering network reinforcement. The cost is part paid for by the connecting customer and part socialised across connected customers. In Optimise Prime we aim to design and test smart charging and energy optimisation 'behind the meter', at depots, to be able to conform to an agreed profiled connection. We are developing the tools and processes to calculate the optimal connection profile and infrastructure, for each site, to minimise the connection cost and/or capacity used. We will also test demand response approaches to identify and quantify the available charging flexibility from an optimal profile. The project will develop the commercial arrangements to enable the rollout of the method following the project.

[1] British Gas is a subsidiary of project partner Centrica.

The business case was created through an estimation of the benefits of these methods. Through the trials the true benefit of these methods to the GB electricity distribution system will be assessed.

1.4 Solution overview

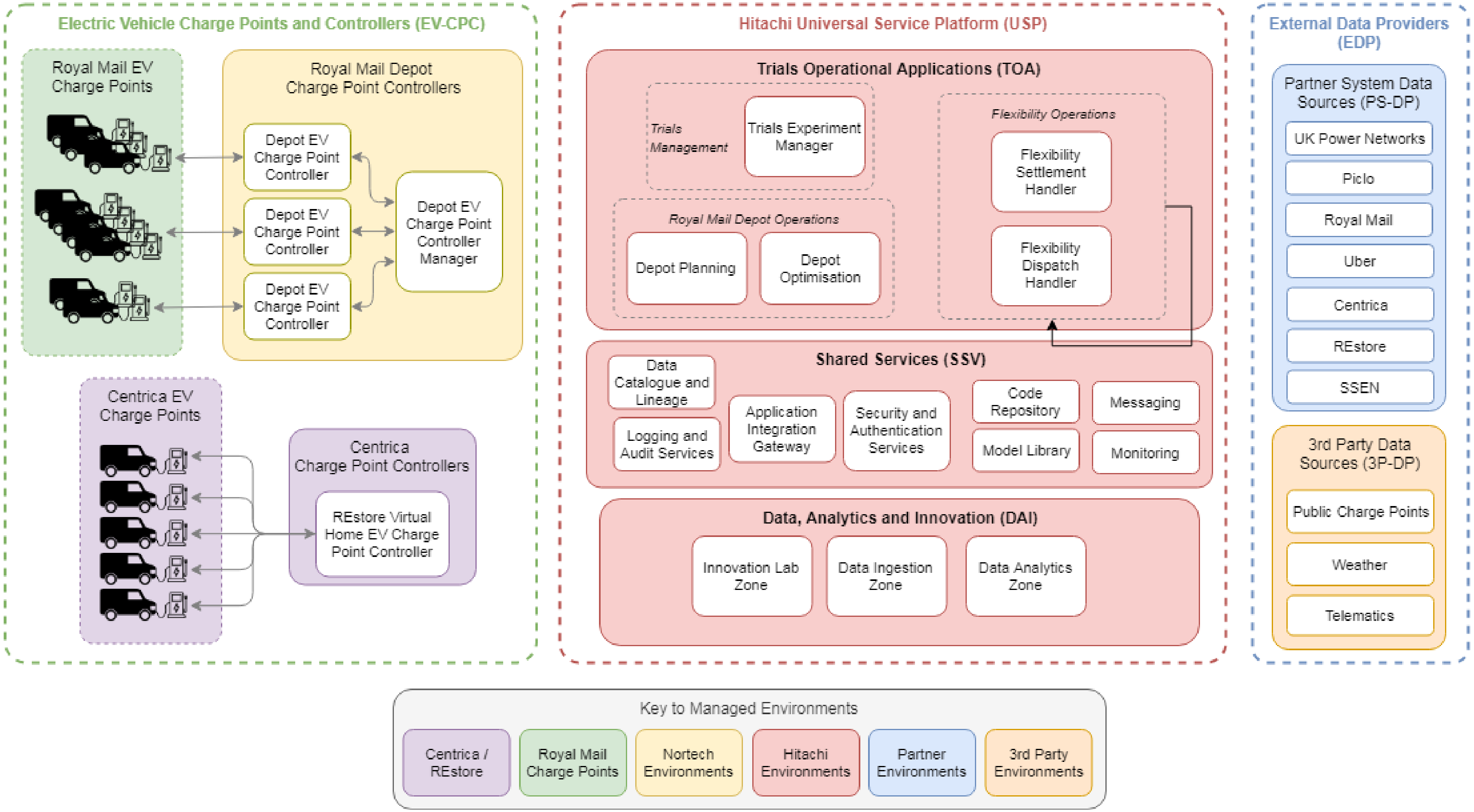
The Optimise Prime technology solution is being developed to enable the trials.

Figure 1 shows the current architecture design for the project. The solution consists of two main aspects:

- A common data platform that will be used to analyse vehicle and network data; and
- A series of tools that will be developed in order to test profiled connections and control vehicle charging.

Since the start of the project, the partners have continued to refine the design of the technology solution, details of which can be found in section 5.

Figure 1 - Optimise Prime technology architecture



2 Trial design & methodology

2.1 Summary of use cases

The Optimise Prime trials address three sectors of the commercial EV charging market that will require different approaches to management of charging demand. Each trial is primarily associated with a different fleet operator (trial partner). The operational differences between these fleet use cases will offer insight into the challenges associated with different types of EV charging. The trials partners were selected to be representative of three EV charging use-cases: home charging, depot charging and mixed charging.

2.1.1 Home charging

Home charging of commercial vehicles results in commercial EV charging load being effectively "hidden" inside the domestic load profile, making forecasting and planning more challenging for DNOs. Hidden loads, without flexibility, mean that the full costs associated with any required network reinforcement, resulting from the increase of background load, are socialised, effecting higher costs for network customers.

Another challenge is that the value of commercial EV flexibility and smart charging to the DNO is currently unquantified. Various projects have focused on the smart-charging of, and flexibility availability from, domestic EVs, but the operation and higher mileage resulting from the commercial use of an EV mean that the value proposition for smart charging is different and requires specific investigation.

The home charging trial will primarily involve British Gas Maintenance vehicles based at employees' homes. Project partner Centrica will trial a method enabling the aggregation of flexibility from home-based commercial vehicles and separate billing for home and business use.

2.1.2 Depot charging

Organisations that operate depots, such as Royal Mail, have substantial numbers of vehicles that are co-located on a single site. Un-managed, clustered EV charging, can impart large, sudden energy demand on the network. As a result, new infrastructure may be required to ensure that the connection has the capacity to deal with increased loads. This presents a problem to the DNO for the following reasons:

- A proportion of reinforcement cost is borne by the depot or charge point operator. However, a proportion may be socialised, resulting in higher costs for customers. Additionally, charging can result in high peak loads, which reduces the efficient use of network capacity, further increasing costs.

- The substantial network reinforcement that may be required to support the electrification of depots could result in long waiting times for connections (while new network infrastructure is deployed), which will slow the rollout of commercial EVs. Similar to the return to home charging use case, the amount, and value, of flexibility and smart charging from depot-based commercial EVs is currently unquantified.

The depot trial will design and implement EV infrastructure at Royal Mail depots. Profiled connections will be developed and depot load will be managed to follow the profile.

Additionally, the potential for ‘behind the meter’ capacity optimisation including other low carbon technologies will be investigated, as will the potential to provide flexibility services both with and without a profiled connection agreement in place.

2.1.3 Mixed charging

The PHV industry is fast growing, and hence the future charging requirements of private hire EVs are likely to be significant. It is expected that the type of charging behaviour will contain elements of both dispersed charging and clustered charging. Where private hire EV drivers have off-street parking they will also often charge their vehicles at home. However public charging points will increasingly be co-located, for example, in electrified ‘filling stations’. The higher power chargers found at these sites, such as rapid DC, will place substantially higher loads on the network and therefore they may present similar challenges and opportunities as per the depots studied in the Royal Mail trial.

Journey data will be collected from Uber to predict the potential impacts that private hire EV charging may have on the distribution network in the future.

2.2 Trial methodology

Through a series of workshops and meetings between Hitachi, UK Power Networks, SSEN and the fleet and PHV partners the project has designed a set of trials, described in section 3, to satisfy the learning objectives. This section outlines the methodology used to define the trial objectives and each of the activities.

2.2.1 Objective deconstruction

- **Objectives** – Objectives are defined as the aims required to be satisfied to deliver the learning ambitions agreed for the project. Project objectives will be broken down into various sub-objectives which more directly align with proposed actions.

- **Sub-objectives** – Sub-objectives are defined as the detailed individual aims, within an objective that together satisfy the aims of that objective. These will be satisfied via successful completion of ‘experiments’.

- **Experiment** – An experiment is defined as ‘an action that is designed to test a specific hypothesis’, and will have associated data pre-requisites and conclusions upon completion.

- **Success criteria** – Objectives, sub-objectives and experiments will be judged against pre-determined ‘success criteria’ according to defined, measurable indicators to ensure completion to the required level of quality. The success criteria will, in turn, enable the critical path to the trials completion to be defined (see Figure 2 below).

- **Activities** – The grouping of data collection, experiments and drawing conclusions are defined as ‘activities’.

This methodology is described in Figure 2.

Figure 2 provides an overview of the relationship between the overall learning aims of the project, the project objectives, sub-objectives and activities that will be undertaken to meet the objectives.

Figure 2 – Breakdown of project objectives and activities

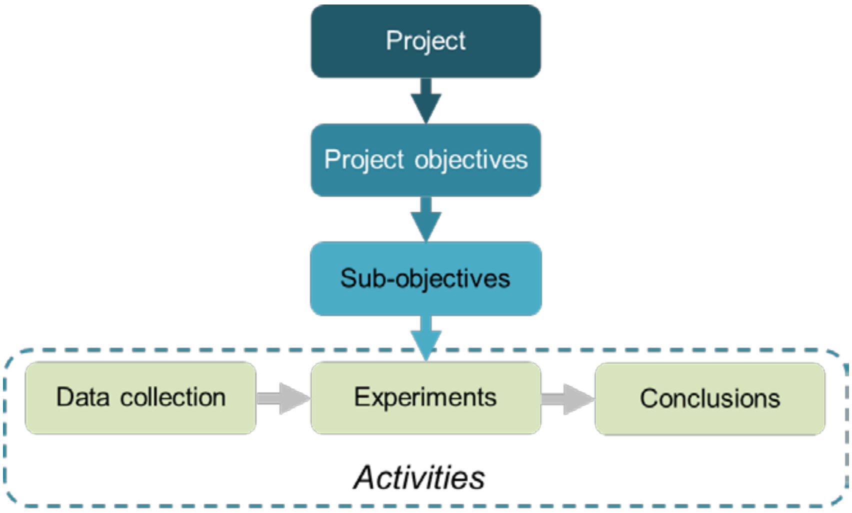
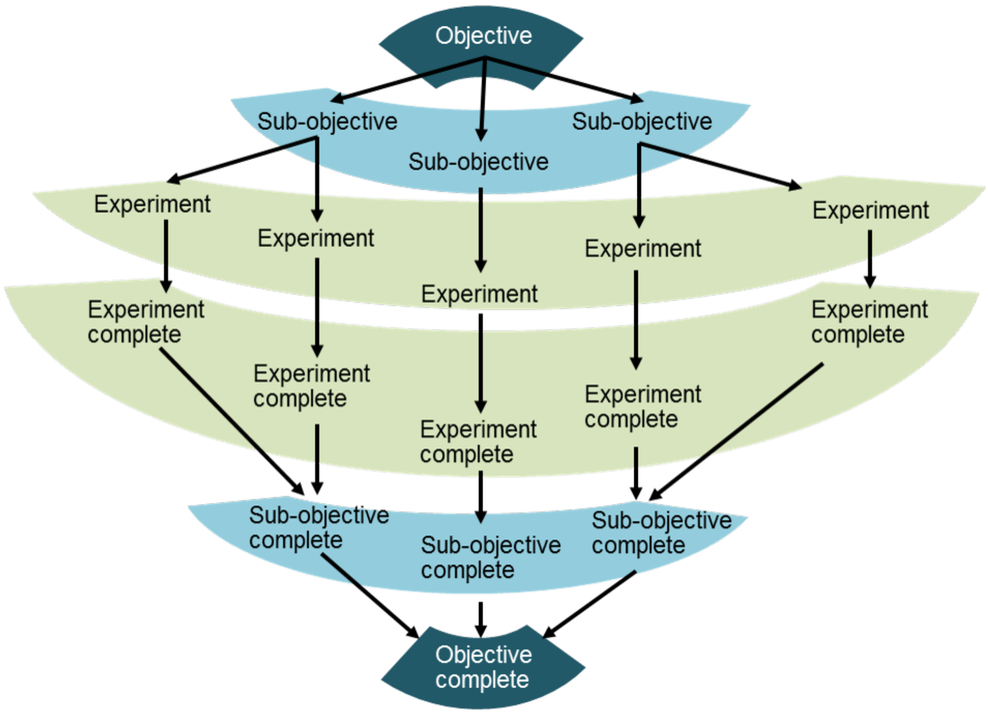


Figure 3 outlines how completing individual experiments satisfies the aims of a given sub-objective. Completion of one or more sub-objectives enables the overall objective to be met. While the sub-objectives are numbered, they are not necessarily sequential and some may run in parallel.

Figure 3 – Objective deconstruction



In Figure 4 the process for determining the successful completion of an experiment or objective is outlined. For each, success criteria are defined together with expected outcomes, which can be compared to the results received. Where success criteria are not met, the experiment will be re-run and if necessary, redesigned.

Figure 4 – Quality assurance

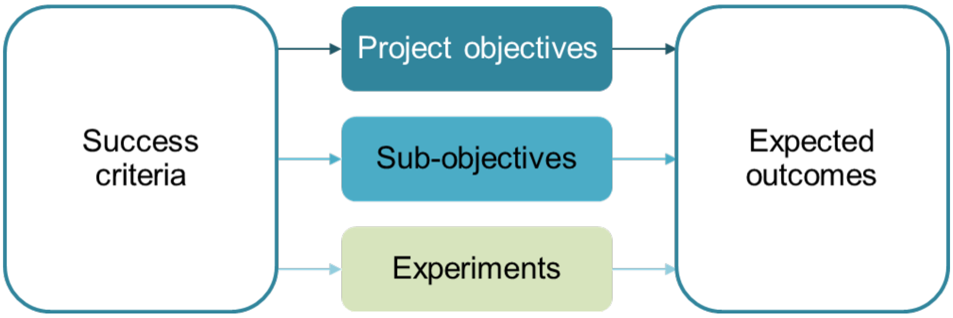
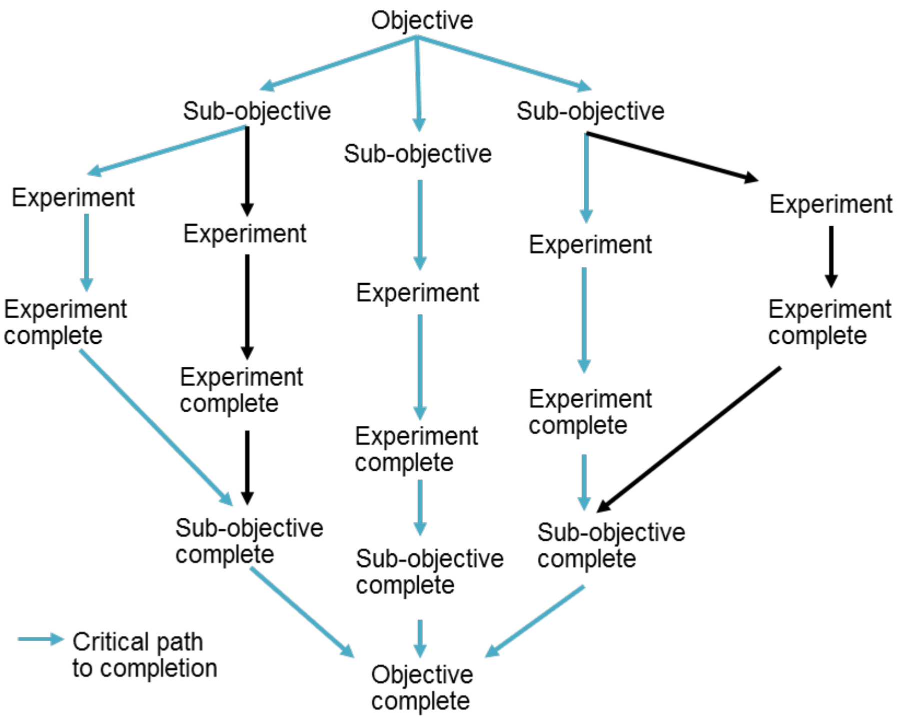


Figure 5 illustrates the non-linear relationship between experiment completion, the satisfaction of the critical path and the minimum activities necessary to achieve the learning objectives for the project. Not all experiments may be necessary to successfully achieve the sub-objectives and objectives; certain experiments may provide valuable learnings beyond the originally foreseen scope, that could be included as 'nice-to-have' if they are achievable within the time and budget constraints. It is important to note that the project will define a 'minimum viable product': the minimum experiments necessary to achieve the learning ambitions; and therefore not all the activities listed in the appendix will be tested.

Figure 5 – Identification of the critical path



2.2.2 Activity levels

Activities will be structured so that their learnings are representative of different levels of technological complexity that are available for commercial fleets. This will allow for a thorough understanding of the implications of different approaches to the electrification of commercial vehicle fleets. The activity learnings will mimic the following 'levels':

Level 1 – No electrification

The activities within this level will work to build a fleet baseline in order to make predictions about the impacts of varying scales of electrification. This will mimic fleets carrying out feasibility studies to implement EVs.

Within trials, this level assumes no communication with EV charge-points (if in place).

Level 2 – Un-managed EV charging[2]

The activities in this level will develop an understanding of the potential impacts of using un-managed-charging to charge commercial EVs. This is a 'worst case scenario' and provides a baseline to determine the value added in managed charging and flexibility.

Within the trials, this level assumes communication with EV charge-points, but no control over when the charge events is carried out. Activities in this level will be risk-assessed prior to execution to ensure that there is no threat to network assets.

Level 3 – EV charging managed by fleet operator/aggregator[3]

The activities in this level will explore the benefits accrued by being able to influence the charge events of commercial EVs (smart charging). Charge events will be manipulated to serve several means, for example to minimise electricity cost for the fleet operator, or to ensure that a profiled connection agreement is adhered to.

Within the trials, this level assumes communication and control over charge-points, but no communication channel with any parties other than the fleet operator.

Level 4 – EV charging with provision of flexibility services[4]

The activities in this level will determine benefits of using commercial EVs as assets with which to communicate, and provide flexibility services to the DNO. Flexibility will be considered both with and without profiled connection agreements in place.

Within the trials, this level aligns with the communication and control of charge-points, with communications open with the DNO (as well as fleet operator) via an aggregator.

Organising activities with this structure allows for forward predictions and backward evaluations, incrementally improving modelling capabilities and maximising the applicability of

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[2] Charging of an electric vehicle at the rate set by the connection until it reaches full charge or is disconnected

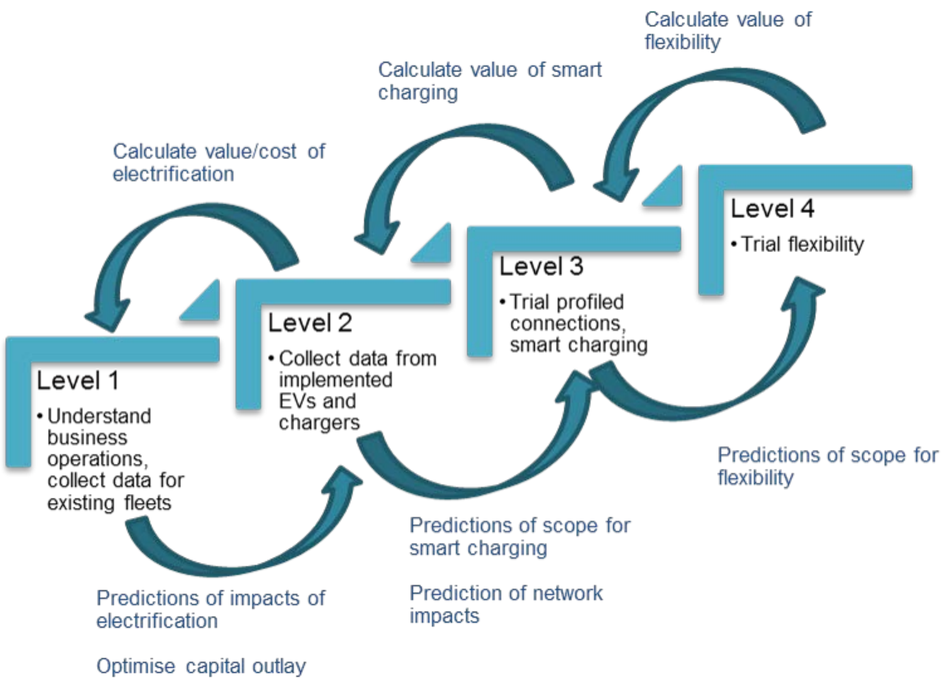
[3] Charging via a smart-charger equipped with two-way communication, enabling charging habits to be adaptive, where limitations on the energy exchanged on the network are decided upon connection agreement (e.g. profiled connections)

[4] The ability to respond dynamically to a signal provided by the DNO to increase or decrease the energy exchanged compared to an initial planned behaviour

learnings to other commercial fleet operators looking to electrify. Value estimations will also ensure the investment associated with each level can be directly compared to the benefits accrued. This process is described in Figure 6.

Note that all charge points installed during the trial will be smart chargers. These will be operated in 'un-managed' mode as appropriate.

Figure 6 – 'Levels' of technological complexity



2.2.3 Ensuring network safety throughout trials

Trials will be carried out in a manner which guarantees their execution does not pose any reliability risk to the network. Using the staggered approach ('levels') a 'simulation before application' process will be adopted. This enables potential network impacts of each experiment/activity to be predicted via simulation before their physical enactment to assess associated risks. Once these risks are identified the experiment design will be adjusted to mitigate them, for example by setting a lower profiled connection as the input to the optimisation tool so that the actual profiled connection is not breached in the experiment execution phase.

2.3 High level statistical approach

While the exact statistical sampling approach will be defined iteratively for each experiment according to the individual datasets and sample sizes required to draw robust conclusions, as outlined below, for the purposes of trial design this project proposes using a multi-level modelling approach. This entails creating homogenous groups of vehicles sharing common features, for example typical driving patterns (urban, sub-urban, rural; scheduled, reactive) for a given vehicle make and model. Multiple separate groups are expected to be created for each trial. Variety within the group will be controlled for by aiming for a significant population of vehicles per group wherever possible. This will reduce the risk of an issue with an individual vehicle resulting in a disproportionate impact on the findings.

In addition to controlling for operational differences in the definition of the groups, variation across groups and within groups will be explored by correlating data to external environmental factors. These include for example differences in weather, season, day of the week, one-off events such as sporting fixtures, strikes or major traffic incidents.

During the project, experiments will be executed with the aim of producing a statistically significant number of unique data points per group per experiment. Thus, sufficient confidence in the data analysis for findings to be applicable to commercial EV fleets in general can be provided.

To ensure the amount of data used within the experiments is sufficient, it is necessary to understand when enough data is enough. In order to answer this, multiple statistical tools will be used, such as: variance, statistical bias and model learning rates.

The project can then run an experiment with three different data sets (test, bias and real data) per make/model and compare the average variance between each run. Enough data would result in small variation between each run whereas not having enough data would result with a significant increase of the variance.

Model learning rates can be used to trace the learning curve per amount of data ingested. This would help identify when the model would have enough data and avoid feeding the model with more data that would not make an impact on the result.

3 Trial objectives

3.1 Common objectives of all trials

The trials methodology translates the headline aims and areas of learning defined in the Optimise Prime FSP submission to Ofgem[5] into discrete objectives that can be explored within each of the project use cases (Home, Depot and Mixed). The objectives have been defined to provide a logical sequence of activities for each workstream and enable data collection, analysis processes and technologies to be specified and built.

Consequently, there is no linear relationship between areas of learning and the trials objectives. Rather, each objective and each of their component sub-objectives within each trial contributes to the completion of one or more overall areas of learning for the project.

In defining the objectives and sub-objectives, several additional learnings that could be explored through the trials have been identified. These are noted as additional to the agreed scope but will be explored, if possible and if agreed with UK Power Networks and the relevant project partners, within the time constraints of the project and without incurring additional costs once the activities to achieve main learning areas have been completed.

To ensure that each individual trial is managed so that combined learnings result in the solution to the key project questions, five objectives have been defined. Satisfaction of these objectives will be achieved across the trials to different extents, as highlighted in Table 8.

Table 8 - Objectives of the Optimise Prime trials

Objective	Home	Depot	Mixed
1. Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment	X	X	X
2. Assess the effects of profiled connections on fleet EV transition		X	
3. Assess smart electrification strategies	X	X	
4. Assess the ability of EV fleets to provide flexibility services to the DNO	X	X	X
5. Evaluate operational limitations to commercial fleet electrification	X	X	[6]

[5] https://www.ofgem.gov.uk/system/files/docs/2018/11/op_fsp_final_public_v1-clean.pdf
[6] Additional to the agreed FSP scope, but will be included if Uber are able to provide summaries of driver and/or passenger ratings in comparison with ICE vehicle data without additional cost to the project

3.2 Home charging trial objectives

3.2.1 Levels

Experiments will be structured so that their learnings are applicable to different 'levels' of complexity of the technical solution available to fleet operators looking to electrify their return-to-home fleets. This will allow for a thorough understanding of the implications of different approaches to fleet electrification. The 'levels' are defined as follows:

- Level 1 – Existing fleet baseline
    - To mimic a pre-EV feasibility study of impacts of electrification
    - Will involve a study of fleet operation prior to EV uptake for baselining purposes
    - Predictions as to the outcome of implementation of the other levels

- Level 2 – Un-managed electrification
    - To mimic the case where no network consideration is taken in electrifying
    - 'Un-managed charging' behaviour will be studied for an appropriate proportion of the implemented EV fleet
    - In practice, the 'Un-managed charging' will be closely monitored (by Hitachi and the aggregator) during the project to ensure there is no reliability risks to network assets
    - Predictions of scope for cost optimisation using 'smart charging' will be made
    - Level 1 predictions will be evaluated against actual data recorded in the trial and the models used to make these predictions will be updated accordingly
    - Learnings from the evaluations will be disseminated to the public so that fleet operators external to the trial can carry out informed feasibility studies

- Level 3 – Electrification managed by the aggregator
    - To mimic a 'network conscious' approach to EV uptake based on charging managed by the aggregator
    - Requires a study of implemented 'smart charging' methods to achieve cost optimisation
    - The usefulness of network driven tariff structures to avoid network constraints will be evaluated in the context of commercial vehicles
    - Predictions of scope for provision of flexibility services to the DNO on a dynamic basis will be made
    - Evaluations of Level 2 predictions against actual data, recorded in the trial, will be made to capture directly the fleet and network benefits enabled by smart charging, and models will be updated to better reflect actual performance

- Level 4 – Aggregator managed electrification with provision of flexibility services
    - To mimic a 'network supportive' approach to EV uptake
    - Study of flexibility available from charge-at-home commercial EVs that can be provided to the DNO on a dynamic basis
    - Evaluations of Level 3 predictions against actual data, recorded in the trial, will be made to assess the predictability of flexibility available from charge-at-home commercial EVs, and models will be updated to reflect better actual performance

Organising experiments with this structure allows for forward predictions and backward evaluations, incrementally improving modelling capabilities and maximising applicability of learnings to other fleet operators looking to electrify.

The expectation is that each level of the trial will improve predictive capabilities for the effects of charging commercial EVs at domestic locations, as well as contributing to developing systems which best deal with these effects. Data and corresponding learnings will be made publicly available throughout, in order to provide DNOs and fleet operators with operationally validated insight into the effects of electrification. In addition to this, the proposed structure allows for comparisons between each level and will determine the value proposition for each increase in technological complexity, ensuring that the solution implemented is appropriate for its use case.

3.2.2 Objective 1

Definition – Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

The following sub-objectives have been derived for this objective:

1.1. Understand the operational requirements of return-to-home commercial vehicles
1.2. Model and validate EV charging profiles
1.3. Model and validate contribution of EV charging to home energy consumption
1.4. Model and validate the effect of charge-at-home EV loads on distribution network infrastructure
1.5. Consider future scenarios for EV uptake and consider effects on distribution networks
1.6. Translate simulated and measured network effects into infrastructure upgrade requirements
1.7. Translate anticipated upgrade requirements into DNO costs

Proposed activities for this objective are given in Table 38 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Table 20 which is in Section 4.1.

Completion of this objective will deliver the following outcomes for Centrica and UK Power Networks:

Table 9 – Objective 1 Outcomes for home trial

centrica	UK Power Networks
• **Understand operational differences between EVs and ICE Vehicles** • **Understand impact of EV charging on home load profiles for future reference** • **Developed load profiles for flexibility services scoping**	• Visibility of charge-at-home commercial EV loads • Understanding of the physical impact of EV loads on distribution network assets (network clusters) • Developed future projections for network planning

3.2.2.1 Sub-objective 1.1

Understand the operational requirements of return-to-home commercial vehicles

Activities in this sub-objective will pave the way for understanding the constraints that must be adhered to in order for the Centrica fleet to operate under ‘business as usual’ conditions throughout the trial. Such constraints will be predominantly based on state-of-charge (SoC) requirements for the vehicles to adequately perform their duties.

Telemetry data from the current internal combustion engine (ICE) vehicle fleet will be analysed to identify vehicle home locations and patterns in vehicle operation. This will enable grouping of data by type of activity undertaken (e.g. response, scheduled, rural, urban, suburban, region of operation), as well as according to locations sharing common distribution network assets (‘Network Clusters’). This could be, for example, locations connected via the same substation. To achieve a comprehensive understanding of the SoC requirements for Centrica’s EVs, experiments in this sub-objective work to build models that will predict the plug-in time of a vehicle, its return SoC, the energy requirements for the next day’s duties, mileage, EV efficiency and the plug-out time.

The outputs of such models will give the bounds and requirements for EV charging events/profiles. Predictions and evaluations will be made between each ‘Level’ of technological complexity so as to capture real-life dynamics in the models created – e.g. how do manufacturers’ estimated efficiency (mile/kWh) compare with the actual efficiency seen and how does this change over time? This will help refine charging optimisation profiles.

3.2.2.2 Sub-objective 1.2

Model and validate EV charging profiles

Given the operational requirements of the vehicles, the EV charging profiles will be determined by when, and by how much, EVs are charged in order to meet these requirements. Activities in this sub-objective will help the project to understand how EVs charge and how charging demand changes with weather conditions and over time. EV charging profiles indicative of un-managed charging and smart charging will be modelled and validated. Smart charging in the context of the charge at home trial refers to the manipulation of charge events by the aggregator to minimise costs for the fleet operator and is thus referred to as ‘aggregator managed’. This is unlike in the depot charging trial where smart charging is also used to adhere to a profiled connection. Different load profiles will result from experimentation with different tariff structures so that, once translated into network effects, the DNO will see which tariff structures best reduce network constraints. Consideration of both aggregator managed and un-managed charging profiles allows for direct comparison of the merits of each method. Comparison between the outputs of predictive models and the operational data from the trials will give insight to the nature of discrepancies between theoretical EV charging profiles and those observed. Such discrepancies will allow for return-to-home fleet operators both internal and external to the project to pragmatically predict EV demand loads, and for networks to assess the reliability of optimised commercial EV load and additional flexibility that can be provided on top.

3.2.2.3 Sub-objective 1.3

Model and validate contribution of EV charging to home energy consumption

This sub-objective will enable understanding of the contribution of charge-at-home commercial EVs to home energy consumption, as well as the resulting contribution to overall load on the distribution network. Activities in this sub-objective will support development of predictive capability in terms of both expected contribution to load on the distribution network and operational cost to the fleet operator. This will be achieved by predicting expected load profile for commercial EV charging for each home location based on rated vehicles and charge point parameters and validating predictions using actual data collected during the trial[7]. The impact of different charge point operation modes ('un-managed' and 'aggregator managed') will be modelled and validated with actual trial data. In each case, the models will assess the ideal load profiles for each home for domestic, commercial and time-of-use energy tariffs. Data will be aggregated across 'Network Clusters', enabling the contribution of the charge-at-home commercial EV fleet to network asset load to be understood.

3.2.2.4 Sub-objective 1.4

Model and validate the effect of charge-at-home EV loads on distribution network infrastructure

In parallel to activities in sub-objective 1.3, activities in this sub-objective will monitor the health of distribution network assets within the relevant 'Network Clusters'. Such monitoring will primarily focus on the load contribution of charge-at-home commercial EVs to congestion at relevant 'feeders' and substations. Monitoring data will be correlated with external data-sets such as weather. This will enable models to be developed showing variations in congestion locations and times as functions of size of charge-at-home commercial EV fleet, concentration of home locations within a 'Network Cluster' and of variables such as day of the week, season, weather. Such models may be used alongside those developed in sub-objective 1.3 to predict where and when congestion points will appear and the likely contribution of charge-at-home commercial EVs to this congestion. Charge-at-home commercial EV load profiles, aggregated by 'Network Cluster', will be overlaid with the corresponding distribution infrastructure load profiles for each level of EV charging technical maturity (un-managed, aggregator managed and aggregator managed plus flexibility) so that the alleviation of constraints by aggregator managed charging can be quantified.

3.2.2.5 Sub-objective 1.5

Consider future scenarios for EV uptake and consider effects on distribution network

The modelling capabilities realised through satisfaction of sub-objectives 1.1-1.4 will be employed to consider the effects of various EV uptake scenarios on the distribution network. Future scenarios will consider EV uptake across the Centrica fleet both internal and external to the trial, as well as applicability for other return-to-home commercial fleets. This will provide a more holistic approximation to the DNO of expected impacts from commercial fleet electrification.

3.2.2.6 Sub-objective 1.6

Translate simulated and measured network effects into infrastructure upgrade requirements[8]

Assessment of infrastructure reinforcement timelines will be made periodically throughout the trials to be able to quantify the impact of different scales of EV uptake with different levels of

[7] Availability of actual home energy use data is subject to the agreement of the Centrica engineers to provide this data.
[8] These are activities related to the "additional learning" objectives, if time and resource permits then it can be investigated.

technological maturity. Activities within this sub-objective will aid the DNO in calculating reinforcement timelines.

3.2.2.7 Sub-objective 1.7

Translate anticipated upgrade requirements into DNO costs[9]

Activities within this sub-objective will quantify the financial implications of bringing forward or delaying reinforcement work. As such the costs of each level and scale of EV uptake can be compared. This will allow for the calculation of the technical potential peak demand reduction associated with shifting charging loads through aggregator managed charging, and the associated financial value to the DNO.

3.2.3 Objective 3

<u>Definition – Assess smart electrification strategies</u>

The following sub-objectives have been derived for this objective:

3.1. Understand the impacts of EV uptake on Centrica fleet total cost of ownership (TCO)
3.2. Compare the effects of un-managed-charging and aggregator managed charging on the distribution network
3.3. Develop future strategies for return-to-home commercial vehicle electrification

Proposed activities for this objective are given in Table 39 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.1, Table 21.

Completion of this objective will deliver the following outcomes for Centrica and UK Power Networks:

Table 10 – Objective 3 outcomes for home trial

centrica	UK Power Networks
• **Identified fleet operator costs saved by separate metering** • **Understanding of EV impact on fleet TCO** • **Assessed impact of optimised charging schedules on TCO**	• Created range of load-profiles from charge-at-home commercial EV fleets • Understand peak shifting potential and associated financial value of aggregator managed charging from return to home commercial EV fleets

[9] These are activities related to the "additional learning" objectives, if time and resource permits without creating additional costs then it can be investigated.

3.2.3.1 Sub-objective 3.1

Understand the impacts of EV uptake on Centrica fleet total cost of ownership

This sub-objective will provide the basis for fleet operators to predict the impact of fleet electrification on TCO. Baseline values for key TCO components (vehicle and equipment purchasing, installation, fuel for ICE Vehicles, maintenance, insurance, tax, depreciation, electricity etc.) will be estimated and validated using actual data collected during the trial[10]. Electricity costs will be compared across different levels of charging technological maturity ('un-managed', aggregator managed and 'aggregator managed + flexibility') for three tariff structures (domestic, commercial and time-of-use), validating estimates with actual data from the trial in each case. The impact of potential legislative changes such as the expansion of the Ultra Low Emission Zone (ULEZ) on TCO will be explored at different levels of fleet electrification.

3.2.3.2 Sub-objective 3.2

Compare the effects of un-managed-charging and smart-charging on the distribution network

Experiments within this sub-objective will deploy capabilities developed in sub-objectives 1.2-1.5 to determine the potential for aggregator managed charging of return-to-home commercial EVs to mitigate network effects and reduce network costs associated with commercial fleet electrification. Load profile and associated cost and network effect data for both charging modes ('un-managed' and 'aggregator managed') will be aggregated across all charge-at-home locations. The potential for charge-point control to avoid risks to distribution network infrastructure will be assessed. Comparisons will also be made between the effectiveness of market approaches (ToU tariffs) and capacity allocation (profiled connections, as explored in the depot charging trial) in alleviating network constraints, allowing for differences resulting from the different approaches (vehicle types, operational parameters etc.) in the different trials.

3.2.3.3 Sub-objective 3.3

Develop future strategies for return-to-home commercial vehicle electrification

Fleet TCO data collected through activities undertaken in sub-objective 3.1 will be aggregated and analysed across groups representing different vehicle usage types (e.g. response, scheduled, urban, suburban, rural). The relative TCO impacts of varying levels of fleet electrification will be explored for each of these groups and translated into recommendations for fleet electrification strategy.

3.2.4 Objective 4

<u>Definition – Assess the ability of EV fleets to provide flexibility</u>

To build on lessons learned from other EV projects such as 'Shift' and 'TransPower' and in accordance with the UK Power Networks Flex Programme and other existing DNO flexibility roadmaps the following sub-objectives have been defined:

4.1. Model and verify the flexibility available from charge-at-home commercial EVs
4.2. Determine DNO flexibility needs

[10] Estimated TCO impacts will be validated through consideration of changes to the headline EV TCO in comparison with TCO for diesel vehicles; this will avoid any potential issues for trial partners regarding commercial sensitivity of data included in the TCO model

4.3. Predict value of flexibility from charge-at-home EVs to fleet/DNO given different market models
4.4. Evaluate the operational limitations to flexibility

Proposed activities for this objective are given in Table 40 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.1, Table 22.

Completion of this objective will deliver the following outcomes for Centrica and UK Power Networks:

Table 11 – Objective 4 outcomes for home trial

centrica	UK Power Networks
• **Measured availability of flexibility from charge-at-home EV fleets** • **Understanding of value of flexibility to fleet operator** • **Developed market frameworks that suit fleet operator flexibility**	• Understanding of current value of flexibility to DNOs • Set out flexibility needs in the short/long term • Measured flexibility availability and reliability from commercial EVs

3.2.4.1 Sub-objective 4.1

Model and verify the flexibility available from charge-at-home commercial EVs

This sub-objective will explore the potential for rescheduling EV charging times, or 'load shifting' via an aggregator (REstore), in response to a flexibility request from the DNO. Activities will build a comprehensive understanding of a charge-at-home commercial EV fleet's ability to provide flexibility – i.e.

- How much aggregated flexibility is available (kW)?
- How much would providing this flexibility cost over the original charging schedule?

Such activities will be based on running simulations using the models developed through prior objectives, shifting the charge-schedules by means of computational modelling and predicting the cost and operational implications. The results of such simulations will be verified with experiments in the operational domain.

3.2.4.2 Sub-objective 4.2

Determine DNO flexibility needs

In parallel to understanding the ability of charge-at-home commercial EV fleets to provide flexibility, the DNO's requirement for flexibility will also be considered. This will be achieved by monitoring network congestion events on LV/HV network infrastructure associated with the 'Network Clusters' involved in the trial and determining patterns in their occurrence. Building on learnings from the 'Shift' and 'TransPower' projects, market frameworks for flexibility trading with the DNO will be assessed given consideration of these patterns across relevant infrastructure – i.e.

- How uniform are the flexibility requirements?
- How early before the flexibility requirement can the need be predicted?

Using the methodology outlined in Objective 1, the financial benefit in reducing constraints in these events will be evaluated. Activities will then establish the extent of overlap between the DNO flexibility requirements on relevant infrastructure and flexibility available from the charge-at-home fleet in terms of duration, magnitude and price of response required/available.

3.2.4.3 Sub-objective 4.3

Predict value of flexibility from charge-at-home EVs to fleet/DNO given different market models

This sub-objective will analyse the overlap between the flexibility available from the charge-at-home commercial EV fleet and that required from the DNO. EV uptake models will be used to consider future network constraints resulting from uptake of commercial EVs and resultant flexibility needs. In addition to this, the suitability of different flexibility procurement market models, (such as those presented by Cornwall Local Energy Market (LEM) and Universal Smart Energy Framework (USEF)) for charge-at-home EV fleets will be assessed. Learning from this will be useful in understanding how charge-at-home fleet TCO may evolve over time.

3.2.4.4 Sub-objective 4.4

Evaluate the operational limitations to flexibility
This sub-objective will qualitatively and quantitatively assess the impact of flexibility on the usability of the vehicles, driver and aggregator perception of EV use and flexibility offered. This will be achieved by surveys and tests before and after the implementation of flexibility trading. Using charge-at-home EVs to provide flexibility services to the DNO must not negatively impact on ability to conduct operations, as well as being economically viable.

3.2.5 Objective 5

<u>Definition – Evaluate operational limitations to commercial fleet electrification</u>

The following sub-objectives have been derived for this objective:

5.1. Evaluate driver satisfaction with EV uptake
5.2. Evaluate fleet operator satisfaction with EV uptake
5.3. Evaluate satisfaction with separate EV metering
5.4. Evaluate aggregator satisfaction with commercial EV flexibility provision

Suggested activities for this objective are given in Table 41 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.1, Table 23.

Completion of this objective will deliver the following outcomes for Centrica and UK Power Networks:

Table 12 – Objective 5 outcomes for home trial

centrica	UK Power Networks
• **Developed organisation-wide response to EV uptake** • **Critically evaluated the operability of EVs/smart-solutions**	• Understanding of the likely uptake of commercial EVs • Predicted the reliability of flexibility procured from return-to-home fleets to inform investment decisions

3.2.5.1 Sub-objective 5.1

Evaluate driver satisfaction with EV uptake
This sub-objective will work to gain qualitative and semi-quantitative understanding of Centrica drivers' perceptions of EVs and their operation, and capture how they change over the project duration. This will be achieved through statistical analysis of driver surveys. This will provide an assessment of the potential to meet the project's ambitions of promoting EV uptake.

3.2.5.2 Sub-objective 5.2

Evaluate fleet operator satisfaction with EV uptake
This sub-objective will capture how the perception of EVs changes over time and with respect to the implementations of different levels of technological maturity. Fleet operator satisfaction will provide a complementary perspective to driver satisfaction, and will capture the pros and cons of EV uptake from a fleet management organisation perspective, including supply chain challenges where they are seen as relevant.

3.2.5.3 Sub-objective 5.3

Evaluate satisfaction with separate EV metering
This sub-objective will provide insight into the fleet operator's perception of the metering systems that enable the installation of home charge points for commercial vehicles. This will be an important factor in assessing likely speed of uptake of EVs for return-to-home commercial fleets.

3.2.5.4 Sub-objective 5.3

Evaluate aggregator satisfaction with commercial EV flexibility provision
This sub-objective will provide insight into the experience of aggregators with working with return to home commercial EV fleets to deliver flexibility services. This will be an important factor in assessing likely uptake of this model with other aggregators.

3.3 Depot trial objectives

3.3.1 Levels

Experiments in this trial will be structured so that their learnings are applicable to different 'levels' of complexity of the technical solution available to depots. This will allow for a thorough understanding of the implications of different approaches to depot electrification. The 'levels' are defined as follows:

- Level 1 – Existing fleet baseline
    - To mimic a pre-EV feasibility study carried out for a depot
    - Will involve study of depot operation prior to EV uptake for baselining purposes
    - Predictions will be made as to the outcome of implementation of the other levels

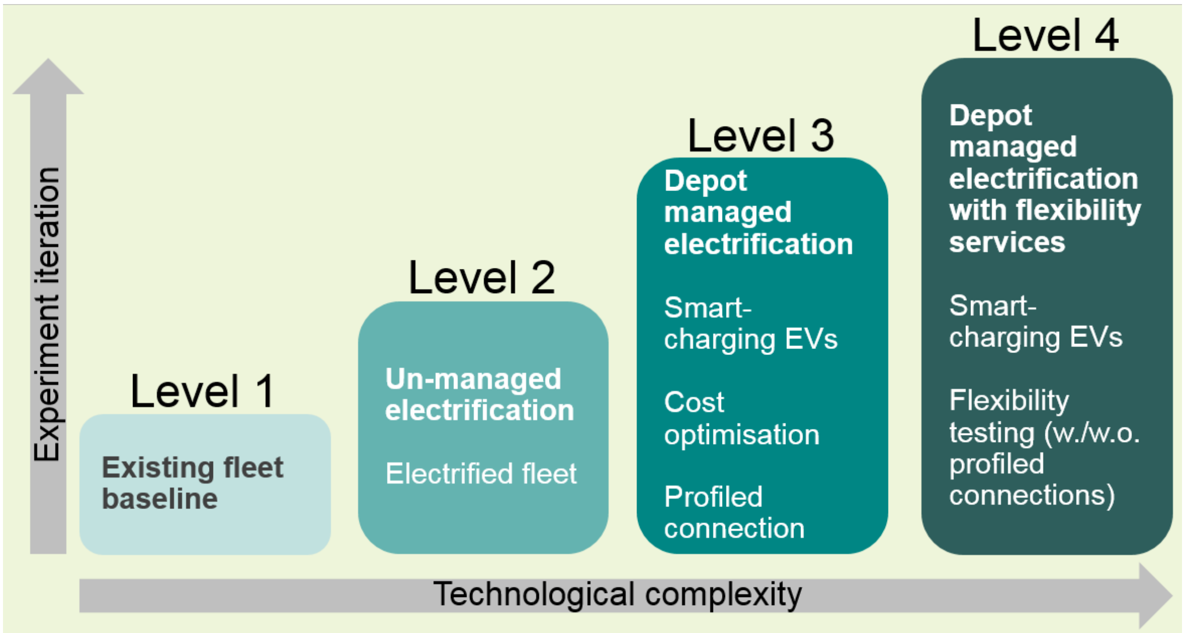
- Level 2 – Un-managed electrification
    - To mimic the case where no network consideration is taken in electrifying – 'worst case' for DNOs
    - 'Un-managed charging' behaviour will be studied for an appropriate proportion of the implemented EV fleet
    - 'Un-managed charging' will be managed (by Hitachi) to ensure there is no reliability risk to network assets
    - Predictions of scope for 'smart charging' will be made
    - Evaluations of Level 1 predictions against actual data recorded in the trial will be carried out to adjust models to reflect better real-life dynamics
    - Learnings from evaluations will be disseminated to the public so that depot operators external to the trial can carry out more informed feasibility studies

- Level 3 – Electrification managed by the depot
    - To mimic a 'network conscious' approach to the electrification
    - Study of the ability of implemented 'smart charging' methods to provide benefit to the network and the fleet operator
    - Methods tested will include adherence to a profiled connection and/or optimisation of costs based on network-driven tariff structures. Smart charging methods will be designed to ensure EV operational requirements are met throughout trials
    - Predictions of scope for additional flexibility will be made
    - Evaluations of Level 2 predictions against actual data recorded in the trial will be made to directly capture the fleet and network benefits enabled by smart charging

- Level 4 – Depot managed electrification with provision of flexibility services
    - To mimic a 'network first' approach to electrification
    - Study of dynamic flexibility available from electrified depots with and without profiled connections
    - Evaluations of Level 3 predictions against actual data recorded in the trial will be made to reveal the predictability of flexibility available from depots

Organising experiments with this structure allows for forward predictions and backward evaluations, incrementally improving modelling capabilities and maximising applicability of learnings to other depots looking to electrify. Figure 7 shows the methods that will be implemented in practice in the trials to simulate the situations described above.

Figure 7 – Depot trial experiment levels



The expectation is that each level of the trial will improve predictive capabilities for the effects of depot EV charging, as well as contribute to developing systems which best deal with these effects. This will inform the development of a depot planning tool which will enable profiled connection applications to be submitted to UK Power Networks and allow for integration with innovative profiled connections. Data and corresponding learnings will be made publicly available throughout, in order to provide DNOs and fleet operators with operationally validated insight into the effects of electrification. In addition to this, the proposed structure allows for comparisons between each level and will determine the value proposition for each increase in technological complexity, ensuring that the solution implemented is appropriate for its use-case.

The depot trial, although focused on the charging of EVs in depots, can be taken to be an assessment of clustered EV charging and is hence applicable (to a certain extent) to other electrification scenarios such as car park charging or rapid on street charging. This will provide a valuable point of comparison to dispersed charging, as explored both in the Centrica trial and external EV charging projects and will be used to provide recommendations to PHV fleet operators in terms of electrification strategy.

3.3.2 Objective 1

Definition – Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

The following sub-objectives have been derived for this objective:

1.1 Understand the operational requirements of Royal Mail EVs

1.2 Model and validate EV charging profiles
1.3 Model and validate load profiles from electrified depots
1.4 Model and validate the effect of depot load on local distribution network infrastructure
1.5 Predict the effect of depot load on distribution network infrastructure at higher voltage levels than the depot connection
1.6 Consider future scenarios for EV uptake and consider effects on the distribution networks
1.7 Translate simulated and measured network effects into infrastructure upgrade requirements
1.8 Translate anticipated upgrade requirements into DNO costs

Suggested activities for this objective are given in Table 42 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.2, Table 24.

Completion of this objective will deliver the following outcomes for Royal Mail and UK Power Networks:

Table 13 – Objective 1 outcomes for depot trial

Royal Mail	UK Power Networks
• Understanding of operational differences between EVs and ICE Vehicles • Basis for profiled connection agreement • Understanding of impact of low carbon technologies (LCTs) on depot load profiles for business modelling	• Analysed physical impact of clustered EV loads on distribution network assets • Developed future load projections for network planning • Understanding of technical potential of smart solutions to reduce/shift peak demand as alternative to infrastructure reinforcement

3.3.2.1 Sub-objective 1.1

Understand the operational requirements of Royal Mail EVs

Activities in this sub-objective will pave the way for understanding the factors that must be adhered to in order for Royal Mail depots to operate under ‘business as usual’ conditions throughout the trial. Such factors will be predominantly based on state-of-charge (SoC) requirements for the vehicles to perform adequately their duties. To achieve a comprehensive understanding of the SoC requirements for Royal Mail EVs, experiments in this sub-objective work to build models that will predict the plug-in time of a vehicle, its return SoC, the energy requirements for the next day’s duties, mileage, EV efficiency and the plug-out time. The outputs of such models will give the bounds and requirements for EV charging events/profiles. Predictions and evaluations will be made between each ‘Level’ of technological complexity so as to capture real-life dynamics in the models created – e.g. how do manufacturers’ estimated efficiency (mile/kWh) compare with the actual efficiency seen and how does this change over time? This will help refine charging optimisation profiles.

3.3.2.2 Sub-objective 1.2

Model and validate EV charging profiles

Given the operational requirements of the vehicles, the EV charging profiles will be determined by when, and how much, EVs are charged in order to meet these requirements. Activities in this sub-objective will help the project to understand how EVs charge and how charging demand changes with weather conditions and over time. EV charging profiles indicative of un-managed charging and smart charging will be modelled and validated. In the context of this trial, smart charging will be used to optimise charging schedules to meet the depot objectives whist ensuring operational and connection agreement constraints are adhered to – it is therefore referred to as 'depot managed charging'. Such an approach allows comparisons between the merits and disadvantages of each possible EV charging method ('un-managed'/'depot managed'). Comparison between the outputs of predictive models and the operational data from the trials will give insight to the nature of discrepancies between theoretical EV charging profiles and those observed. Such discrepancies will allow for depot operators (both internal and external to the project) and DNOs to realistically predict EV demand loads.

3.3.2.3 Sub-objective 1.3

Model and validate load profiles from electrified depots

Satisfaction of this sub-objective is necessary in order to understand the total load that depots are putting onto the distribution network and the relative contribution of EV charging to this load. Activities in this sub-objective will work towards developing predictive capability in terms of depot load profiles and will provide inputs for the Depot Optimisation Tool. As such, the causes of variability in the electricity consumption of the depot (other than EV charging loads) will be understood and modelled according to the stated performance rating of the equipment. The predicted 'background profiles' will then be validated with trial data. EV charging profiles will then be added to the 'baseline profiles' to give the predicted overall depot load profile, which will be validated with actual trial data. Incorporation of on-site renewable and storage technologies will also be simulated to investigate the business case for their inclusion. In achieving this sub-objective, capability will be developed to build indicative depot load profiles for various scenarios (e.g. proportion of fleet electrified, low carbon technology (LCT) incorporation, charger rating), being a necessary step towards a profiled connection agreement with the DNO.

3.3.2.4 Sub-objective 1.4

Model and validate the effect of depot load on network assets in the region surrounding the depot at the same voltage level

In parallel to activities in sub-objective 1.3, activities in this sub-objective will monitor the health of distribution network assets for which the depots are the only or the most significant contributor to demand. Such monitoring will primarily focus on the load contribution of electrified depots to congestion at relevant feeders and substations. Monitoring data will be correlated with external data-sets such as weather. This will enable models to be developed showing variations in congestion locations and times as functions of proportion of fleet electrification, and of variables such as day of the week, season and weather. Such models may be used alongside those developed in Sub-objective 1.3 to predict where and when congestion points will appear and the likely contribution of electrified depots (and EVs) to this congestion. Depot load profiles will be overlaid with the corresponding distribution infrastructure load profiles for each level of EV charging technical maturity (un-managed, depot managed and depot managed plus flexibility) so that the alleviation of constraints by depot managed charging can be quantified.

3.3.2.5 Sub-objective 1.5

Predict the effect of depot load on distribution network infrastructure at higher voltage levels than the depot connection

Within this sub-objective, activities will consider the effects of EV charging at depots on the higher voltage distribution network infrastructure. Understanding such effects is important because DNOs will be responsible for required upgrades with the costs recovered from the connecting customers and/or socialised across non-connecting customers. Monitoring activities will mimic those in Sub-objective 1.4 and will take place on any infrastructure involved in the chain of power delivery to the depot. The solution of this sub-objective will result in modelling capabilities representing the relationship between LV and HV network constraints so the impacts of EV uptake may be traced throughout the distribution network.

3.3.2.6 Sub-objective 1.6

Consider future scenarios for EV uptake and consider effects on the distribution networks

The modelling capabilities realised through satisfaction of sub-objectives 1.1-1.5 will be employed to consider the effects of various EV uptake scenarios on the distribution network. Future scenarios will consider EV uptake at Royal Mail depots both internal and external to the trial, as well as applicability for other depot based fleets. This will provide a more holistic estimate to the DNO of expected impacts from depot electrification.

3.3.2.7 Sub-objective 1.7

Translate simulated and measured network effects into infrastructure upgrade requirements[11]

Assessment of infrastructure reinforcement timelines will be made periodically throughout the trials to be able to quantify the impact of different scales of EV uptake with different levels of technological maturity. Activities within this sub-objective will aid the DNO in calculating reinforcement timelines.

3.3.2.8 Sub-objective 1.8

Translate anticipated upgrade requirements into DNO costs[12]

Activities within this sub-objective will quantify the financial implications of bringing forward or delaying reinforcement work. As such the costs of each level and scale of EV uptake can be compared. This will allow for the calculation of the value of profiled connections to the DNO.

[11] These are activities related to the “additional learning” objectives, if time and resource permits without creating additional costs then it can be investigated.
[12] These are activities related to the “additional learning” objectives, if time and resource permits without creating additional costs then it can be investigated.

3.3.3 Objective 2

Definition – assess the effects of profiled connections on fleet EV transition

Sub-objectives for this objective are as follows:

- 2.1 Explore risks associated with roll-out of profiled connections for the DNO
- 2.2 Develop pricing strategy for profiled connections
- 2.3 Evaluate the impact of profiled connections on fleet TCO
- 2.4 Quantify the acceleration of depot based EV roll out enabled by profiled connections

Proposed activities for this objective are given in Table 43 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.2.2, Table 25.

Completion of this objective will deliver the following outcomes for Royal Mail and UK Power Networks:

Table 14 – Objective 2 outcomes for depot trial

Royal Mail	UK Power Networks
• Profiled connection agreement • Understanding of total Cost of Ownership (TCO) • Reduced lead time for connection upgrades	• Understanding of network security risks • Developed profiled connection pricing strategy • Reduced impacts on EV roll out from connections lead time

3.3.3.1 Sub-objective 2.1

Explore risks associated with roll-out of profiled connections for the DNO

The aim of this sub-objective is to help the DNO achieve a balance between facilitating network capacity release while ensuring network resilience.

Given that the concept of a profiled connection is new, understanding its suitability for protecting the distribution network is of high importance. Activities within this sub-objective will explore this issue by defining and designing profiled connection options for the depots (e.g. static blocks) and simulating a range of profiled connection agreements (with varying percentage safety margin), communicating these to the depot energy management systems and observing the ability of smart systems to adhere to the connection profile. Activities will also monitor the health (e.g. harmonics, unbalance, network capacity, where appropriate and available) of the distribution network surrounding the depot(s) and determine the duration and magnitude of a profiled connection breach that would result in unacceptable stress on the network and compare these to the actual breaches observed during trials.

3.3.3.2 Sub-objective 2.2

Develop pricing strategy for profiled connections

Activities in this sub-objective will build on the results gained in sub-objective 2.1 by devising an economic model which best facilitates a healthy balance of risk and reward. This will include the cost savings due to avoidance of network reinforcements correlated to the operational cost of adhering to a profiled connection for the depot operator. Traditional 'you break it, you pay for it' models ('hard profiled connections') will be compared to 'soft profiled connections' whereby a £/kW charge will be levied on the connection agreement breach. Whether and under which conditions a breach would be acceptable will be investigated and the two options will be compared in terms of maximising total value across all parties.

This will help to inform Ofgem's network charging and access rights work.

3.3.3.3 Sub-objective 2.3

Evaluate the impact of profiled connections on fleet TCO

In this sub-objective the value of profiled connections to the depot operators will be assessed via consideration of the fleet total cost of ownership (TCO). The TCO will be assessed periodically throughout the trial to capture dynamics of scale and level of electrification. In addition to this, predicted TCO for implemented electrification strategies will be assessed and updated to reflect real-life operation (fuel efficiency, maintenance, etc.). The differences between predicted and actual TCO will be examined and communicated so that other depot operators, both internal and external to the trials, understand the scope for variability in their TCO predictions for electrifying their fleet. Key to understanding the benefits of smart solutions for commercial vehicle electrification is the impact of profiled connections on the TCO. This will be achieved by submitting various profiled connection applications throughout the trial to understand how costs vary with different levels of EV penetration and the 'levels' of technological complexity (profiled connection costs versus standard connection costs).

3.3.3.4 Sub-objective 2.4

Quantify the acceleration of depot based EV roll out enabled by profiled connections

In line with UK Power Networks' ambition to be an enabler of the EV revolution, activities in this objective will attempt to determine the value of implementing a profiled connection in terms of 'months saved' to connect the charge-points, as well as the capacity savings and their impact on the number of EVs that can be accommodated with and without a profiled connection. Time savings are expected to be a result of avoidance of connection infrastructure upgrades. In consideration of a wider range of depots, situations where depots are now suitable for electrification due to profiled connections, but would not have been economically feasible previously, will be analysed. Benefits associated with time savings, for example carbon savings and air quality improvements, will also be calculated within this sub-objective.

3.3.4 Objective 3

<u>Definition – assess smart electrification strategies</u>

Sub-objectives:

- 3.1 Compare levels of electrification for their effects on the network

3.2 Determine the value in low carbon technology (LCT) integration into depots for fleet operators
3.3 Determine the value in LCT integration into depots for the DNO

Proposed activities for this objective are given in Table 44 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.2.3, Table 26.

Completion of this objective will deliver the following outcomes for Royal Mail and UK Power Networks:

Table 15 – Objective 3 Outcomes for depot trial

Royal Mail	UK Power Networks
• Analysed Low Carbon Technologies (LCT) impact on TCO • Understanding of LCT impact on carbon footprint	• Understanding of risks/benefits associated with LCT integration • Developed a range of load-profiles from electrified depots • Understanding of technical potential of smart-charging to shift peak demand

3.3.4.1 Sub-objective 3.1

Compare levels of electrification for their effects on the network

Throughout the trial, activities will be run to mimic the different 'levels' of technological complexity. This sub-objective will bring together the results from each of these levels and directly compare the effects of un-managed charging and depot managed charging – e.g. 'on average delaying charge-events until 11pm saves X% of network capacity in peak times as opposed to standard un-managed-charging'. Such activities are necessary in order to affirm the expected benefits from using smart technologies and weighing them up against the potential costs.

3.3.4.2 Sub-objective 3.2

Determine the value in LCT integration into depots for fleet operators

This sub-objective will focus on the simulated load profiles that model for inclusion of solar, battery storage and, where this is possible within the time and resource constraints of the project, two-way vehicle-to-everything (V2X) charge-points into the depots[13]. Such profiles will be considered for their effects on the TCO for each depot's fleet. The impact of LCTs on the value of flexibility services that depots can provide will be considered alongside Objective 4. Differences from depot to depot will be analysed to postulate conditions in which additional LCTs would be most valuable to depot operators. Having an informed view on the value of

[13] V2X will be investigated only if time and resources permit, and if the project Board approves it.

LCT integration into depots will inform DNO of the likelihood of their roll out and therefore also help with network forecasting.

3.3.4.3 Sub-objective 3.3

Determine the value in LCT integration into depots for the DNO

This sub-objective will result in an understanding of the grid benefits associated with 'behind-the-meter' energy generation and consumption. The contribution to congestion of simulated load profiles will be used to determine whether solar generation inclusion has any negative network impacts and the extent to which battery storage negates this impact. The impact of LCT integration on non-financial benefits (e.g. carbon, air quality) will also be assessed.

3.3.5 Objective 4

<u>Definition – assess the ability of EV fleets to provide flexibility services to the DNO</u>

In the context of this trial, flexibility services are defined as 'the manipulation of a depot electricity demand profile away from that which is optimal for the depot owner in response to a communicated need from the DNO'. This objective will explore the economic and operational viability of such behaviour via the following sub-objectives:

- 4.1 Model and verify the flexibility available from electrified depots
- 4.2 Determine DNO flexibility needs
- 4.3 Predict value of flexibility from depot based EVs to fleet/DNO given different market models

Proposed activities for this objective are given in Table 45 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.2.4, Table 27.

Completion of this objective will deliver the following outcomes for Royal Mail and UK Power Networks:

Table 16 – Objective 4 outcomes for depot trial

Royal Mail	UK Power Networks
• Understanding of availability of flexibility from electrified depots • Analysed flexibility value to depot • Developed market frameworks that suit depot flexibility	• Understanding of current flexibility value to DNO • Set out flexibility needs in the short/long term • Measured flexibility available from commercial EVs and its reliability

3.3.5.1 Sub-objective 4.1

Model and verify the flexibility available from electrified depots

This sub-objective will explore the potential for rescheduling EV charging times, or 'load shifting', in response to a flexibility signal from the DNO. Activities will build a comprehensive understanding of each depot's ability to provide flexibility, and how this changes with movement from flat to profiled connection agreements – i.e.

- Is changing the charging schedule possible given operational constraints?
- How much flexibility is available per depot (kW)?
- How much would providing this flexibility cost over the original charging schedule?

Such activities will be based on running simulations using the models developed through prior objectives, shifting the charge-schedules by means of computational modelling and predicting the cost and operational implications. The results of such simulations will be verified with experiments in the operational domain.

3.3.5.2 Sub-objective 4.2

Determine DNO flexibility needs

In parallel to understanding the ability of depots to provide flexibility, the DNO's requirement for flexibility will also be considered. This will be achieved by monitoring network congestion events on network infrastructure associated with each depot and determining patterns in their occurrence. Market frameworks for flexibility provision to DNOs and other balance responsible parties will be assessed given consideration of these patterns across relevant depot-related infrastructure – i.e.

- How uniform are the flexibility requirements?
- How early before the flexibility requirement can the need be predicted?

Using the methodology outlined in Objective 1, the financial benefit in reducing congestion in these events will be evaluated. Activities will then establish the extent of overlap between the DNO flexibility requirements on relevant infrastructure and flexibility available from the depots in terms of duration, magnitude and price of response required/available.

3.3.5.3 Sub-objective 4.3

Predict value of flexibility from depot based EVs to fleet/DNO given different market models

This sub-objective will analyse the overlap between the flexibility available from the depot (in terms of both magnitude, duration and reliability) and that required from the DNO. EV uptake models will be used to consider future network constraints and resulting flexibility needs. In addition to this, the suitability of different flexibility procurement market models (such as those presented by Cornwall LEM, Piclo and Universal Smart Energy Framework (USEF)) in terms of their ability to share the value of flexibility across stakeholders will be assessed. Learning from this will be useful in understanding how depot fleet TCO may evolve over time.

3.3.5.4 Sub-objective 4.4

Evaluate the operational limitations to flexibility provision

This sub-objective will qualitatively and quantitatively assess the impact of flexibility on the usability of the vehicles. This will be achieved by surveys and tests before and after the implementation of flexibility trading. Using depot based EVs to provide flexibility services to the DNO must be operationally neutral, in effect, as well as being economically viable.

3.3.6 Objective 5

Definition – evaluate operational limitations to commercial fleet electrification

Sub-objectives:

5.1 Evaluate driver satisfaction with EV uptake
5.2 Evaluate the satisfaction of depot operators with EV uptake
5.3 Evaluate the use of smart software systems to ensure business-as-usual conditions

Proposed activities for this objective are given in Table 46 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.2.5, Table 28.

Completion of this objective will deliver the following outcomes for Royal Mail and UK Power Networks:

Table 17 – Objective 5 outcomes for depot trial

Royal Mail	UK Power Networks
• Developed organisation-wide response to EV uptake • Critically evaluated operability of EVs/smart-solutions	• Understanding of likely uptake of profiled connections • Predicted likely uptake of commercial EVs

3.3.6.1 Sub-objective 5.1

Evaluate driver satisfaction with EV uptake

This sub-objective will build on work undertaken in other projects such as Black Cab Green to gain a qualitative and semi-quantitative understanding of Royal Mail drivers' perceptions of EVs and their operation, and capture how they change over the project duration. This will be achieved by statistical analysis of surveys conducted throughout the trials. This will provide an assessment of the potential to meet the project's ambitions of promoting EV uptake.

3.3.6.2 Sub-objective 5.2

Evaluate the satisfaction of depot operators with EV uptake

This sub-objective will capture how the perception of EVs changes over time and with respect to the implementations of different levels of technological maturity. Depot operator satisfaction will provide a complementary perspective to driver satisfaction, and will capture the pros and cons of EV uptake from a depot organisation perspective.

3.3.6.3 Sub-objective 5.3

Evaluate the use of smart software systems to ensure business-as-usual conditions

This sub-objective will give an indication of the suitability of integration of new systems into depots where fleet operability is key. Activities will explore how the systems may interact with existing procedures and systems, as well as gauging the opinions of their performance from depot operators. This will allow for the development of features which make the incorporation of smart systems easier, and thus speed up the uptake of profiled connections.

3.4 Mixed trial objectives

Unlike the Home and Depot trials, the Mixed trial will focus exclusively on interpretation and analysis of vehicle data. Telematics data will be provided from up to 1,500 Uber Battery Electric Vehicles (BEVs) in order to determine their charging requirements. Unique to Optimise Prime, the data collected in this trial will analyse both the charging infrastructural requirements for private hire EV uptake and the effects that such uptake will have on the distribution network.

The trials will develop a deep understanding of private hire EV behaviour in order to improve modelling capabilities and accurately forecast the network effects of PHV electrification.

Objectives relevant to the Mixed trial are:

Objective 1

Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

3.4.1 Objective 1

<u>Definition – Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment</u>

Within this objective, private hire EV charging events will be mapped against capacity available on the distribution network by location and time stamp. This will allow for an understanding of the current constraints private hire EV charging places on the network as well as facilitating the construction and validation of predictive models which can be used to help DNO construct investment strategies.

The following sub-objectives have been derived for this objective:

1.1 Understand the variation in trips taken by private hire EVs
1.2 Analyse the charging requirements of private hire EVs
1.3 Model the effect private hire EV charging loads on distribution network infrastructure
1.4 Develop private hire EV uptake models
1.5 Identify potential charging infrastructure requirements
1.6 Predict the impact of private hire EV charging on the network in the future

1.7 Translate simulated and measured network effects into infrastructure upgrade requirements
1.8 Translate anticipated upgrade requirements into DNO costs

Proposed activities for this objective are given in Table 47 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.3.1, Table 29.

Completion of this objective will deliver the following outcomes for Uber and UK Power Networks:

Table 18 – Objective 1 outcomes for mixed trial

Uber	UK Power Networks
• Indicative energy requirements for categories of private hire EVs • Approximation of charge locations • Suggestions for charging infrastructure location/specs	• Visibility of private hire EV charging • Understanding of current impacts of private hire EV charging on network • Vision of future constraints on network from private hire EV charging

3.4.1.1 Sub-objective 1.1

Understand the variation in trips taken by private hire EVs

Activities for this sub-objective will use trip data supplied by Uber BEVs to identify patterns in trips taken based on influences such as weather and large public events. To achieve this, trip time, location and duration (minutes, miles) will be analysed with external data sets, such as weather data and TfL open data.

The main learning ambition in this sub-objective is to group individual vehicles into categories which broadly describe their behaviour. Examples of categories may be: peak hours operators, night-time operators, long-trip operators, short-trip operators etc. However, the extent to which private hire EV behaviour can be grouped into distinct categories will be better understood once data analysis has commenced. Understanding the relative composition of the fleet according to these groups and how this changes over time will allow for the construction of predictive models that allow for forecasts that represent different uptake scenarios – e.g. the expected increase of BEVs that will operate in the inner city due to Ultra Low Emission Zone (ULEZ) regulations.

3.4.1.2 Sub-objective 1.2

Analyse the charging requirements of private hire EVs

To determine EV charging requirements, it is necessary to approximate the start and end locations of the private hire EVs. This location will be used in combination with availability for off-street parking in order to estimate the likely charge location type (home or on street). Additional activities will be used to approximate the charging requirements (time, magnitude, location) by approximating the state of charge of individual PHVs throughout their use.

Assumptions will be made on charger power rating where this data is not available from other sources.

The outputs to this sub-objective will be indicative charging profiles (time, magnitude, location) for the different categories of private hire EVs as well as heat maps showing incidences of low EV estimated state of charge (SoC). The SoC will be a derived value from vehicle journeys and therefore will have less accuracy than if this data was obtained from the battery directly (Uber cannot provide SoC battery data). SoC heatmaps will be used to enable demand for private hire EV charging to be estimated for a given location at a London borough level. Suggestions of potential locations for new charging infrastructure installation will be made based on these heat maps, alongside additional available data such as potential costs of charging sites in the borough, availability for on-street parking.

3.4.1.3 Sub-objective 1.3

Model the effects private hire EV charging loads on distribution network capacity

To satisfy this sub-objective, load profiles modelled in sub-objective 1.2, taking into account varying levels of utilisation and differences in charging station type, will be translated into distribution network effects by overlaying with distribution network capacity. The time, duration, magnitude and location of the private hire EV charge events will be used to estimate the contribution to the utilisation of 'headroom' capacity on relevant distribution network infrastructure during peak utilisation periods. Heat-maps will be produced to show overlap between low network capacity availability and high private hire EV charging demand.

Learnings from activities in this sub-objective will allow for predictions of how private hire EV charging may reduce the available capacity on the network in the future.

3.4.1.4 Sub-objective 1.4

Develop private hire EV uptake models

It is anticipated that the number of EVs included in the study will increase throughout the trial. Activities in this sub-objective will monitor the additions of new EVs and determine patterns in uptake. Variables of particular interest are: home location of EVs, access to off-street parking, average location and duration of operation (minutes, miles).

These patterns will be used to model future uptake scenarios by combining with existing PHV operator data and existing commercial and non-commercial EV uptake models similar to what has been done in the 'Recharge the Future' project. Such uptake models are necessary to identify future charging infrastructure requirements and resultant distribution network effects.

3.4.1.5 Sub-objective 1.5

Identify potential charging infrastructure requirements

Activities in this sub-objective will take the outputs of private hire EV uptake models and associate them with EV charging requirements. This will indicate the density of incidences of low charge given future uptake levels which will be compared to the level of existing charging infrastructure to identify potential 'blind spots'. Operational requirements and estimated EV SoC will then be used to suggest appropriate locations and charge-point ratings for future charging installations at a London borough level.

3.4.1.6 Sub-objective 1.6

Predict the impact of private hire EV charging on the network in the future

Given the outputs of the private hire EV uptake models and suggested infrastructure upgrades and installation, activities in this sub-objective will serve to generate future EV charging load. This load will be estimated according to the size of the fleet predicted in sub-objective 1.4, and through analysis of where and by how much the vehicles tend to be charged (sub-objective 1.2). These load profiles will be associated with distribution network infrastructure to predict network effects using the learning from sub-objective 1.3 and sub-objective 1.5.

Outputs from these activities will be used to communicate a future picture to the DNO, highlighting the locations and times of day/week/year that infrastructure is likely to be put under strain.

3.4.1.7 Sub-objective 1.7

Translate simulated and measured network effects into infrastructure upgrade requirements

Predictive models developed in sub-objective 1.6 will be extended so that predicted network constraints may be interpreted by the DNO as upgrade requirements[14]. Sensitivity analysis will be performed to determine critical factors that impact the reinforcement timeline for network infrastructure.

3.4.1.8 Sub-objective 1.8

Translate anticipated upgrade requirements into DNO costs

Satisfaction of this sub-objective will require understanding the DNO costing method for bringing forward reinforcement investments. Once this is understood, financial costs will be associated to the scenarios explored in sub-objective 1.7[15].

3.4.2 Objective 4

Definition: Assess the ability of EV fleets to provide flexibility services to the DNO

Once an understanding of the impact of private hire EV charging on the distribution network capacity has been built, charging patterns with the potential to alleviate specific network constraints will be considered. Activities in this objective will be model based and will utilise predictions of future network constraints and anticipated private hire EV load profiles. The practicality of flexibility service provision from private hire EVs will be assessed from both operational and commercial perspectives.

The following sub-objectives have been derived for this objective:

4.1 Consider DNO future flexibility needs at relevant voltage level(s)
4.2 Determine operational feasibility of private hire EV operators providing flexibility services to DNOs within relevant voltage level(s)

[14] Activities under this sub-objective are additional learnings and will be carried out subject to time and resources being available.
[15] Activities under this sub-objective are additional learnings and will be carried out subject to time and resources being available.

4.3 Develop business models for private hire EV flexibility provision

Suggested activities for this objective are given in Section Table 48 of the appendix.

The expected high-level data requirements to achieve the activities are summarised in Section 4.3.2, Table 30.

Completion of this objective will deliver the following outcomes for Uber and UK Power Networks:

Table 19 – Objective 4 outcomes for mixed trial

Uber	UK Power Networks
• Understanding of scope for EVs to provide flexibility to DNO • Understanding of value of flexibility provision • Evaluation of business models and operational impacts of flexibility provision	• Developed long-term flexibility requirements • Understanding of potential for private hire EVs to address flexibility needs • Evaluation of market mechanisms for value sharing

3.4.2.1 Sub-objective 4.1
Consider DNO future flexibility needs

Activities in this sub-objective will take predicted network effects from sub-objective 1.6 and consider ways in which these network effects may be reduced by using demand turn down. The outputs of these activities will be locational recommendations for times of day/week/year in which flexibility services may be required. Recommendations will be aligned with Flexibility Programme + Shift/TransPower work on LV flexibility. Such estimations will be compared to current DNO flexibility requirements as understood through UK Power Networks' flexibility roadmap and existing markets mechanisms.

3.4.2.2 Sub-objective 4.2
Consider the technical feasibility and logistical impacts of private hire EV operators providing flexibility services to the DNO within relevant voltage level(s)

In this sub-objective, the extent to which flexibility needs identified in sub-objective 4.1 can be met through charging load shifting by private hire EVs will be determined. Activities will consider different methods for flexibility provision subject to their feasibility such as:

- Charging deferral or pre-emptive charging by private hire EV drivers
- Flexibility provision via an aggregator for charge-at-home private hire EVs
- On street flexibility provision
- Car-share depot flexibility

The outputs will highlight the impact of such flexibility provision on the normal operations of the driver and the magnitude of flexibility likely to be available from private hire EVs.

3.4.2.3 Sub-objective 4.3

Develop business models for private hire EV flexibility provision

Activities in this sub-objective will explore the potential for innovative business models to share value of flexibility across the DNOs, charge-point operators and private hire EV operators. Comparisons will be made between the outcomes of Sub-objective 4.1 and Sub-objective 4.2 to develop solutions which best meet the DNO flexibility needs within the operational constraints of the private hire EV operator. Future scenarios for market reforms and high EV uptake will be considered.

4 Trial specifications: trial data requirements

The trial objectives have driven the formation of high level non-functional and data requirements that are currently shaping the design of the Optimise Prime technical solutions. High-level data requirements are listed, by trial and objective, in this section. These data requirements will be refined as experiments are designed.

4.1 Home trials

4.1.1 Objective 1

Create, verify and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Table 20 – Home Trial objective 1 high level data requirements

Fleet data		Network data	External data
Centrica	**Trials activities**	**UK Power Networks**	**External sources**
• EV and ICE vehicle telematics • EV and ICE vehicle make/model • Historical home location electricity consumption • Relevant tariff structures	• EV charge-event time, magnitude, duration	• Network capacity • Network monitoring data for infrastructure in 'Network clusters' • Infrastructure upgrade requirements • Indicative infrastructure costs to implement infrastructure upgrades	• EV specifications (manufacturer) • Weather • Seasonal events • EV uptake • Home locations in UK Power Networks/Scottish & Southern Electricity Network regions

4.1.2 Objective 3

Assess smart electrification strategies

Table 21 – Home trial objective 3 high level data requirements

Fleet data		Network data	External data
Centrica	**Trials activities**	**UK Power Networks**	**External sources**
• Electricity consumption (**pre**/post EV charge-point installation)[16]	• Electricity consumption (pre/**post** EV charge-point installation)[17]	• Relevant network infrastructure loading data, by 'Network Cluster'	• Commercially available charge-point ratings (un-managed/smart/V2X)

[16] Centrica will investigate sharing this data within a General Data Protection Regulation-compliant Data Sharing Agreement

[17] Centrica will retain TCO model and provide overall TCO output values for ICE vehicles and BEVs to Hitachi. Hitachi will provide variables to be input into Centrica's TCO model.

Fleet data		Network data	External data
• Applicable energy tariffs (domestic, commercial, Time of Use) • Baseline fleet TCO data [17] (maintenance, insurance, tax, depreciation etc.)			• Expected legislative changes • LCT operating costs

4.1.3 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 22 – Home trial objective 4 high level data requirements

Fleet data		Network data	External data
Centrica	**Trials activities**	**UK Power Networks**	**External sources**
• Electricity tariff • Operational requirements	• Historical EV charge event data	• Patterns in network constraints (location) • Magnitude/duration of flexibility required to offset constraints (flexibility product specifications)	• Weather • Season • Time-of-day

4.1.4 Objective 5

Evaluate operational limitations to EV fleet electrification

Table 23 – Home trial objective 5 high level data requirements

Fleet data		Network data	External data
Centrica	**Trials activities**	**UK Power Networks**	**External sources**
• Driver surveys[18] • Fleet operator surveys	• EV charge event data	• Flexibility requests to trial the fleet response	• N/A

[18] Driver surveys will be conducted in conjunction with Hitachi Capital Vehicle Solutions

4.2 Depot charging

4.2.1 Objective 1

Create, verify and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Table 24 – Depot trial objective 1 high level data requirements

Depot data		Network data	External data
Royal Mail	**Trials activities**	**UK Power Networks**	**External sources**
• EV and ICE vehicle telematics • Historical depot electricity consumption • Original connection agreement • Original electricity tariff structure	• EV charge-event time, magnitude, duration • Depot connection load	• Network capacity • Network monitoring data for associated distribution network infrastructure • Infrastructure upgrade requirements • Infrastructure costs	• EV specifications (manufacturer) • Weather • Seasonal events • EV uptake • Depots in UK Power Networks/Scottish & Southern Electricity Network regions

4.2.2 Objective 2

Assess the effects of profiled connections on fleet EV transition

Table 25 – Depot trial objective 2 high level data requirements

Depot data		Network data	External data
Royal Mail	**Trials activities**	**UK Power Networks**	**External sources**
• Electricity tariff • Vehicle purchasing costs (EV and ICE vehicle) • EV charging infrastructure costs • Vehicle operating costs (EV and ICE vehicle)	• Depot electricity consumption • EV charge-event data	• Connection agreement technical characteristics • Connection agreement cost • Network monitoring • Infrastructure upgrade planning timeline	• Weather • Events • Depots in UK Power Networks/Scottish & Southern Electricity Network regions

4.2.3 Objective 3

Assess smart electrification strategies

Table 26 – Depot trial objective 3 high level data requirements

Depot data		Network data	External data
Royal Mail	**Trials activities**	**UK Power Networks**	**External sources**
• Depot electricity consumption (pre EV charge-point installation) • Installed capacity of LCTs by depot	• Depot electricity consumption (post EV charge point installation)	• Relevant network infrastructure loading data	• Solar irradiance • Commercially available charge-point ratings (un-managed/smart/V2X) • Commercially available battery sizes • LCT purchasing and installation costs • LCT operating costs

4.2.4 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 27 – Depot trial objective 4 high level data requirements

Depot data		Network data	External data
Royal Mail	**Trials activities**	**UK Power Networks**	**External sources**
• Electricity tariff • Operational requirements	• Historical EV charge event data	• Patterns in network constraints • Magnitude/duration of flexibility required to offset constraints • Flexibility signals	• Weather • Season • Time-of-day

4.2.5 Objective 5

Evaluate operational limitations to EV fleet electrification

Table 28 – Depot trial objective 5 high level data requirements

Depot data		Network data	External data
Royal Mail	**Trials activities**	**UK Power Networks**	**External sources**
• Driver surveys • Depot operator surveys • Fleet operator surveys	• EV charge event data	• N/A	• N/A

4.3 Mixed charging

4.3.1 Objective 1

Create, verify and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Table 29 – Mixed trial objective 1 high level data requirements

Fleet data	Network data	External data
Uber	**UK Power Networks**	**External sources**

• Anonymised Trip data:
  • Start/end time
  • Location
• Vehicle make and model
	• Network capacity for primary and secondary substations	• Weather
		• Public events
		• TfL open data
		• EV uptake models
		• TfL rapid charging network proposals
		• Existing charging infrastructure

4.3.2 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 30 – Mixed trial objective 4 high level data requirements

Fleet data	Network data	External data
Uber	**UK Power Networks**	**External sources**

• Anonymised trip data:
  • Start/end time
  • Location
• Vehicle make and model
	• Patterns in network constraints
	• Magnitude/duration of flexibility required to offset constraints
		• Flexibility market data

5 Specification of the technical solutions

5.1 The Optimise Prime technical solution

The Optimise Prime technical solution will deliver a software system that can execute and manage the project's operational and analytical trials and experiments. It therefore combines the following core capabilities.

- **Trials Operational Applications.** A collection of bespoke software applications built to run the operational trials and experiments. These will run over periods from a few hours to days, weeks, months or even years. All data captured will be made available for detailed analysis. Three primary functions will be delivered:
    - Depot planning – A web application to capture Royal Mail's depot energy resources and delivery schedules to output energy demand profiled connection requests to UK Power Networks.
    - Depot optimisation – A set of services and web interfaces to optimise the day-to-day running of the EV charging points.
    - Flexibility services – A set of services and web interfaces to manage and execute flexibility products with UK Power Networks and experiment with other approaches.
- **Data Analysis and Modelling.** Provision of a suite of industry standard data analysis software applications. This will also include an appropriate execution environment in which to conduct the analysis, modelling and reporting on the captured datasets.
- **Secure and Robust Data Management.** The ability to ingest, cleanse, store and maintain all the data captured during the project securely and safely for the life-time of the project prior to post-project archiving.
- **Scalable Platform.** A robust, scalable and managed infrastructure and platform upon which the solution will be built.

Within the Operational Trials Applications capability, the following core components are to be delivered as a service to the trials.

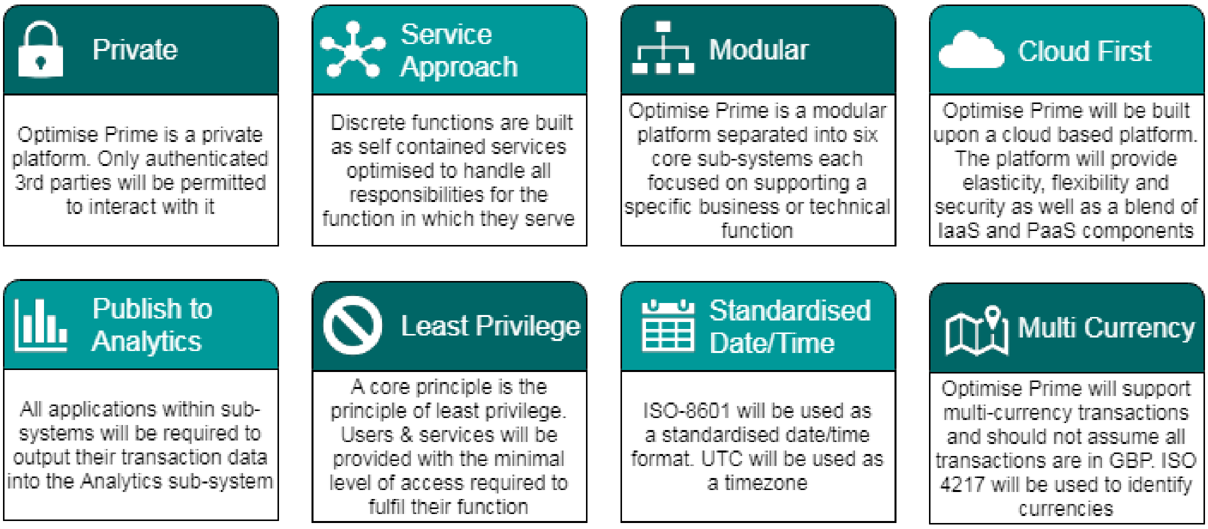
5.2 Design process & principles

The Logical Solution Architecture has been designed with the primary purpose of:

- Supporting the management of the development, operational and maintenance effort across project partners.
- Allowing the ability to mix technology and software architecture patterns; to use the right tool for the job.
- To minimise disruption to other parts of the application minimised through cohesive service boundaries. This simplifies the release and test process and can facilitate continuous development practices.
- Increasing security through separation at the logical level.

It is important to note that this approach of having loosely coupled sub-systems that have dependencies on one another will require careful planning and coordination across the responsible parties. At a software implementation level this manifests primarily as integration specifications, contracts and clear delivery deadlines. Figure 8 presents the key architectural design principles for the Optimise Prime Solution. These principles will be adopted throughout the solution.

Figure 8 – Architectural principles



5.2.1 Security and privacy

Security and privacy (including GDPR compliance) will be designed and built into the Optimise Prime Solution from the bottom-up. It will form a core part of the Solution Design and will propagate from the management of all data in the solution (ingestion, extraction, transformation, storage, analysis, aggregation, archiving, deletion, etc.) through to all applications built and used.

5.2.2 Service approach

The Optimise Prime Solution will leverage a service model in its architectural design. Discrete functions of the system will be built as self-contained services that are optimised to handle all responsibilities for the function they serve. A set of monitoring operations and controls within the Optimise Prime Solution will ensure that the entire platform continues to support desired service levels and access requirements. It will provide archival and restoration capabilities that ensure data integrity and OLA and SLA compliance.

5.2.3 Modular approach

The Optimise Prime Solution will be built as a modular platform that implements scalable data analytics strategies that are easily able to adapt for ongoing requirements of growing EV market.

5.2.4 Deployed in the cloud

The Optimise Prime Solution will be hosted in Hitachi's private cloud called the Hitachi Enterprise Cloud (HEC). The HEC provides the necessary databases, schemas, processes and specific compute resource allocation to support several sub-systems that constitute the Optimise Prime Solution.

5.2.5 Least privilege

The Optimise Prime Solution will apply service levels that provide authorised users with access to only the data they need, when and how they need them.

5.2.6 Publish to analytics

The core purpose of any application within the solution is to capture and make its data available for analysis. As part of this commitment, each application will be required to tag its data with the appropriate trials metadata to ensure that it can be accurately and reliably tracked against the experiment for which it was captured.

5.2.7 Standardisation and multi-currency

The Optimise Prime Solution will establish a set of effective policies for the full-lifecycle enterprise data management to control data growth and to lower overall storage costs through the effective use of data and metadata. It will empower data management standards that are configured in easy and transparent way allowing to store data securely and cost-effectively, according to the evolving business value.

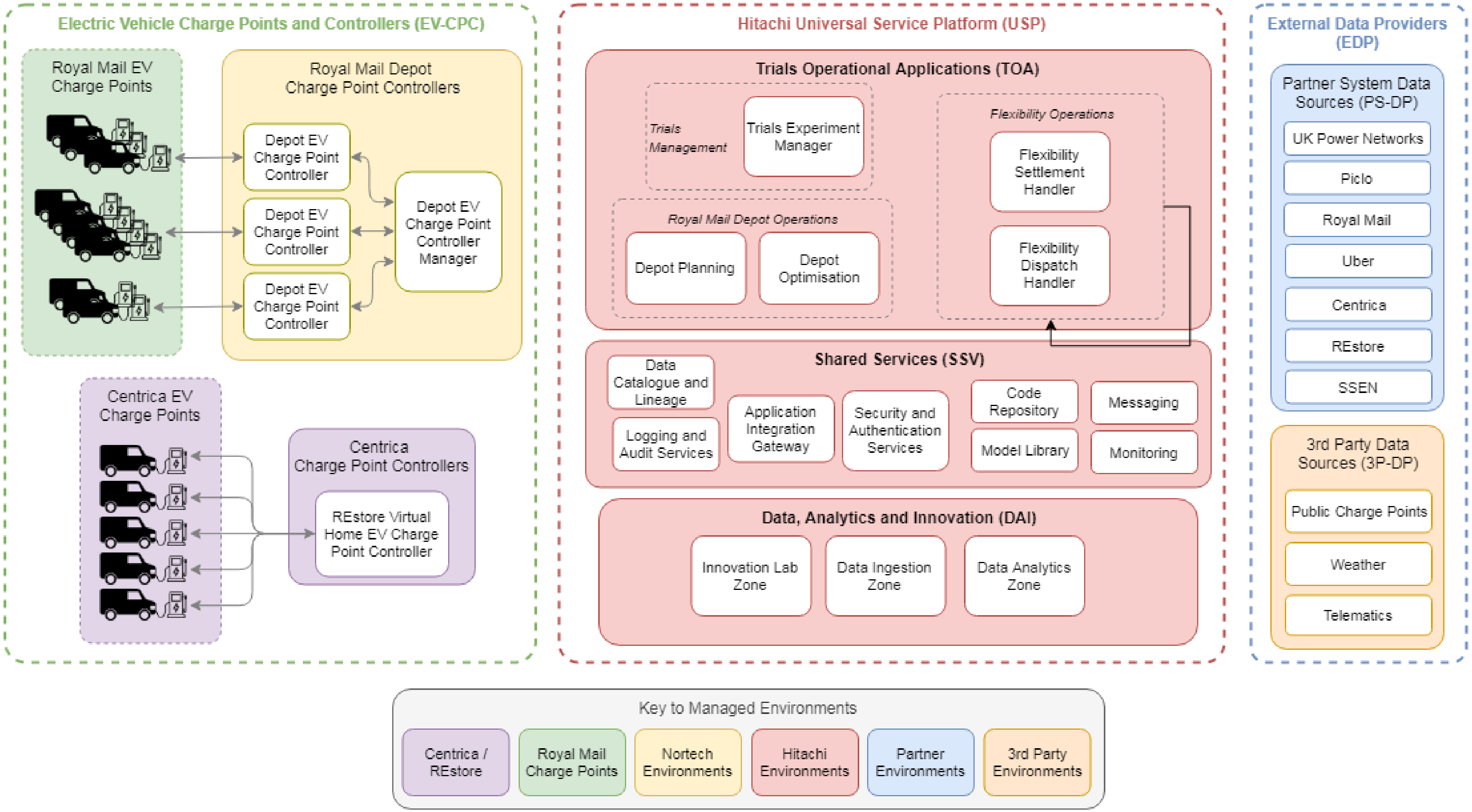
The Optimise Prime Solution will be built on a platform that is adapted to work across regions with different currencies and UTC standard time zone. It incorporates single time management through NTP and multi-currency transactions feeding data on exchange rates through web services.

5.3 Top-level logical solution architecture

Figure 9 shows the top-level logical architecture of the Optimise Prime Solution. The Solution is divided into three logical areas based on ownership (operational and management responsibility) and primary function within the Optimise Prime Solution. Each logical area is further divided into one or more sub-systems that group together collections of applications and services. These sub-systems provide specific functions that are directly aligned to the delivery of the project trials and goals.

The following sub-sections provide a brief overview of each logical area and their sub-systems.

Figure 9 – Architectural overview



5.3.1 Electric Vehicle Charge Points and Controllers (EV-CPC)

The EV-CPC area comprises EV charge points and their controllers. Its purpose is to provide active management of the charging of EVs when connected to the controlled charge points. The EV-CPC provides remote management capability for the controlled charge points at an individual or aggregated level.

The EV-CPC is divided into two sub-systems that are based on each partner involved in the EV-CPC trials (note, there is not an EV-CPC sub-system for Uber as they are not part of the charge point optimisation trials).

Each sub-system may have duplicate components achieving the same purpose, but they will be specific to the partner assets that they are responsible for. They will therefore be completely independent of each other.

5.3.1.1 Royal Mail EV-CPC

The Royal Mail EV-CPC sub-system manages the EV charge points and controllers for the Royal Mail depots. The charge points will be sourced by Royal Mail and the Charge Point Controllers will be provided by Hitachi via a third party following a tender process.

5.3.1.2 Centrica EV-CPC

The Centrica EV-CPC sub-system manages the EV charge points and controllers for Centrica's home-based fleet. The Charge Points will be provided by Centrica and the Charge Point Controller will be provided by REstore.

REstore manage Centrica's EV fleet as belonging to one or more virtual depots. Individual charge points exist within a virtual depot as a logical grouping and are not necessarily co-located either geographically or by grid connection.

5.3.2 Hitachi Universal Service Platform (USP)

The Hitachi Universal Service Platform provides a common area where the following sub-systems will be built and operated:

- Trials Operational Applications (TOA)
- Shared Services (SSV)
- Data, Analytics and Innovation (DAI)

At the core of the USP is Hitachi’s Enterprise Cloud (HEC). The HEC provides the infrastructure and platform upon which the TOA, SSV and DAI sub-systems will be built. As a managed service it is important that the HEC delivers against the minimum set of non-functional requirements listed in Table 31.

Table 31 – Hitachi Enterprise Cloud non-functional requirements

Requirement	Details
Scalability	It must be possible to scale the infrastructure (storage, compute and network) during the project if the initial provisioning proves to be inadequate. Timescales for the provisioning for scale-out should be within hours of the request. As a science and innovation project there is the potential for compute and storage demands to increase if new large datasets are discovered (or created) or more complex models and algorithms are developed.
Availability	Project trials and experiments will run against Royal Mail and Centrica day-today operations. Therefore, the HEC must be available to 99.9% of the time (i.e. acceptable downtime of 43.83 minutes per month) during normal operating conditions. Exceptional circumstances where this may be exceeded are in the case of a critical failure of the data centre where the infrastructure is hosted.
Maintenance	All software, databases and services provided by the HEC must be patched and kept within one minor version of latest release. All version increases should be communicated to the project team. Expected timescales for the role-out of patches and version updates will vary by software and criticality. The HEC should provide a documented policy on the role-out times it will adhere to.
Support	Technical support must be available to the project's direct users of the HEC during normal working hours. • Response to initial query/issue raised within 4 hours. • Initial Investigation within 24 hours. • Resolution within 5 working days. These users requiring support will predominantly be the project's development operations (DevOps) and Pentaho[19] administrators. Access to technical documentation regarding the day-to-day usage of the HEC should also be provided to minimise the need for support services on minor/trivial issues.
Security	A significant proportion of the data stored, and applications developed, will contain both personal and commercial sensitive data. Therefore, the HEC must provide a highly secure environment in which physical, user and programmatic access is restricted on a least privilege basis. All access should be logged and monitored for abnormalities. Access privileges should regularly be reviewed to ensure they are still required and be automatically revoked after three months of non-activity. Security policies and regular testing will ensure cyber security.
Storage	An initial minimum of 30 Terabytes storage is required. This will be continually reviewed and monitored throughout the project. If deemed insufficient at any time, then a request will be made to increase the allowance in line with the Scalability requirements of the HEC.
Performance / Compute	An initial minimum of 48 CPU Cores with 32 Gb RAM has been specified. This will be continually reviewed and monitored throughout the project. If deemed insufficient at any time, then a request will be made to increase the allowance in line with the Scalability requirements of the HEC.

[19] Pentaho is a Hitachi business intelligence tool which will be used for data integration and analytical tasks.

Requirement	Details
Monitoring	Each solution component will publish log entries to the logging and audit shared-service. Log entries could be generated for a multitude of reasons including applications recording exceptional workflows, technical components such as firewalls showing valid/invalid access attempts, resource issues such as running low on disk. Logs must be examined on a daily basis (standard working days – Mon to Friday, 08:00 to 18:00) and any issues should be raised for resolution by following support arrangements (see support requirement above). Note that during specific trials it may be necessary to increase monitoring to seven days a week and extended working hours (e.g. 05:00 to 21:00).

5.3.2.1 Trials Operation Applications (TOA)

The TOA sub-system provides an environment for the rapid development, integration and deployment and then execution of Operational Applications.

The TOA will leverage the infrastructure and platform services provided by the HEC. Table 32 lists the core platform services that the TOA will require to support rapid software application development. Several of the requirements listed are intrinsically provided by the Shared Services sub-system described in Section 5.3.2.2 below. The remainder will be installed, configured, operated and executed as development operations (DevOps) services and applications from within the Optimise Prime project team.

Table 32 – HEC Requirements for Rapid Application Development

Service	Requirement
Virtual Private Cloud (VPC)	• Isolated Cloud Resources – CPUs, Memory, Disks etc. • Public/Private subnets • Development/QA/Prod environments – separate VPCs • Routing
Networking	• Certificate Manager (Provision, manage, deploy SSL/TSL certificates) • VPN (e.g. OpenVPN) – Platform level • Internet access – download software/patches/docker images, resolve build dependencies, etc • API Gateway – (e.g.. 3scale) • Identity and Access Management (e.g. Keycloak)
Security	• Firewall (Whitelisting IP Ranges and Port combination) • DDoS protection • Track user activity • Track API usage
Identify and User Management	• Manage user access • Manage service access, including the generation of keys as required • Ability to apply policies at individual service level
Management and Monitoring	• Infrastructure as code (e.g. Terraform) • Dashboard to monitor resources and applications • Create/Manage Metrics, setup Alarms/Notifications • Centralised logging

Service	Requirement
Container Services	• Container Orchestration for docker containers (e.g. Kubernetes) • Automation deployment/scaling • Management of clusters • Application Load Balancing (e.g. NGINX)
Integration Services	• Notification service – Email, http/https • Messaging queue - pub/sub, point to point, request/reply (e.g. RabbitMQ) • High volume streaming, pub/sub messaging (e.g. Kafka) • Service Discovery
Developer Tools	• Code Build, Deploy, Pipeline (e.g. Jenkins) • Artifactory (like Nexus)
Database (application / microservice)	• SQL – (e.g. MySQL/Postgres) • NoSQL – (e.g. Mongo) • InMemory – (e.g. Redis) • Data Replication
Storage	• Files, database backups • File sharing

5.3.2.2 Shared Services (SSV)

The SSV sub-system provides a range of cloud computing services to all sub-systems in the Optimise Prime Solution that will be developed, operated, and managed within a consistent and efficient manner. Table 33 lists the set of standard services that will be provided by the SSV.

Table 33 – SSV Sub-System Primary Services

Service	Requirement
Logging & Audit	Provides an API so that subsystems can record information within a centrally managed framework. Providing a standardised logging and audit system provides a quicker and more structured environment whereby issues can be investigated.
Security and Authentication	Provides a single centralised mechanism for the management of security including the creation and management of users and the assignment of roles and privileges. It also serves as a mechanism for the creation and management of service accounts and other security tokens such as keys, which permit component parts of Optimise Prime Solution to communicate with one another.
Monitoring	Service collects information from individual components relating to their status such as requests, latency, CPU usage, data volumes. The information will be collated onto a series of dashboards to support the ongoing operation of the solution and to support in the identification of operational issues.
Messaging	A message bus will be responsible for the collation and delivery of messages between various components within the architecture. It will be based on a publish/subscribe model allowing multiple consumers to send and receive relevant messages
Data Ingestion	A single unified mechanism for the collection and transformation of data. The incoming data can arrive in a variety of data formats and speeds. Data is converted into a common form for further processing and storage within the analytics sub-system.
Data Catalogue and Lineage	A service to provide user and programmatic access to discover what data is available in the system and a record of its source and history.

5.3.2.3 Data, Analytics and Innovation (DAI)

The primary function of the Data, Analytics and Innovation (DAI) layer is to support the execution and measurement of trials, as well as the collection, processing and enrichment of data for the purposes of analytics.

The DAI is responsible for data intensive processing, utilising specialist tools and techniques such as Machine Learning. The Trials are expected to require a broad set of data (as specified in Section 4) supported by statistical modelling. The analytics sub-system is service-orientated and provides these specialised data and analytics services to the broader architecture.

Table 34 – HEC requirements for Data Analysis and Modelling

Service	Requirement
Separate Compute / Storage	• Processing of analytical workloads to be scaled independently of storage. • Data held on storage persists outside the lifecycle of compute resources.
Storage	• Data lifecycle management, ability to remove or archive data once it meets certain criteria such as age. • Ability to audit and secure access to data at the storage layer.
Database / Data Lake	• NoSQL database, suitable for ingesting low-latency streaming data.
Machine Learning	• Support for common machine learning frameworks such as TensorFlow, scikit-learn, Keras • Ability to train and tune machine learning models. • Ability to host machine learning models that can be used to make recommendations in batch or online (streaming).
Container Services	• Container Orchestration for docker containers (e.g. Kubernetes). • Ability to execute containers in batch and/or schedule their execution. • Resource definition and management e.g. describe CPU and memory demands of workload. • Horizontal scaling.
Analytical Query Engine	• Columnar, massively parallel processing (MPP) database optimised for data and analytics. • Data Lake, query execution technology allowing data to be consumed on demand from the Data Lake store(s). On demand meaning that the files do not have to be loaded into the Analytical Query Engine before they can be queried. • Object-level and row-level security. • Supports SQL dialect. • Cache/in-memory layer that provides fast responses to recently queried data or an ability to create cache based on anticipated demand.
Data Processing	• Batch and stream processing capability • Ability to transform and load data into platform storage/database resources • Consume data arriving in pub/sub queue e.g. Kafka. • Execute Machine Learning models whilst processing data.

Service	Requirement
	• Consume multiple file formats such as CSV, JSON and XML.
Analytical Tools	• Data science notebooks e.g. jupyter. • Reporting service providing the ability to create and publish dashboards and reports. Should support ad-hoc creation of components without having to write SQL by hand. • Ability to schedule analysis and have them delivered to different mediums such as email and shared file system. • Security at the report and dashboard level.
Orchestration	• Capability to orchestrate all components that constitute the analytics platform including, container services, data processing, machine learning. • Ability to execute containers in batch and/or schedule their execution. • Orchestration services can be invoked via external tools if required (commonly over API).

5.3.3 External data providers

Along with the internal sources of data created by the operational applications within the TOA, there are several external systems that will be providing inputs to the USP.

5.3.3.1 Partner Systems Data Providers (PS-DP)

Several project partners and other related stakeholders will be providing data into the Optimise Prime Solution.

Table 35 lists the types of data expected to be provided by the project partners. The detail provided is estimated based on current understanding. Each data source will be defined in detail with the providers following detailed trial experiment design and requirements definition exercises.

Table 35 – PS-DP data sources

Data Source	Description	Flow	Data Type	Size	Period	Method
UK Power Networks	Profiled Connection Request Profiled Connection Offer Flexibility Product details Flexibility Dispatch Flexibility Settlement Network capacity data	In In In In Out In	CSV CSV User JSON JSON CSV	Kb Kb Kb Kb Kb Mb	Months Months Months Minutes Hours One Off	SFTP SFTP App API API SFTP
SSEN	Network capacity data	Out	CSV	Mb	One Off	SFTP
Royal Mail	Depot Operations, schedules. Depot energy usage.	In In	User CSV	Kb Kb	Weekly Monthly	GUI API
Uber	Anonymised electric vehicle trip data within London area.	In	CSV	Mb	Monthly	SFTP
Centrica	Home charger operations, schedules.	In	CSV	Kb	Monthly	
REstore	Charge point setting commands Charge point status readings	Out In	JSON JSON	Kb Kb	Minutes Minutes	

Data Source	Description	Flow	Data Type	Size	Period	Method
Piclo/ANM platform	Not yet defined. If included this will replace UK Power Networks' provision of Flexibility Products details.	-	-	-	-	-
RM Charge Point Controllers	Charge point setting commands Charge point status readings	In In	JSON JSON	Kb Kb	Minute Minute	API Stream / API?

5.3.3.2 Third-Party Data Providers (3P-DP)

It is anticipated that the Optimise Prime Solution will require data to be ingested from one or more third party data sources (Table 36). To date the only anticipated data is meteorological / weather forecasts from a supplier such as Darksky or the UK Met Office and vehicle telematics for Royal Mail vehicles.

Ingestion of this data will be likely to follow a two-step process:

1. Sample/sub-set one-time supply of third party data used for initial analysis and evaluation. The quantity of data may be significant to determine long term or large-scale trends. It may also be structured or un-structured, file based, obtained via an API or even stream based.
2. Regular data supply into the DAI and TOA sub-systems for further analysis and operational use respectively.

Table 36 – 3P-DP data sources

Data Source	Description	Flow	Data Type	Size	Period	Method
Weather	Forecast and observed metrics such as wind speed, temperature, etc.	In	JSON	Kb	hourly	API
Telematics	Vehicle position, status and performance. Supply to be agreed, could be anything from weekly batch or real-time stream. Current supplier would be the EV manufacturer's telemetry direct via API	In	JSON	Mb	Second / Minute	Stream / Batch

5.4 Technical use cases

The following section describes a series of high-level technical use cases that need to be supported by the Optimise Prime Solution. Each use case will be validated and elaborated throughout the lifecycle of the project as part of the delivery of the solution.

5.4.1 Data ingestion

5.4.1.1 Batch ingestion

The Optimise Prime Solution needs to ingest data securely from several sources including Royal Mail, Centrica, Uber and UK Power Networks. Most of these sources are expected to provide data that will be loaded in batch (i.e. data would be provided and loaded pertaining to a specific schedule via file upload or JSON/XML via Webservice/API). This is a very common requirement for a data/analytics platform.

5.4.1.2 Streaming ingestion

Modern data platforms make a provision for the analysis of streaming data (i.e. data that is constantly received by platform and analysed in low latency). This type of requirement is common to IoT projects whereby various instruments would fire messages into the data platform for immediate consumption. The inclusion of streaming analytics adds inherent complexity. Some examples include:

- What is a suitable latency?
- What volume is expected?
- How much hardware is required to adequately process the data?
- What metrics should apply to streaming data e.g. moving average power consumption?
- Does the data need to be split into windows e.g. fixed 10-minute slots, sliding window of 10 minutes, before analysis is conducted?
- How will dashboards displaying results remain current? What technology will be used?
- What happens to late arriving data (typically caused by network latency, errors or instruments going offline)?
- Do statistical or machine learning processes need to be applied to data whilst it's streaming? Is there a need for "real time" decisions?
- How is data stored? Is the detail stored or is a summary enough?

At this point the project does not envisage that there will be any requirement to process streaming data. The most likely candidates if this does change will be Charge Point Controller and telematics data. The Optimise Prime Solution will however contain technology components that could be used to satisfy such a requirement should it arise in the future.
The technical solution for this use case sits within the detailed design of the DAI and PaaS sub-systems.

5.4.2 Data exploration

A key aspect of the solution is the ability to execute a series of trials and measure their outcome. These trials will be dynamic in nature and their definition could vary over time as the project evolves. As a result, specific details such as the type of trial, the duration, the exact data they will capture and measure, could change over time. The project envisages that core data to support the analysis of a trial would come from pre-determined enterprise data sources such as Royal Mail and Centrica. Data from these sources would be integrated into the platform using robust and standardised ETL patterns.

In addition to this core data the project also expects that there is a need to load ad-hoc data to supplement a specific trial and to enhance analytics. This could, for example, involve external data or user defined data such as weather, geographic groupings. Since this data is considered experimental and may have a very short lifespan it would not be appropriate to load it via the same ETL patterns as the core data – which would introduce unnecessary overhead and lag. Therefore, an alternative ingest mechanism must be provided to allow an analyst to gain rapid access to any required data for the duration of their experiment. Should it be discovered that the data does have a long term benefit it must be added to the list of core data sources and undergo the same strict ETL process as other such data sources. The management of this process will fall under the remit of the Data Governance team.

5.4.3 Statistical analysis & machine learning

There are multiple opportunities for the usage of statistical analysis and machine learning within this project. Some examples include, supporting trials, planning/forecasting, vehicle/EV optimisation (utilising data such as weather, traffic, age of vehicle) and dispatch management. To support this functionality several workflows must be catered for by the solution, including:

- **Model creation**. An analyst must have the right combination of tools and data to support this task. A typical process for the creation of a model would involve a detailed understanding of the business problem supplemented by an amount of data exploration (see above) with statistical-based experiments & observations.
- **Training & tuning**. Some models, once created, would have to be trained and tuned before they can be used to return meaningful results. The process of training and tuning can be resource intensive, dependent on the model developed and data volumes. To reduce training/tuning time typically graphics processing units are used in conjunction with frameworks optimised for this purpose. A good model would require frequent training, and infrequent tuning, to ensure it continues to produce optimal results.
- **Deployment**. Once models have been created they have to be deployed and/or hosted. Models can be used either in batch mode or interactive mode. A batch model would run at a pre-determined time, produce a result and then stop executing. An interactive model would have to keep running all the time so that it is available to make online predictions when required.
- **Measurement**. There is often a requirement to visualise the output of a statistical analysis/machine learning model once they are used to make predictions/forecasts, etc. The visualisations in this instance are aimed at business users rather than analysts. The visualisations are typically produced in a dashboard tool and may be enriched with other enterprise data to provide further context and support analysis.

The technical solution for this use case sits within the detailed design of the DAI and SSV sub-systems.

5.4.4 Analytics as a service

The Optimise Prime Solution will have a core analytics capability. Rather than viewing this as a standalone component it should instead be conceived as a platform that provides data and analytics services to the wider solution. Conceptually this means that any analytical / decision-based requirement could be satisfied by the analytics platform which would be integrated with consuming services within the wider architecture. Ultimately a decision needs to be made during detail level design as to how best each requirement would be satisfied which would involve either embedded logic within applications or the creation of a specific analytics service. Factors which might influence the decision might include, data volumes, latency, technology fit, timescales, and reuse.

5.5 Business use cases

The Optimise Prime Solution will support many Business Use Cases. A summary of the primary use cases is presented below.

5.5.1 Trial management and execution

The Optimise Prime project will design, plan, execute and analyse a series of trials and experiments (see Section 2) throughout its life-span. Trials activity will be executed at the "Experiment" level. Each experiment will be planned and managed within specific start and end dates. The Optimise Prime Solution will facilitate the management of the trials by providing software functions where needed to start and stop the execution of trials along with labelling data and analysis outputs with appropriate experiment metadata.

The prerequisite to execution will require each experiment to have the following aspects clearly defined:

- Start and end dates.
- Responsible person(s) for the experiment execution.
- Specific end-users and analysts involved in the experiment.
- User and data inputs.
- Expected behaviour, scenarios
- Required sub-systems, integrations, partner systems, software applications.
- Execution and success-criteria.
- Post experiment state – how the system should be left after the experiment.

The execution of experiments will vary from a period of data analysis on existing data to targeted data capture based on normal activity, coordinated activity or activity because of the implementation of a project deliverable (e.g. a new depot optimisation model version).

Throughout the execution the appropriate components of the Optimise Prime Solution will be monitored to ensure that everything is behaving as expected.

5.5.2 Depot planning

The depot planning use case is aimed at creating optimised profiled connection requests to UK Power Networks. In standard business operations this would most likely be an annual process performed individually by depot. However, within the context to the project trials this use case will be performed far more frequently. The planning algorithms and model will be iterated through a series of experiments geared towards finding the optimal solution for both Royal Mail and UK Power Networks.

A planning experiment will take a set of inputs specific to a depot's operations (such as delivery schedules and general depot energy usage) and apply a set of algorithms and/or model to output a profiled connection request. The profiled connection request will be shared with UK Power Networks and in turn they will respond with a profiled connection offer based on their network constraints. This new plan will then be applied to the depot for implementation within their day-to-day EV operations. After an agreed period, the results of the operations will be compared against the profiled connection agreement and measure of performance calculated.

5.5.3 Depot optimisation

The depot optimisation use case is aimed at making the day-to-day EV operations for any given depot as cost effective as possible within the constraints of business as usual operations and profiled connection constraints.

In contrast to depot planning, this is a more “real-time” or “day-to-day” use case where various inputs will be utilised to vary the EV charging schedules and behaviour based on algorithms and models developed within the project.

Trial experiments will be executed for defined periods of time where specific data inputs are used with new algorithms and models to control EV charging for a given depot(s). The impacts of these changes will be evaluated as the final output of the experiment.

5.5.4 Flexibility optimisation

The Flexibility Products use case is based on the work currently being developed by UK Power Networks and their Active Network Management (ANM) project. The model being developed is based on those already in use or under development across other DNOs within the UK.

Flexibility products are auctioned by the DNOs for specific geographical locations based on an energy demand for a specific period on specific days between specific hours (e.g. September 2019 to March 2020 on Monday to Friday between the hours of 11:00 and 14:00). The Flexibility Products are generally auctioned 6-18 months in advance. Auctions are currently advertised using the Piclo Flex solution.

The Optimise Prime Solution will implement this use case by trying to manage the EV-CPCs so that they can deliver against any Flexibility Products that the project commits to. Prior to a Flexibility Product delivery period the Solution will request the EV-CPCs to maintain the required demand capacity in case it is needed. If a dispatch request is received from UK Power Networks then the instruction will be passed onto the appropriate EV-CPC and its delivery monitored for post evaluation and settlement.

Experiments are likely to be executed against individual partners, cross-partners and geographic locations/depots.

5.5.5 Uber EV charging optimisation

The use case for Uber is focused on data analysis and modelling. Monthly data extracts from Uber’s driver tracking system will be received, extracted, processed and stored by the Optimise Prime Solution. Experiments will then be performed on the data within the DAI sub-system to determine trends and forecasts for EV usage and optimal charging locations.

5.6 Trials operational applications

The following section provides a summary of the Trials Operational Applications (TOA) sub-system. The TOA sub-system will be described in detail in the project’s Applications Solution High-Level Design document.

The TOA sub-system will provide several bespoke software applications in order to deliver the business use cases defined in Section 5.5. They will be used to control and execute the operational EV management processes necessary to capture the data required by the programme trials and experiments.

The operational functions that these applications will provide are:

1. **Depot planning** – Long term demand profile planning for connection agreements resulting in a contracted demand profile constraint.
2. **Depot optimisation** – Real-time optimisation of energy usage within the contracted demand profile constraints using external parameters such as weather, operational variance and telematics.
3. **Flexibility services** – Long term flexibility delivery to UK Power Networks – triggered by UK Power Networks flexibility dispatch process (ANM project integration).
4. **Trials management** – Provide control and creation of metadata for the execution of trials experiments that leverage the applications that have been developed.

All applications within the TOA are required to output their transactional data into the data, analytics and innovation sub-system. Each application will also support the concept of executing the project trials and therefore be able to tag all data with the trial to which it is associated. This functionality will be facilitated by a Trials Management application.

The TOA application development and implementation plan will be designed around the project trials to develop and deploy the initial set of applications as 'Minimum Viable Products' (MVP). The MVPs will provide the minimum level of functionality required that will enable the trials to begin and start capturing data. Once released and operational the initial release applications will then enter a process of continuous development and integration so that they can deliver the software requirements as the complexity and direction of the trials evolve throughout the project.

6 Preparation for trial execution: planning and progress

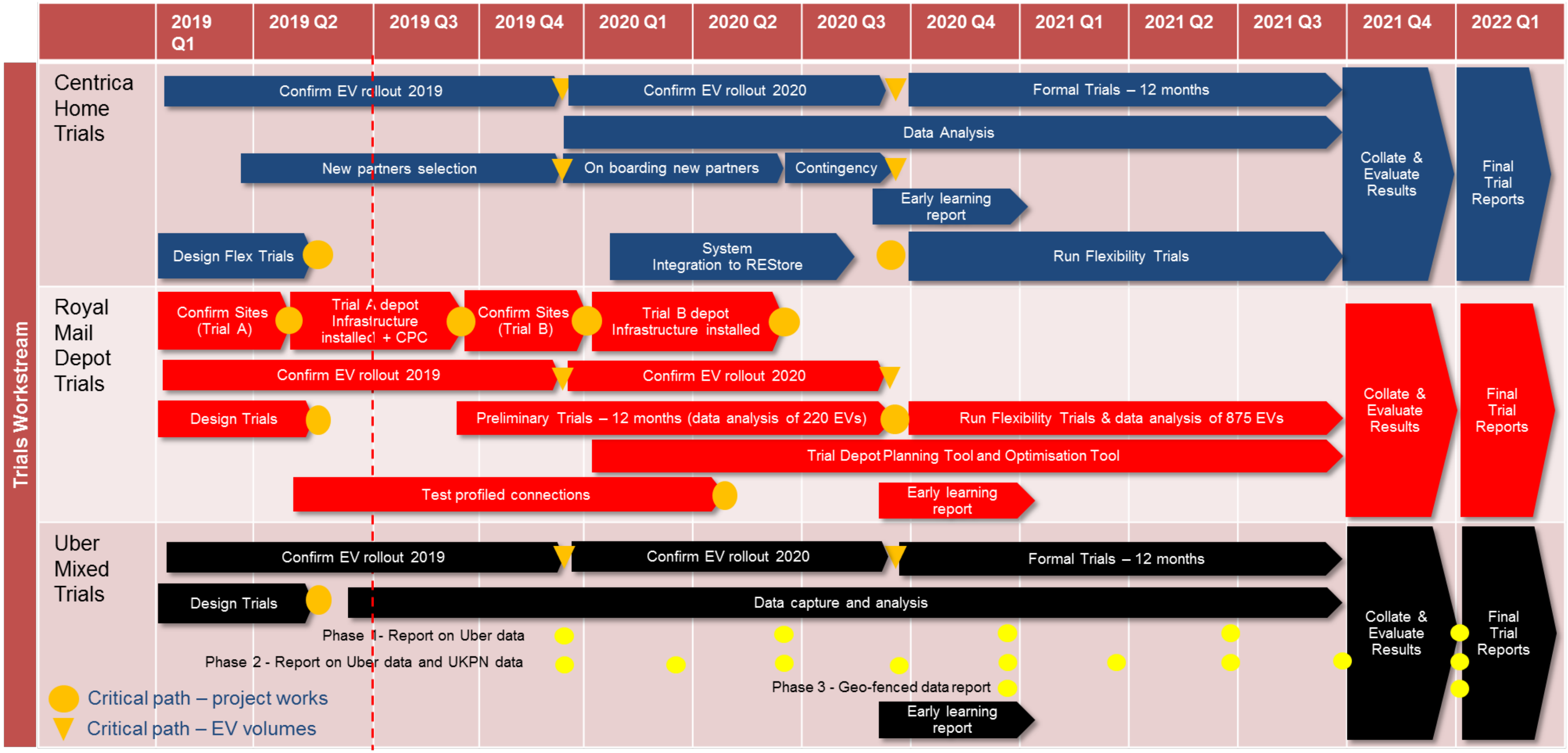
6.1 Trial timelines and phasing

The Gantt chart in Figure 10 shows the planned timeline for trial execution.

It is currently planned that the main trial period (when all EVs will be on the road) will run from October 2020 for 12 months. In advance of this, the project partners will scale up their EV fleets, and data from these vehicles will be collected for a number of preliminary trial activities. In support of the introduction of vehicles, electric vehicle charging infrastructure will be installed at depot and home locations.

The Gantt chart below sets out the trials plan:

Figure 10 – Optimise Prime trial plan



6.2 Trial locations

Technology and vehicles will be tested in a range of locations across the three trials, with varying approaches taken to site selection, depending on the specific requirements of each use case. The project is still in the early phases of trials design, therefore the precise trial locations remain fluid, particularly for the Home trials given Centrica's ongoing activities in procuring fit-for-purpose EVs (see section 6.3.2). Additional information on the trial locations will be provided as the project progresses and more data becomes available. Significant work has been done where data is currently available with Royal Mail having selected the sites for the first phase of the depot trial as described later in this section. The trial locations are limited to the four DNO regions involved in the project (UK Power Networks' London, Eastern and South Eastern regions and SSEN's Southern region).

6.2.1 Home trials

The location of the Home trials is defined by where the drivers of the 'return-to-home' fleet vehicles live. Therefore, Optimise Prime has limited control over the locations where home trials will take place. Charging infrastructure will be installed at the homes of drivers of 'return-to-home' fleet vehicles throughout the four DNO regions covered by the project. The trial will capture data regarding the location of charge events in order to allow participation in demand response services and identify any issues from clustering.

6.2.2 Depot trials

A number of sites have been selected for the first phase of EV rollout by Royal Mail, working together with UK Power Networks. These locations have been chosen in order to balance potential risk and cost to Royal Mail with the learning opportunities and benefits that a particular site may give the project. Seven sites are planned to take part in Trial A. This is subject to additional charging infrastructure being successfully installed at five of the depots, at the remaining two sites the project will make use of existing charging infrastructure. A second phase of depot electrification will result in a total of up to 20 depots being part of Trial B. The second phase of depots will be chosen based on the learnings from implementing Trial A and will be designed using the Depot Planning Tool developed by the project, subject to Royal Mail approval.

6.2.2.1 Site selection considerations and methodology

In selecting the sites, Royal Mail have taken a number of factors into account:

- The delivery routes served by the depot and the practicality of converting them to EV, given the performance and capacity of currently available vehicles.
- Depot ownership – Royal Mail has chosen to implement trials at both freehold and leasehold sites to expose any issues that may arise from electrifying leasehold sites.
- Depot layout – to select sites where there is sufficient space and where infrastructure can be installed quickly and at a reasonable cost.
- Whether there is existing EV charging equipment at the site.
- Existing connection capacity – the project aims to trial at a variety of sites, including where the depot has existing capacity and where the depot modelling tool can be demonstrated to overcome capacity constraints which will lead to avoidance of traditional network reinforcements.
- Locations that need to make fleet changes to comply with ultra-low emissions zones, or where congestion charging can be avoided.
- Trialling sites with near 100% EV adoption.

Following the initial shortlisting, eight sites were selected by Royal Mail and were subject to more detailed study. This included:

- Full power analysis of each site
- Site visits by the Optimise Prime team
- Drawing up plans for required infrastructure
- Calculating indicative costs for depot electrification
- Issuing tender for the selection of a charge point provider for the Trial A sites (which has now been completed).

6.2.2.2 Selected depot sites – Trial A

The following sites have been confirmed by Royal Mail to take part in the first phase of the trials:

Table 37 – Trial A depot locations

Depot	Network	Number of vehicles at site	Expected number of EVs	Number of chargers to be installed
Islington	LPN	34	24	18
Whitechapel	LPN	37	32	27
Dartford	LPN	119	16	16
West London Premier Park	LPN	105	42	42
Mount Pleasant	LPN	192	87	87
Bexleyheath	LPN	28	12	0
Orpington	SPN	53	6	0

Note that the exact number of EVs and chargers at each site may be subject to change in order to meet Royal Mail's operational requirements or due to unanticipated site constraints.

6.2.3 Mixed trials

The mixed trials do not involve the deployment of physical infrastructure at specific sites. Uber will provide the project with data from their private hire EVs operating within the Greater London area.

6.3 Vehicle recruitment

The availability of vehicles by the project partners is key to Optimise Prime's ability to deliver statistically significant trials. In the FSP, it was specified that 2-3,000 vehicles would be involved, split across the three trials. This remains the project's target.

It is intended that all of the vehicles will be involved in the trial for a minimum period of 12 months (October 2020 – September 2021). However, the project will capture data for a longer period where possible. The trial phasing has been designed to test the experiment design and data analysis systems and approach with an initial, smaller set of vehicles before scaling up to the full trial volumes.

The project partners have put in significant effort to prepare for the trials, for example in preparing their data systems and sites, and working to acquire the necessary vehicle volumes.

6.3.1 Vehicle availability

The availability of sufficient EVs is a key factor in delivering statistically significant trials. As this project is aiming to measure the effects of EV adoption before the majority of vehicle operators have switched to EV Optimise Prime is working with a number of fleets with particularly advanced plans for EV adoption.

Vehicle availability has been identified as a significant, and the main, risk to the project and a number of factors have been identified that may impact the timely availability of suitable vehicles to the project partners:

- Clean Air for Europe (CAFE) regulations have being cited by Centrica and Royal Mail as a reason for the delivery delays in EVs to the UK market during 2019.
- Lack of manufacturing capacity for EVs, restricting supply, resulting in waiting lists – manufacturers failing to expand production to meet growing demand.
- Manufacturers focusing limited production capacity on passenger cars, rather than vans, due to higher profit margins.
- Limited supply resulting in higher vehicle prices than originally forecast.
- Long development cycles for new models resulting in delays in market launch of new vans.
- Increasingly strict clean air legislation incentivising some manufacturers to delay introduction of Ultra Low Emission Vehicles to 2020.

In order to mitigate against the risks associated with vehicle availability the project is taking a number of actions:

- Reporting progress towards vehicle number targets for each partner on a weekly basis.
- Delaying the start of the 12 month trial period, where all vehicles are expected to be on the road, by three months using contingency time within the project plan. The project team are continuing to evaluate whether additional time may be required.
- Setting up a working group to approach potential additional participants to join the trials.
- Conducting research in order to fully understand the issues affecting vehicle availability
- Managing the work effort in each of the work streams according to vehicle volume milestone dates.

6.3.2 Trial vehicles

The issues of availability have had a varying effect in the ability of the project partners to order vehicles and commit them to the trials. This is as a result of the different trial use cases requiring different types of vehicle.

The home trial has been the most challenging trial to plan for vehicle roll-out. Centrica has requirements for a light commercial vehicle with sufficient range to visit callout customers and sufficient payload to carry an engineer's equipment. The Centrica EVs require custom modifications for their equipment.

While in the planning stages of the trial it was anticipated that suitable vehicles would come to market in 2019, it now appears that delivery slots will not be available until 2020. Centrica has attempted to speed up this process by engaging with multiple manufacturers.

Royal Mail's depot based vehicles generally travel much shorter distances each day, and have different requirements for carrying capacity. As a result, Royal Mail has been able to place orders for 190 light commercial vehicles to be delivered in 2019, complementing 30 EVs that are already on the road. To do this, Royal Mail has had to introduce a new vehicle manufacturer and model to its fleet. As of 12 August 2019, 28 of these vehicle have been delivered to Royal Mail depots. It is anticipated that further orders will be placed in 2020 once lessons have been learnt from the Phase A trials.

Figure 11 – Royal Mail EV that will be introduced as part of Optimise Prime

The mixed trial partner, Uber, provides data of journeys from EVs purchased by its driver partners. As these vehicles are predominantly cars, there is a wider range of models in the market and at present over 300 EVs are operating on Uber's platform within London.

Despite this, there are still supply issues within the market for electric cars, with waiting lists for many models. Uber is working with manufacturers to ensure that sufficient supply is available to its driver partners in order to meet its EV transition objectives.

7 Lessons learnt from planning of the trials

The Optimise Prime project is at an early stage in its development, and it is expected that the majority of the project learnings will materialise once the project begins to implement infrastructure, capture data and perform analysis. However, the trials design process encountered several challenges as the methodology to meet the trials objective was defined and specific requirements for each partner were clarified. A certain amount of adaptation to the practical realities and individual operational requirements of the trials partners is to be expected in creating a trials methodology, but there are some specific challenges that this project has addressed that future projects are also likely to face.

7.1 Trials design

By its nature, this project involves introduction of unfamiliar technologies and processes into a busy environment where uninterrupted operations are crucial. It was therefore essential that the trials were designed to minimise risk of disruption to business as usual activities, which could foreseeably conflict with some of the project's innovation ambitions. To address this, a 'simulation before application' methodology was designed to enable any potential unacceptable risks to be identified and mitigated through simulation at each level of technological complexity, before any changes to physical systems are implemented. In addition, the project is planning to install all physical equipment at a test facility prior to installation at trials partner locations.

7.2 Total cost of ownership

One of the learning ambitions for Optimise Prime is to clarify the impact of adoption of EVs on fleet total cost of ownership (TCO). For this learning to be useful to other fleets with different TCO models, the impacts should be visible at an individual line item level (e.g. impact on fuel costs). Much of this baseline data is commercially sensitive, however, and is unable to be shared across the trials partners. The project will therefore develop a generic TCO model and use this to calculate the impact on each line item. The impact will be verified by the trial partners, who will share the overall percentage change to their TCO resulting from fleet electrification.

7.3 Connections

For the depot charging trial, there is no established process for defining and establishing a profiled connection agreement at present, as it is a new product that this project seeks to design and trial. The trial has been structured to generate a range of profiles for the DNO to consider (cost optimal, network optimal, operations optimal), within a proposed connection offer, agreement and order cycle with the DNO. The formalisation of this into an ongoing process for future profiled connection agreements has been included within the project objectives.

It is possible that some or all of the depots selected for inclusion in the trial may not suffer from network constraints at the level of EVs planned to be introduced during the trial. The connection agreement in place may provide enough capacity to cover the additional EV charging load. In these cases, assessment of the benefit of profiled connection agreements will be simulated by considering the potential cost and capacity benefits to the wider distribution network, rather than the depot itself. The simulated profiled connections will be live for the trial period only.

7.4 Telematics

For the mixed trial, baseline telematics data from Internal Combustion Engine (ICE) Vehicles is not available due to privacy restrictions. This is due to the nature of Uber's business model – responsibility for the vehicles providing transport services via their platform rests with the driver partners. This situation is likely to arise with other companies working with owner-driver fleets. This creates a challenge for the project as EV data cannot be directly compared with ICE vehicle data to identify differences. Instead, the project will define baseline vehicle operation as that observed for the part of Uber's existing EV drivers who charge their vehicles at or close to their home, outside of their working times. These vehicles will be identified through continuous analysis of Uber trip data alongside the location and operational status of public charge points, thereby showing which vehicles do not use public charging infrastructure during their working hours. For this solution to address the issue, the assumption must hold that EVs that do not require charging during their working hours behave in an equivalent manner to existing ICE vehicles. This assumption will be validated by continuous analysis of behaviour of off-shift charging EV drivers and discussions with Uber.

7.5 Network Data

There is a wide variation in the availability and accuracy of utilisation data for different assets on the distribution network, particularly at low voltage where monitoring is limited and is currently being deployed at strategic locations. As such, the necessary data may not be available in all locations to enable detailed analysis of the impact of EVs on network asset performance – for example the maximum demand at a transformer resulting from addition of EV charging load at a specific home or public charge point. To address this, the trials plan to identify the crucial infrastructure requiring monitoring early in the implementation process, so that it can be set up as a priority in UK Power Networks' LV (Low Voltage) monitoring roll-out process. Royal Mail sites will all be monitored, and clusters identified in the Centrica and Uber trials will also be fitted with monitoring. Assets with the necessary monitoring data available will be used to incrementally improve modelling capabilities as the trials progress, with these modelled impacts being applied to other locations. This will be conducted across multiple voltage levels, to explore the interaction of flexibility across at different levels in the network.

7.6 Statistically significant results

For the findings of the trials to be applicable beyond the scope of the project, the experiments must be designed to provide statistically significant results. Due to the nature of these field trials, the experiments will be conducted subject to a wide range of uncontrolled variables (e.g. weather, traffic incidents, driver behaviour, events). To address this, trials will be structured to produce statistically significant using representative sample groups. Multi-level models will be developed that account for variation both within the sample group and between sample groups. The quality of crucial learnings will be controlled through experiment success criteria, demanding stringent statistical significance before experiment completion in order to be considered viable.

8 Incorporating learnings for other innovation projects

In order to maximise the value of the Optimise Prime programme, trials will be executed to ensure that their learnings supplement or further those achieved in other projects. As such, several relevant studies have been identified for in depth analysis to ensure Optimise Prime builds on existing learning avoiding duplication. The Optimise Prime team have participated in meetings with representatives of a number of these projects, and where this has not been possible project deliverables have been studied.

Examples of relevant projects and their synergies are:

- Domestic EV trials, such as NIA funded 'Electric Nation', 'Shift' projects as well as LCN funded 'My Electric Avenue', will be particularly relevant to Centrica trials. Such studies will be used as a reference to compare the effects of domestic and commercial EV charging on the network as to give DNOs a comprehensive view on charge-at-home vehicles.
- The NIA 'Smart Charging Architecture Roadmap' (SmartCAR) and 'Shift' projects aim to support UK Power Networks enable a market for smart charging. 'SmartCAR' has shaped UK Power Networks' market-led position on smart charging informed by a wide consultation with industry and policy stakeholders. While 'Shift' is designing the customer value proposition of smart charging. Building on the learning from 'SmartCAR', 'Shift' is trialling different approaches to smart charging, assessing the technical and commercial requirements to enable the benefits of smart charging for UK consumers. This will be particularly relevant for the flexibility services provided by home-charging commercial vehicles investigated in the Centrica trial.
- UK Power Networks' study of the effects of the electrification of clusters of PHVs and taxis on local networks in 'Black Cab Green'. This provides a benchmark on which to further explore these effects and develop solutions in the Uber trial as well as useful learning on qualitative insights from taxi and PHV drivers. This will be relevant insight for both the Uber and Centrica trials.
- 'Recharge the Future' has enhanced the forecasting model used by UK Power Networks to predict EV load growth, increasing the accuracy and location of peak load increase caused by EVs. The project has also carried out a Charger Use Study investigating EV charging behaviour through literature review, expert consultation and additional data analysis. Despite commercial fleets not being in scope for Recharge the Future, the methodology used for the EV peak load growth forecast will inform the modelling activities carried out across the three Optimise Prime trials.
- The NIA project 'TransPower' evaluates the technical, commercial and customer proposition of V2G technology to the distribution network. In conjunction with 'Shift', the project investigates network impact and flexibility services for several different vehicle customer segments from domestic, to commercial and public charging through demonstrator trials and collaborative research and development. Specifically, the InnovateUK projects 'Bus2Grid' and 'e4future' supported by 'TransPower' will provide crucial insights and points of comparison for the flexibility available from commercial fleets.
- NIC funded 'Charge', in which various connection strategies will be considered for on-street charging, will be relevant to both Uber and Royal Mail trials.

9 Conclusions & next steps

9.1 Conclusions

This report forms the key evidence for the first Optimise Prime deliverable. The project has successfully delivered on the requirements of deliverable D1 and this report provides a comprehensive overview of the high level design of the three project trials and the specification of the systems that will enable the trials.

This report should prove valuable to any DNO considering how to plan for the future growth of commercial EVs. The trial methodology may also prove useful to DNOs planning to implement similar innovation projects in the future. Elements of this report will also prove useful to vehicle fleet operators planning their transition to EVs.

The main report introduces the three trial use cases and scenarios, providing details of the high-level requirements, broken down into a series of objectives and sub-objectives of each trial. The appendix provides a catalogue of the activities that may be pursued by the project in order to reach the objectives. Although some aspects of the trial design are specific to Optimise Prime and its partners, the principles and objectives are applicable to all DNOs and to vehicle fleets planning a transition to ultra-low carbon vehicles.

Based on the trial design the report provides an overview of the data that the applications and IT platform will be required to process. The report goes on to present a high-level solution architecture for the technology that will enable the project to meet its objectives. This architecture consists of a core Universal Service Platform that will be used to manage data and carry out analysis, and a suite of applications which will be adaptable after the project to support the electrification of commercial vehicles.

It is important to note that populating the trials with sufficient commercial EVs is a key requirement of the project. This report sets out how, despite limited supply in the developing market for commercial EVs, the project partners have made good progress in ordering vehicles and planning infrastructure at the trial locations. Over the next few months this will allow the project to start capturing and analysing the first data from the EVs, ahead of the plan set out in the FSP.

As mentioned in section 8, the design builds on learnings from several other Ofgem funded innovation projects and this deliverable report ensures future Innovation projects can build on the learning from Optimise Prime.

For further questions on the evidence provided in this report, or more general questions about the project, please contact Optimise Prime team at: communications@optimise-prime.com or visit the project website www.optimise-prime.com.

9.2 Next steps: Open items & future activities

Following the definition of the high-level design and specification of the three trials, work is now ongoing to further detail the trial design and plan for building of the analytics solution and trials operational applications. Next steps for the project include:

- Identifying the locations and precise methodology for Method 1 (Home trials). This activity is expected to continue up until October 2020, as drivers are selected by the project partners to operate electric vehicles.

- Selection of sites for the second phase of Depot trials. This activity is expected to take place in early 2020, building on the lessons learned in Trial A.
- Detailed mapping of objectives, sub-objectives and experiments into FSP learning to confirm which activities are must have or nice-to-have should be prioritised. This mapping has already been completed at a sub-objective level and will be updated as experiments are designed;
- Aggregation of activities into experiments, with associated hypotheses and success criteria, to inform software development requirements development;
- MoSCoW rating each experiment;
- Ownership assignment of each experiment;
- Resource allocation for each experiment;
- Identification of dependencies between experiments;
- Anchoring of experiments in a timeline and updating project plan with detailed and finalised experiments and activities;
- Definition of all success criteria;
- Identification of the critical path;
- Development of quality assurance plan for software development and acceptance;
- Development of data analysis approach, including methodology to compare findings across trials.
- Establishing a trial site for the testing of the depot trial solution in advance of it being rolled out to live depots.

In addition to this, the design of the project's technical solutions is in progress, building on the data requirements to specify the project tools and analysis requirements.

10 Appendices

10.1 Home trial activity tables

10.1.1 Objective 1

Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment.

Table 38 – Home trial objective 1 activities

Activity ID	Sub-objective	Activity	Outputs
CEN1	Understand the operational requirements of return-to-home commercial vehicles	Predict kWh daily energy requirements based on vehicle mileage/fuel spending on ICE vehicles prior to EV uptake (current operation baseline)	Groupings of vehicles and charge locations according to shared characteristics Statistical profiles for charge events (plug-in/plug-out times and kWh energy requirements) are available based on both predictions made from ICE vehicle analysis and learnings from 'un-managed' EV charging Charge event statistical profiles are subject to change given factors such as weather, day type and events calendar EV charging curves showing rate of charge within charge events are available
CEN2		Geofence home locations based on ICE vehicle telematics	
CEN3		Estimate plug-in/plug-out times from telemetry data prior to EV transition (current operation)	
CEN4		Develop indicative energy requirements for each region of vehicle operation based on mileage, time of year, day type (WE/WD), weather, events, payload based on predictions made prior to electrification (current operation)	
CEN5		Identify patterns in trips taken (region of operation, time of day, day of the week, season)	
CEN6		Create ‘Trip Profiles’ by comparing trips (response, scheduled, rural, urban, suburban, region of operation)	
CEN7		Create 'Vehicle Profiles' including make, model	
CEN8		Create 'Vehicle Categories' by combining 'Trip Profiles' and 'Vehicle Profiles'	
CEN9		Create 'Network Clusters' by identifying charge at home locations sharing distribution network assets (LV, HV, EHV)	
CEN10		Track plug-in/plug-out times once charge-points have been installed	
CEN11		Compare to predictions of plug-in/plug-out times made before electrification	

Activity ID	Sub-objective	Activity	Outputs
CEN12		Monitor state of charge (SoC) at plug-in time once charge-points have been installed and are operating in 'un-managed' mode (‘un-managed’ charging expressed as maximum power delivery at plug in until plug out or maximum charge)	
CEN13		Monitor SoC at plug-out time once charge-points have been installed and are operating in 'un-managed' mode	
CEN14		Compare energy requirements observed in 'un-managed' charging experiments to those predicted prior to charge-point installation (compared to manufacturers’ estimations and ICE vehicles)	
CEN15	Model and validate EV charging profiles	Develop indicative energy requirements for 'Vehicle Categories’ based on mileage, time of year, day type (WE/WD), weather, events, payload based on learnings from 'un-managed' charging EVs	EV plug-in time, plug-out time and kW draw is available for each installed charge-point at each depot A model for charge-events is available, predicting aggregated EV charging loads for a given number of EVs for a given depot Model is variable to factors such as weather, day-type and events calendar Model can be used to simulate ‘aggregator managed charging' by optimisation of charge events Model is analysed and updated with learning from ‘aggregator managed charging' trials
CEN16		Create charging curves for EVs versus time (charging power, cell voltage, charging current, state of charge) based on learnings from 'un-managed' charging EVs	
CEN17		Determine how these profiles may change subject to temperature variations, interference from other electrical equipment, etc. based on learnings from 'un-managed' charging EVs	
CEN18		Develop and test predictive capabilities for energy requirements, plug-in/plug-out time, SoC at plug-in/plug-out times given the implementation of 'smart' charge-points	
CEN19		Predict aggregated EV charging load grouped by 'Network Cluster'	

Activity ID	Sub-objective	Activity	Outputs
CEN20	Model and validate contribution of EV charging to home energy consumption	Estimate contribution of EV load to home energy consumption for each charge-at-home location prior to charge-point installation	Baselines for home electricity consumption minus EV charging requirements are created Understanding of sensitivity of total home electricity demand to EV load is developed Model has functionality to produce load profiles given a mix of different charging types (un-managed/aggregator managed) Model is variable to factors such as weather, day-type and events calendar Load is aggregated across 'Network Clusters' - groups of properties that share common network assets (LV/MV/HV)
CEN21		Collect home electricity metering data (half-hourly) prior to charge-point installation	
CEN22		Baseline indicative aggregated load profiles for 'Network Clusters' as a function of day type (WE/WD), season, weather, events prior to charge-point installation	
CEN23		Build indicative aggregated load profiles for 'Network Clusters' as a function of day type (WE/WD), season, weather, events assuming implementation of un-managed-charging EVs	
CEN24		Select locations EVs for 'un-managed charging' such that 'Network Clusters' do not pose a risk to the distribution network	
CEN25		Calculate contribution of EV load to home energy consumption for each charge-at-home location based on data collected in trials	
CEN26		Collect home electricity metering data (half-hourly) given 'un-managed' charge-point operation	
CEN27		Collect EV charge-point meter data home connection point loads (half-hourly) given 'un-managed' charge-point operation	
CEN28		Aggregate EV charging load for charge-at-home vehicles across 'Network Clusters'	
CEN29		Compare the expected 'Network Cluster' loads from predictions made prior to charge-point installation with those realised, analyse discrepancies and update models	
CEN30		Compare the expected contribution of EV load to whole home energy consumption from predictions made prior to charge-point installation with those realised, analyse discrepancies and update models	

Activity ID	Sub-objective	Activity	Outputs
CEN31	Model and validate contribution of EV charging to home energy consumption	Build optimal EV charging load profile for each home for day type (WE/WD) and season including 'aggregator managed' charging' EV loads based on minimising electricity cost (using domestic tariff)	Baselines for home electricity consumption minus EV charging requirements are created Understanding of sensitivity of total home electricity demand to EV load is developed Model has functionality to produce load profiles given a mix of different charging types (un-managed/aggregator managed) Model is variable to factors such as weather, day-type and events calendar Load is aggregated across 'Network Clusters' - groups of properties that share common network assets (LV/MV/HV)
CEN32		Build optimal EV charging load profile for each home for day type (WE/WD) and season including 'aggregator managed charging' EV loads based on minimising electricity cost (using commercial tariff)	
CEN33		Build optimal EV charging load profile for each home for day type (WE/WD) and season including 'aggregator managed charging' EV loads based on minimising electricity cost (using time-of-use tariff)	
CEN34		Build optimal aggregated EV charging load profile for each 'Network Cluster' for day type (WE/WD) and season including 'aggregator managed charging' EV loads based on minimising risk of network constraints	
CEN35		Collect EV charge-point meter data home connection point loads (half-hourly) given aggregator managed charge-point operation	
CEN36		Compare the actual EV charging load profile for each home to that predicted from 'un-managed charging experiments', analyse discrepancies and update model to include 'aggregator managed charging' predictive capabilities	
CEN37		Compare actual aggregated EV charging load profile for each 'Network Cluster' to that predicted from 'un-managed charging' experiments, analyse discrepancies and update model to include 'aggregator managed charging' predictive capabilities	
CEN38		Develop and test 'Network Cluster' load predictive capabilities (dependent on EV energy requirements, weather, type of day, season, etc.) given 'aggregator managed' charging EVs	

Activity ID	Sub-objective	Activity	Outputs
CEN39	Model and validate the effect of charge-at-home EV loads on distribution network infrastructure	Collect load capacity for each 'Network Cluster' (kVA) prior to charge-point installation	The contribution of each 'Network Cluster' to capacity reduction on relevant network assets is modelled and measured given different charging methods A relationship between EV loads and network health is established The differences between network impacts resulting from 'un-managed charging' and ‘aggregator managed charging' are analysed
CEN40		Collect historical electricity loading data (load factor, max peak) (kVA/kW) for 'Network Clusters' for the two years prior to charge-point installation	
CEN41		Identify DNO concerns surrounding EV charging (voltage stability, power quality) prior to charge-point installation	
CEN42		Identify variables available for monitoring at relevant 'Network Cluster' assets (transformer hot-point temperature, voltage, current, (re)active power flows, etc) prior to charge-point installation	
CEN43		Record relevant variables at 'Network Cluster' assets throughout 'un-managed charging' trials	
CEN44		Analyse monitored variables for incidences of network stress for 'un-managed charging' trial duration	
CEN45		Overlay relevant EV 'un-managed charging' load profiles with monitored 'Network Cluster' asset variables to assess correlation	
CEN46		Determine contribution of Centrica 'un-managed charging' EVs to network stress	
CEN47		Record relevant variables at 'Network Cluster' assets throughout ‘aggregator managed charging' trials	
CEN48		Analyse monitored variables for incidences of network stress for 'aggregator managed charging' trial duration	
CEN49		Overlay relevant EV ‘aggregator managed charging' load profiles with monitored 'Network Cluster' asset variables to assess correlation	
CEN50		Determine contribution of Centrica ‘aggregator managed charging' EVs to network constraints	

Activity ID	Sub-objective	Activity	Outputs
CEN51	Consider future scenarios for EV uptake and consider effects on the distribution network	Model network effects with high charge-at-home commercial EV uptake	All models are variable to EV numbers and charge-point specifications Impacts simulated at minimum for all Centrica vehicles in greater London
CEN52		Extrapolate findings from Centrica fleet to other return-to-home commercial fleets	
CEN53	Translate simulated and measured network effects into infrastructure upgrade requirements	Determine network asset upgrade requirements based on 'Network Cluster' monitoring data in 'un-managed charging' trials	Relationship between network capacity and reinforcing schedules is understood
CEN54		Determine network asset upgrade requirements based on 'Network Cluster' monitoring data in 'aggregator managed charging' trials	
CEN55	Translate anticipated upgrade requirements into DNO costs	Apply DNO costing method for bringing reinforcements forwards/delaying reinforcements to evaluate network benefits/costs associated with un-managed/aggregator managed charging of EVs	Relationship between network reinforcing schedules and network costs is understood

10.1.2 Objective 3

Assess smart electrification strategies

Table 39 – Home trial objective 3 activities

Activity ID	Sub-objective	Activity	Outputs
CEN56	Understand the impacts of EV uptake on Centrica fleet TCO	Estimate vehicle purchasing costs prior to charge-point installation	Effects of charging type ('un-managed'/'aggregator managed') on TCO predicted and calculated Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
CEN57		Estimate charge point purchasing costs prior to charge-point installation	
CEN58		Estimate electrical infrastructure costs prior to charge-point installation	
CEN59		Estimate installation costs prior to charge-point installation	
CEN60		Estimate asset insurance costs prior to charge-point installation	
CEN61		Estimate asset depreciation prior to charge-point installation	
CEN62		Estimate fuel expenditure on non-EVs prior to charge-point installation	
CEN63		Estimate maintenance costs prior to charge-point installation	
CEN64		Estimate vehicle taxation costs (ULEZ, road-tax, congestion charge, etc.)	
CEN65		Estimate electricity costs based on domestic tariff structure for 'un-managed' load profiles	
CEN66		Estimate electricity costs based on commercial tariff structure for 'un-managed' load profiles	
CEN67		Estimate electricity costs based on ToU tariff structure for 'un-managed' load profiles	
CEN68		Assess sensitivity of TCO models to capital and installation costs	
CEN69		Assess sensitivity of TCO models to non-electricity operating costs	

Activity ID	Sub-objective	Activity	Outputs
CEN70	Understand the impacts of EV uptake on Centrica fleet TCO	Calculate electricity costs based on domestic tariff structure for 'un-managed' load profiles	Effects of charging type ('un-managed'/'aggregator managed') on TCO predicted and calculated Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
CEN71		Calculate electricity costs based on commercial tariff structure for 'un-managed' load profiles	
CEN72		Calculate electricity costs based on ToU tariff structure for 'un-managed' load profiles	
CEN73		Estimate electricity costs based on domestic tariff structure for 'aggregator managed' load profiles	
CEN74		Estimate electricity costs based on commercial tariff structure for 'aggregator managed' load profiles	
CEN75		Estimate electricity costs based on ToU tariff structure for 'aggregator managed' load profiles	
CEN76		Estimate software costs for 'aggregator managed' optimisation systems	
CEN77		Calculate electricity costs based on domestic tariff structure for 'aggregator managed' load profiles	
CEN78		Calculate electricity costs based on commercial tariff structure for 'aggregator managed' load profiles	
CEN79		Calculate electricity costs based on ToU tariff structure for 'aggregator managed 'load profiles	
CEN80		Estimate electricity costs based on domestic tariff structure for aggregator managed + flexibility' load profiles	
CEN81		Estimate electricity costs based on commercial tariff structure for 'aggregator managed+ flexibility' load profiles	
CEN82		Estimate electricity costs based on ToU tariff structure for 'aggregator managed + flexibility' load profiles	
CEN83		Estimate software costs for 'aggregator managed' optimisation systems with flexibility trading capabilities	

Activity ID	Sub-objective	Activity	Outputs
CEN84	Understand the impacts of EV uptake on Centrica fleet TCO	Evaluate impact of potential legislative changes (e.g. expansion of ULEZ) on TCO (varying EV percentage)	Effects of charging type ('un-managed'/'aggregator managed') on TCO predicted and calculated Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
CEN85		Estimate flexibility services revenue	
CEN86		Calculate flexibility services revenue	
CEN87		Calculate electricity costs based on domestic tariff structure for 'aggregator managed + flexibility' load profiles	
CEN88		Calculate electricity costs based on commercial tariff structure for 'aggregator managed + flexibility' load profiles	
CEN89		Calculate electricity costs based on ToU tariff structure for 'aggregator managed + flexibility' load profiles	
CEN90		Calculate software costs for 'aggregator managed' optimisation systems with flexibility trading capabilities	
CEN91	Compare the effects of un-managed-charging and aggregator managed charging on the distribution network	Compare aggregated 'aggregator managed'/'un-managed' load profiles across all charge-at-home locations	Network impact and opportunities associated with 'aggregator managed charging' over 'un-managed charging' Best tariff structures for reducing network constraints identified
CEN92		Compare distribution network effects caused by 'aggregator managed'/'un-managed' charging EVs at domestic locations	
CEN93		Compare network costs for EV uptake aggregated across all charge-at-home locations at trial end ('aggregator managed'/'un-managed')	
CEN94		Assess potential for network risk avoidance due to charge-point control	
CEN95	Develop future strategies for return-to-home commercial vehicle electrification	Compare the relative impact of electrification of 'vehicle categories' on TCO	Recommendations made with regards to which 'types' of vehicles are most suitable to be replaced by EVs (from both fleet operator and DNO perspectives)
CEN96		Develop roll-out strategy recommendations	

10.1.3 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 40 – Home trial objective 4 activities

Activity ID	Sub-objective	Activity	Outputs
CEN97	Model and verify the flexibility available from charge-at-home commercial EVs	Model all possible EV charging profiles that adhere to operational requirements	Technical characteristics of charge-at-home EV fleet flexibility have been modelled and verified (magnitude availability over each day, maximum speed of response) Price dynamics of charge-at-home commercial EV flexibility and respective influences are understood Average difference in price and magnitude of flexibility available between different tariff structures is known for at least two tariff structures Reliability of charge-at-home EV fleet flexibility provision assessed
CEN98		Estimate minimum plugged-in capacity at any one time	
CEN99		Calculate maximum plugged-in capacity at any one time	
CEN100		Predict trends in flexibility availability (time of day, month, events)	
CEN101		Calculate costs associated with shifting away from the cost optimum given domestic tariff	
CEN102		Calculate costs associated with shifting away from the cost optimum given commercial tariff	
CEN103		Calculate costs associated with shifting away from the cost optimum given TOU tariff	
CEN104		Determine price variability in available flexibility	
CEN105		Determine best tariff structure to minimise the costs of flexibility for fleet operator	
CEN106		Evaluate carbon costs associated with flexibility	
CEN107	Determine DNO flexibility needs	Compare LV, HV and EHV 'Network Cluster' constraint patterns	Constraint patterns are analysed for each network cluster and the impact of current and future EV charging loads on these constraints are visible
CEN108		Based on 'Network Cluster' constraint patterns, determine magnitude and duration of flexibility required for appropriate alleviation	
CEN109		Assess existing market frameworks for flexibility provision according to constraint patterns	

Activity ID	Sub-objective	Activity	Outputs
CEN110	Predict value of flexibility from charge-at-home EVs to fleet/DNO given different market models	Calculate potential reinforcement cost offset by provision of maximum available flexibility from charge-at-home commercial EVs	The likely extent of overlap between flexibility availability from charge-at-home EVs and flexibility required from DNO is understood. The potential scope for value sharing across parties is determined. Price discrepancies between EV fleet flexibility and DNO willingness to pay are visible Future scope for charge-at-home commercial EV fleet flexibility provision determined
CEN111		Optimise fleet flexibility provision to maximise network savings and minimise cost to fleet	
CEN112		Determine maximum magnitude of reward for providing flexibility services (£/kW)	
CEN113		Evaluate predictive capabilities for flexibility availability from charge-at-home EVs over different time scales	
CEN114		Compare the viability of long-term/short-term flexibility contracts	
CEN115	Evaluate the operational limitations to flexibility provision	Enumerate flexibility interruptions due to human interaction	Qualitative/quantitative understanding of barriers to flexibility provision from charge-at-home commercial EVs is achieved
CEN116		Determine drivers' range anxiety before and after flexibility services were offered by the depot	
CEN 117		Survey aggregator to determine satisfaction with EVs as a flexibility asset	

10.1.4 Objective 5

Evaluate operational limitations to EV fleet electrification

Table 41 – Home trial objective 5 activities

Activity ID	Sub-objective	Activity	Outputs
CEN118	Evaluate driver satisfaction with EV uptake	Enumerate incidences of inadequate charge	Understanding of driver perspectives on electric vehicles and how they change throughout the project is achieved At least 30 drivers surveyed each quarter
CEN119		Survey drivers throughout trial gauging attitude towards EVs at six-month intervals throughout project duration	Understanding of operator perspectives on electric vehicles and how they change throughout the project is achieved At least 10 operators surveyed quarterly
CEN120	Evaluate the satisfaction of fleet operators with EV uptake	Survey fleet operators throughout trial gauging attitude towards EVs at six-month intervals throughout project duration	
CEN121		Enumerate routes which were deemed inappropriate for EV operation	
CEN122	Evaluate satisfaction with separate EV metering	Survey drivers throughout trial gauging attitude towards metering solution at six-month intervals throughout project duration	At least 30 drivers and 10 operators surveyed quarterly
CEN123		Survey fleet operators throughout trial gauging attitude towards metering solution at six-month intervals throughout project duration	
CEN124	Evaluate aggregator satisfaction with commercial EV flexibility provision	Survey aggregator throughout trial gauging attitude towards commercial EV flexibility provision at 6-month intervals throughout project duration	Understanding of aggregator perspective on commercial EV flexibility provision and how this changes throughout the project is achieved At least one aggregator surveyed every six months

10.2 Depot trial activities

10.2.1 Objective 1

Create, verify and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Table 42 – Depot trial objective 1 activities

Activity ID	Sub-objective	Activity	Outputs
RM001	Understand the operational requirements of Royal Mail EVs	Predict kWh daily energy requirements based on vehicle mileage/fuel spending on ICE vehicles prior to depot electrification (current operation)	Statistical profiles for charge events (plug-in/plug-out times and kWh energy requirements) are available based on both predictions made from ICE vehicle analysis and learnings from 'un-managed' EV charging Charge event statistical profiles are subject to change given factors such as weather, day type and events calendar EV charging curves showing rate of charge within charge events are available
RM002		Predict plug-in/plug-out times from telemetry data prior to depot electrification (current operation)	
RM003		Develop indicative energy requirements for each region of vehicle operation according to expected mileage, time of year, day type (WE/WD), weather, events, payload, etc. based on typical ICE vehicle usage data	
RM004		Track plug-in/plug-out times once charge-points have been installed	
RM005		Define regions of vehicle operation, e.g. borough, depot, loop	
RM006		Compare to predictions of plug-in/plug-out times from telemetry data made before electrification	
RM007		Monitor state of charge (SoC) at plug-in time once charge-points have been installed and are operating in 'un-managed' mode (‘un-managed’ charging expressed as maximum power delivery from plug-in until plug-out or maximum charge)	

Activity ID	Sub-objective	Activity	Outputs
RM008	Understand the operational requirements of Royal Mail EVs	Monitor SoC at plug-out time once charge-points have been installed and are operating in 'un-managed' mode	Statistical profiles for charge events (plug-in/plug-out times and kWh energy requirements) are available based on both predictions made from ICE vehicle analysis and learnings from 'un-managed' EV charging Charge event statistical profiles are subject to change given factors such as weather, day type and events calendar EV charging curves showing rate of charge within charge events are available
RM009		Compare EV energy requirements observed in 'un-managed' charging experiments to those predicted prior to charge-point installation (compared to manufacturers estimations and ICE vehicles)	
RM010		Develop indicative energy requirements for each region of vehicle operation based on mileage, time of year, day type (WE/WD), weather, events, payload based on learnings from 'un-managed' charging EVs	
RM011		Create charging curves for EVs versus time (charging power, cell voltage, charging current, state of charge) based on learnings from 'un-managed' charging EVs	
RM012		Determine how these profiles may change subject to temperature variations, etc. based on learnings from 'un-managed' charging EVs	
RM013		Develop and test predictive capabilities for energy requirements, plug-in/plug-out time, SoC at plug-in/plug-out times given the implementation of 'smart' charge-points	
RM014		Predict EV charging load profiles assuming ‘un-managed’ charging varying scale of EV uptake, based on observed performance across a range of external variables (weather, day type, payload, etc.)	
RM015	Model and validate EV charging profiles for each level of technological complexity	Monitor the time and magnitude of charge events once charge-points have been installed and are operating in 'un-managed' mode	EV plug-in time, plug-out time and kW draw is available for each installed charge-point at each depot A model for charge-events is available, predicting aggregated EV charging loads for a given number of EVs for a given depot
RM016		Create EV charging load profiles based on charging events monitored in the 'un-managed' charging experiments	
RM017		Model EV charging load profiles based on charging events monitored in the 'un-managed' charging experiments incorporating different charger speeds	

Activity ID	Sub-objective	Activity	Outputs
RM018		Compare realised aggregated charge-point load profiles with those predicted prior to charge-point installation, analyse discrepancies (percentage deviation from predictions, any peaks un-accounted for, derive origin of discrepancies) and update models	Model is variable to factors such as weather, day-type and events calendar Model can be used to simulate 'depot managed charging' by optimisation of charge events Model is analysed and updated with learning from 'depot managed charging' trials
RM019		Determine the minimum plugged-in time required for charging to meet operational energy requirements (average for region of operation based on learning from 'un-managed' charging)	
RM020		Model aggregated EV charging profiles that avoid peak hours/pricing in absence of additional depot load	
RM021		Compare EV load to historical depot load	
RM022		Monitor the time and magnitude of charge events once charge-points have been installed and are operating in depot managed mode (charging to meet a profile)	
RM023		Compare charge events in depot managed charging mode to the dispatched charging orders	
RM024		Create EV charging load profiles based on charging events monitored in the depot managed charging experiments	
RM025		Model EV charging load profiles base on charging events monitored in the depot managed charging experiments including different charger speeds	
RM026		Compare predicted aggregated charge-point load (from 'un-managed' charging mode) with that realised, analyse discrepancies (ability to meet optimum charge profile in reality) and update models	
RM027	Model and validate load profiles from electrified depots	Collect historical electricity consumption data (kWh) data from each depot for the two years prior to installation of charge-points	A model for total depot electricity consumption is available for each depot given a varying number of EVs for each depot
RM028		Build indicative load profiles for each depot based on day type (WE/WD), season, weather, events	

Activity ID	Sub-objective	Activity	Outputs
RM029		Build indicative load profiles for each depot based on day type (WE/WD), season, weather, events including corresponding 'un-managed charging' loads	Differences from electricity consumption from depot to depot are understood and incorporated into the model Model has functionality to produce load profiles given a mix of different charging types (un-managed/depot managed) and LCT integration Model is variable to factors such as weather, day-type and events calendar Several indicative ‘depot managed charging' load profiles are produced to form a profiled agreement application
RM030		Scale the depot load according to the proportion of the fleet electrified and determine the point at which the connection agreement is violated (using 'un-managed charging' loads)	
RM031		Assess whether the proposed number of EVs for the depot under consideration will violate the connection agreement given 'un-managed charging'	
RM032		Select number of EVs for 'un-managed charging' trial	
RM033		Model indicative load profiles for each depot for day type (WE/WD) and season including 'un-managed charging' EV loads and varying solar generation loads	
RM034		Model indicative load profiles for each depot for day type (WE/WD) and season including 'un-managed charging' EV loads and with varying and solar generation loads with varying battery storage capacity	
RM035		Monitor depot connection point loads (half-hourly) given 'un-managed' charge-point operation	
RM036		Compare the expected depot connection point loads from predictions made prior to charge-point installation with those realised, analyse discrepancies and update models	
RM037		Monitor solar production (if installed)	
RM038		Monitor battery imports/exports (if installed)	
RM039		Build optimal load profiles for each depot for day type (WE/WD) and season including 'depot managed charging' EV loads and loads from installed LCTs based on electricity cost (using depot structure)	
RM040		Build optimal load profiles for each depot for day type (WE/WD) and season including ‘depot managed charging' EV loads and loads from installed LCTs based on electricity cost (using time-of-use tariff)	

Activity ID	Sub-objective	Activity	Outputs
RM041		Build optimal load profiles for each depot for day type (WE/WD) and season including 'depot managed charging' EV loads and loads from installed LCTs based on maximising the distance from connection agreement limit	
RM042		Monitor depot connection point loads given the uptake of 'depot managed charging' to meet a set profile	
RM043		Compare the predicted depot connection point loads (from 'un-managed charging' experiments) with those realised, analyse discrepancies and update model to include 'depot managed charging' predictive capabilities	
RM044		Develop and test depot load predictive capabilities (dependent on EV energy requirements, weather, type of day, season, etc.) given 'depot managed' charging EVs	
RM045		Build load profiles for 100% electrification of depot vehicles using 'depot managed' charging	
RM046	Model and validate the effect of depot load on local distribution network infrastructure network assets in the region surrounding the depot at the same voltage level	Gather depot connection details (connection agreement capacity, position in network) prior to charge-point installation	Each depots contribution to capacity reduction on relevant network assets is modelled and measured given varying proportion of fleet electrified and different charging methods Depot load profiles submitted to DNO analysed for their potential impact on the network Profiled connection agreement designed for at least one depot Effectiveness of profiled connections at releasing capacity to the grid analysed
RM047		Gather details (name, location) of network infrastructure that may be associated with delivering power to each depot prior to charge-point installation	
RM048		Collect feeder load capacity for each depot (kVA) prior to charge-point installation	
RM049		For feeders with multiple connections, collect historical electricity loading data of the feeder (kVA/kW) for the two years prior to charge-point installation	
RM050		Collect relevant substation max load capacity (kVA) prior to charge-point installation	
RM051		Collect relevant substation historical electricity loading data (load factor, max peak loads) (kVA/kW) for the two years prior to charge-point installation	
RM052		Identify DNO concerns surrounding EV charging (voltage stability, power quality) prior to charge-point installation	

Activity ID	Sub-objective	Activity	Outputs
RM053	Model and validate the effect of depot load on local distribution network infrastructure network assets in the region surrounding the depot at the same voltage level	Identify variables available for monitoring at relevant substations and at the depot connection point (transformer hot-point temperature, voltage, current, (re)active power flows, etc.) prior to charge-point installation	Each depots contribution to capacity reduction on relevant network assets is modelled and measured given varying proportion of fleet electrified and different charging methods Depot load profiles submitted to DNO analysed for their potential impact on the network Profiled connection agreement designed for at least one depot Effectiveness of profiled connections at releasing capacity to the grid analysed
RM054		Record voltage at depot connection throughout 'un-managed charging' trial duration	
RM055		Record current at depot connection throughout 'un-managed charging' trial duration	
RM056		Record voltage at relevant network infrastructure throughout 'un-managed charging' trial duration	
RM057		Record current at relevant network infrastructure throughout 'un-managed charging' trial duration	
RM058		Monitor, record and measure all the variables identified as required to monitor the effects of depot electrification under different models (un-managed, depot managed and depot managed + flexibility).	
RM059		Overlay depot load profiles with 'un-managed charging' EVs with relevant feeder and substation load profiles	
RM060		Overlay depot load profiles with 'depot managed charging' EVs with relevant feeder and substation load profiles	
RM061		Translate each individual depot load to percentage of capacity used in local network infrastructure (local feeders/substations)	
RM062		Identify time periods with maximum capacity usage and determine percentage contribution by the depot in these time periods	
RM063		Determine trends in peak loading times (weather, season, events)	

Activity ID	Sub-objective	Activity	Outputs
RM064	Model and validate the effect of depot load on local distribution network infrastructure network assets in the region surrounding the depot at the same voltage level	Determine trends in percentage contribution from depots to peak loading periods for 'un-managed charging' profiles	Each depots contribution to capacity reduction on relevant network assets is modelled and measured given varying proportion of fleet electrified and different charging methods Depot load profiles submitted to DNO analysed for their potential impact on the network Profiled connection agreement designed for at least one depot Effectiveness of profiled connections at releasing capacity to the grid analysed
RM065		Determine trends in percentage contribution from depots to peak loading periods for 'depot managed charging' profiles	
RM066		Considering data collection across all depots and network infrastructure, relate reductions in capacity (or spikes in loading) with other network indicators (e.g. hot-point temperature, voltage)	
RM067		Assess potential load profiles generated by learnings from 'un-managed charging' trials and select the depot load profile that mitigates undesirable network effects for a basis of the profiled connection	
RM068		Model network effects with high penetration of EVs at depots assuming 'depot managed charging'	
RM069		Determine the amount of capacity released by introduction of profiled connections	
RM070	Predict the effect of depot load on distribution network infrastructure at higher voltage levels than the depot connection	Identify HV/EHV transformers which are in the direct network for each depot prior to charge-point installation	The relationship between depot load profile and associated high voltage network asset performance at a given level of fleet electrification is understood
RM071		Monitor physical attributes of HV/EHV transformers throughout the duration of un-managed charging and depot managed charging trials	
RM072		Associate lower voltage sub-station constraints with higher voltage substation constraints from data collection	
RM073	Consider future scenarios for EV uptake and model effects on the distribution network	Extrapolate findings from Royal Mail depots to other depots and predict effects on entire distribution network	All models are variable to depot EV numbers and charge-point specifications Impacts simulated at minimum for all Royal Mail depots in greater London

Activity ID	Sub-objective	Activity	Outputs
RM074	Translate simulated and measured network effects into infrastructure upgrade requirements	Use methods such as loss of lifetime analysis to determine transformer upgrade requirements based on data collected in 'un-managed charging' trials	Relationship between network capacity and reinforcing schedules is understood
RM075		Use methods such as loss of lifetime analysis to determine transformer upgrade requirements based on data collected in 'depot managed charging' trials	
RM076		Communicate measured network indicators from 'un-managed charging' trials to DNO (peak loads, min/max voltage, min/max current, etc.) and request update on reinforcement timelines[20]	
RM077		Communicate measured network indicators from 'depot managed charging' trials to DNO (peak loads, min/max voltage, min/max current, etc.) and request update on reinforcement timelines	
RM078	Translate anticipated upgrade requirements into DNO costs	Apply DNO costing method for bringing reinforcements forwards/delaying reinforcements to evaluate network benefits/costs associated with un-managed/depot managed charging of EVs	Relationship between network reinforcing schedules and network costs is understood
RM079		Compare relative cost impact across infrastructure (LV/HV/EHV)	

10.2.2 Objective 2

Assess the effects of profiled connections on fleet EV transition

Table 43 – Depot trial objective 2 activities

Activity ID	Sub-objective	Activity	Output
RM080	Explore risks associated with roll-out of profiled	Using learning from 'un-managed charging' experiments, prove EV charging load-shifting can be used to adhere to a profiled connection (i.e. prove EVs have flexibility and make up a large percentage of depot load)	Volatility in depot load profiles understood and contributing factors incorporated into models Probability of depots breaching their connection

[20] These are activities related to the "additional learning" objectives, if time and resource permits then they can be investigated.

Activity ID	Sub-objective	Activity	Output
RM081	connections for the DNO	Run sensitivity analysis on the load-profile model used to generate potential depot managed charging load profiles (EV energy requirements, depot electricity consumption, solar generation, storage)	agreement is visible based on proportion of vehicles electrified and profiled connection agreement safety margin over expected behaviours Network effects of connection agreement breaches are understood
RM082		Catalogue scenarios which would result in the profiled connection agreement being breached (based on load profile modelling using 'un-managed charging' learnings)	
RM083		Model the influence of proportion of fleet electrified on the ability to adhere to a profiled connection (based on learnings from 'un-managed charging' trial)	
RM084		Artificially lower the profiled connection that is input into optimisation tool until the EV charging schedule results in vehicle charge-level being within 5% of what is operationally acceptable (chargers in depot managed charging mode)	
RM085		Determine the size of breach of profiled connection required to threaten network infrastructure	
RM086		Determine patterns in events that approach/breach the connection agreement maximum during 'depot managed charging' trials	
RM087		Determine optimisation system behaviour when close to breaching profiled connection agreement	
RM088		Determine a sensible safety margin for profiled connections over load profiles using learning from 'depot managed charging' trials	
RM089		Associate breaches in profiled connection with network cost using models developed in Objective 1	
RM090	Develop pricing strategy for profiled connections	Predict costs to Royal Mail if a £/kW breach charge in combination with a cheaper connection cost (soft profiled connection) with a lower safety margin was implemented (based on modelled 'depot managed charging' load profiles)	At minimum two pricing structures trialled at each depot with associated depot and network operator costs calculated Effects of pricing structure on fleet TCO considered
RM091		Predict costs to Royal Mail if a hard profiled connection was implemented with more expensive one-off connection cost (based on modelled 'depot managed charging' profiles)	

Activity ID	Sub-objective	Activity	Output
RM092		Submit hard profiled connection application to DNO prior to 'depot managed charging'	
RM093		Submit soft profiled connection application to DNO prior to 'depot managed charging'	
RM094		Submit profiled connection application for 100% electrification of depot prior to 'depot managed charging' (hard/soft)	
RM095		Calculate yearly connection cost with soft profiled connections once 'depot managed charging' is implemented	
RM096		Calculate yearly connection cost with hard profiled connection once 'depot managed charging' is implemented	
RM097	Evaluate the impact of profiled connections and flexibility on TCO	Estimate vehicle (EV and ICE vehicle) purchasing costs prior to charge-point installation	Effects of charging type ('un-managed'/'depot managed') on TCO predicted and calculated for each depot Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
RM098		Estimate un-managed charge-point purchasing costs prior to charge-point installation	
RM099		Estimate smart charge-point purchasing costs prior to charge-point installation	
RM100		Estimate electrical infrastructure costs prior to charge-point installation	
RM101		Estimate installation costs prior to charge-point installation	
RM102		Estimate asset insurance costs prior to charge-point installation	
RM103		Estimate asset depreciation prior to charge-point installation	
RM104		Estimate fuel expenditure on non-EVs prior to charge-point installation	
RM105		Estimate maintenance costs prior to charge-point installation	
RM106		Estimate electricity costs (energy) based on depot tariff structure for 'un-managed' load profiles	
RM107		Estimate electricity costs (energy) based on time-of-use (ToU) tariff structure for 'un-managed' load profiles	
RM108		Calculate EV purchasing costs	
RM109		Calculate smart charge-point purchasing cost	

Activity ID	Sub-objective	Activity	Output
RM110	Evaluate the impact of profiled connections and flexibility on TCO	Calculate electrical infrastructure costs post charge-point installation	Effects of charging type ('un-managed'/'depot managed') on TCO predicted and calculated for each depot Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
RM111		Calculate installation costs post charge-point installation	
RM112		Calculate asset insurance costs post charge-point installation	
RM113		Update asset depreciation projections periodically post charge-point installation	
RM114		Update maintenance costs projections periodically post charge-point installation	
RM115		Calculate electricity costs (energy) based on depot tariff structure for 'un-managed' load profiles	
RM116		Calculate electricity costs (energy) based on ToU tariff structure for 'un-managed' load profiles	
RM117		Calculate electricity costs (energy) based on depot tariff structure for 'depot managed' load profiles	
RM118		Calculate electricity costs (energy) based on ToU tariff structure for 'depot managed' load profiles	
RM119		Calculate electricity costs (energy) based on depot tariff structure for 'depot managed + flexibility' load profiles	
RM120		Calculate electricity costs (energy) based on ToU tariff structure for 'depot managed + flexibility' load profiles	
RM121		Estimate connection costs for each level of electrification	
RM122		Estimate software costs for 'smart' optimisation systems	
RM123		Estimate software costs for 'smart' optimisation systems with flexibility trading capabilities	
RM124		Estimate vehicle taxation costs before and after EV uptake (including ULEZ)	
RM125		Evaluate impact of potential legislative changes (e.g. expansion of ULEZ) on TCO (varying EV percentage)	
RM126		Submit profiled connection application for depot based on 'un-managed' load profiles (expected percentage EVs)	

Activity ID	Sub-objective	Activity	Output
RM127	Evaluate the impact of profiled connections and flexibility on TCO	Submit profiled connection application for depot based on 'depot managed' load profiles (expected percentage EVs)	Effects of charging type ('un-managed'/'depot managed') on TCO predicted and calculated for each depot Effects of flexibility revenues on TCO identified for different scales of EV uptake Effect of real-life dynamics on electricity spending (e.g. energy requirements of vehicles expected versus realised) analysed and incorporated into models Potential future market and regulatory impacts on TCO modelled and communicated
RM128		Submit flat profiled connection application to DNO based on 'un-managed charging' load profiles (expected percentage EVs)	
RM129		Submit profiled connection application for depot based on 'un-managed' load profiles (100% electrification)	
RM130		Submit profiled connection application for depot based on 'depot managed' load profiles (100% electrification)	
RM131		Submit flat profiled connection application to DNO based on 'un-managed charging' load profiles (100% electrification)	
RM132		Estimate flexibility services revenue (see Objective 4)	
RM133		Calculate flexibility services revenue (see Objective 4)	
RM134	Determine reduction in lead-time for electrifying depots	Quantify cumulative months across depots saved by avoidance of upgrades due to adherence to a profiled connection	Number of months saved given varying simulated levels of EV uptake modelled for both un-managed/depot managed charging Carbon benefits associated with reduction in lead times calculated
RM135		Translate months of reinforcement saved from implementation of profiled connections into EV uptake rates and carbon benefits	

10.2.3 Objective 3

Assess smart electrification strategies

Table 44 – Depot trial objective 3 activities

Activity ID	Sub-objective	Activity	Outputs
RM136	Compare levels of electrification for their effects on the network	Compare average 'depot managed'/'un-managed' electrification depot load profiles across depots	Value of 'depot managed charging' over 'un-managed charging' understood from the DNO perspective
RM137		Compare network effects of 'depot managed'/'un-managed' electrification across depots	
RM138		Compare network costs at end of trials for associated with each depot ('depot managed'/'un-managed')	

Activity ID	Sub-objective	Activity	Outputs
RM139		Compare network costs for simulated 100% electrification of each depot ('depot managed'/'un-managed')	
RM140	Determine the value in LCT integration into depots for fleet operators	Translate modelled LCT depot load profiles into electricity costs assuming solar consumed behind-the-meter is free of charge with/without feed-in-tariffs or licensed supply arrangement in place (for both flat and profiled connection agreements)	Optimal configuration of smart technologies (from a fleet operator perspective) is calculated for each depot
RM141		Translate modelled LCT inclusive depot load profiles into electricity costs assuming purchased solar (for both flat and profiled connection agreements)	
RM142		Determine value in battery storage based on 'depot managed charging' load models	
RM143		Compare the impact on TCO for LCTs based on 'depot managed charging' load models	
RM144		Estimate carbon savings enabled by LCTs	
RM145		Estimate the percentage load overlap between solar generation and Royal Mail EV charging demands	
RM146		Estimate cost savings associated with V2B charge-point capability (for both flat and profiled connection agreements)	
RM147		Estimate revenue streams associated with V2G charge-point capability (for both flat and profiled connection agreements)	
RM148	Determine the value in LCT integration into depots for the DNO	Compare the network impacts of depots with/without LCTs by comparing load profiles for both 'depot managed'/'un-managed' cases	Optimal configuration of smart technologies from DNO perspective is calculated for each depot

10.2.4 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 45 – Depot trial objective 4 activities

Activity ID	Sub-objective	Activity	Outputs
RM149	Model and verify the flexibility available from electrified depots	Model all possible EV charging schedules that would ensure operational requirements are met and connection agreements are not violated (for both flat and profiled connection agreements). These profiles will show the potential for manipulating EV charging schedules away from that which provided the optimum solution of the objective function set by depot operators (e.g. electricity cost minimisation).	Technical characteristics of depot flexibility have been modelled and verified (magnitude availability over each day, maximum speed of response) Price dynamics of depot flexibility and respective influences are understood Average difference in price and magnitude of flexibility available between flat and profiled connection agreements is known Reliability of depot EV flexibility provision quantified Predictability of flexibility availability assessed
RM150		Ignoring profiled connection limitations (flat profiled connection agreement), model the maximum magnitude of response available at each time whilst adhering to operational requirements	
RM151		Adhering to profiled connection limitations, model the maximum magnitude of response available at each time whilst adhering to operational requirements	
RM152		Estimate average costs associated with shifting the charging loads (to give maximum response at each time) based on depot tariff structure given simulated flat connection agreement	
RM153		Estimate average costs associated with shifting the charging loads (to give maximum response at each time) based on ToU tariff structure given simulated flat connection agreement	
RM154		Estimate average costs associated with shifting the charging loads (to give maximum response at each time) based on depot tariff structure given simulated profiled connection agreement	
RM155		Estimate average costs associated with shifting the charging loads (to give maximum response at each time) based on ToU tariff structure given simulated profiled connection agreement	
RM156		Predict trends in flexibility availability/cost given simulated flat connection agreement (time of day, month, events)	

Activity ID	Sub-objective	Activity	Outputs
RM157		Predict trends in flexibility availability/cost given simulated profiled connection agreement (time of day, month, events)	
RM158		Determine patterns in flexibility availability/cost through initiation of flexibility requests given adherence to flat connection agreement	
RM159		Determine best tariff structure to minimise the costs of available flexibility for depot operator given adherence to flat connection agreement	
RM160		Determine the carbon costs (if any), associated with flexibility given flat connection agreement	
RM161		Determine how price for depot flexibility varies with proximity to the time of the flexibility event (value in planning) given adherence to a flat connection agreement	
RM162		Determine patterns in flexibility availability/cost through initiation of flexibility requests given adherence to profiled connection agreement	
RM163		Given the flexibility available in the EV charging schedule, determine the depot electricity tariff structure that best minimises the cost of load shifting (flat, peak/off-peak, three tier time-of-use)	
RM164		Determine the carbon costs (if any) associated with flexibility given adherence to a profiled connection agreement	
RM165		Determine how price for depot flexibility varies with proximity to the time of the flexibility event (value in planning) given adherence to a profiled connection agreement	
RM166		Evaluate predictive capabilities for depot flexibility availability over different time scales (i.e. how long before the fact can flexibility availability can be accurately predicted)	
RM167		Compare the viability of long-term/short-term flexibility contracts given flat/profiled connections	

Activity ID	Sub-objective	Activity	Outputs
RM168		Compare the percentage of flexibility agreements that are not met due to operational limitations for flat/profiled connection agreements	
RM169		Compare the percentage of installed capacity typically available for flexibility at different times of day for flat/profiled connection agreements	
RM170		Determine which vehicle operation region provides the highest percentage of installed capacity for flexibility for both flat and profiled connection agreements	
RM171		Determine quantity of flexibility provided which is not a direct result of EV charging load shifting for both flat and profiled connection agreements	
RM172		Enumerate instances where the depots fail to deliver flexibility ordered by DNO (simulated or contracted)	
RM173		Determine the minimum time taken (response speed) to achieve maximum flexibility delivery in response to a DNO communicated need for both flat/profiled connection agreements	
RM174		Determine how well the prices for flexibility compare to successful bids within existing flexibility markets	
RM175		Compare depot flexibility availability/price with Centrica and Uber flexibility availability/price	
RM176		Compare the best reward structure for flexibility provision from fleet operator perspective for both flat/profiled connection agreements	
RM177	Determine DNO flexibility needs	Compare constraint patterns across associated network infrastructure (LV/HV) throughout un-managed/depot managed charging trials	Constraint patterns are analysed and the impact of current and future EV charging loads on these constraints are visible
RM178		Based on constraint patterns, determine magnitude and duration of flexibility required for appropriate alleviation	
RM179		Based on predictive models generated throughout project, identify constrained areas/times of day of the network which may require flexibility services given high penetration of EVs	

Activity ID	Sub-objective	Activity	Outputs
RM180	Predict the value of flexibility from electrified depots to the fleet operator/ DNO given different market models	Calculate potential reinforcement cost offset by provision of maximum available flexibility from depot based commercial EVs	Regions of overlap (time, location) of DNO flexibility requirements and depot flexibility availability are identified Price discrepancies between depot flexibility and DNO willingness to pay are visible Network benefits of any flexibility provided by the depots are quantified Consistency and predictability of network constraints analysed Future scope for depot EV flexibility provision determined
RM181		Determine maximum magnitude of reward for providing flexibility services (£/kW)	
RM182		Optimise fleet flexibility provision to maximise network savings and minimise cost to fleet	
RM183		Evaluate predictive capabilities for flexibility availability from depot based EVs over different time scales	
RM184		Compare the viability of long-term/short-term flexibility contracts	
RM185		Bid for flexibility required by DNO for zones of overlap with depots (if they exist)	
RM186		Given flexibility sold to DNO or understanding of network constraints, manipulate EV charging schedules to achieve the flexibility requirements	
RM187		Record all relevant variables (e.g. voltage, current, temperature) at depot connection throughout 'depot managed charging + flexibility' trial duration	
RM188		Compare the market mechanisms which appear to best suit the nature of flexibility required by the DNO (how far ahead of time can flexibility requirements be predicted? Do flexibility requirements reliably fall within certain time-bands?) to those uncovered in flexibility projects external to the trial	
RM189	Evaluate the operational limitations to flexibility provision	Enumerate flexibility interruptions due to human interaction	Qualitative/quantitative understanding of barriers to flexibility provision from depot EVs is achieved
RM190		Determine drivers range anxiety before and after flexibility services were offered by the depot	
RM191		Evaluate physical limitations to fleet flexibility provision, e.g. availability of parking for required hours of charging	

10.2.5 Objective 5

Evaluate operational limitations to commercial fleet electrification

Table 46 – Depot trial objective 5 activities

Activity ID	Sub-objective	Activity	Outputs
RM192	Evaluate the satisfaction of drivers with EV uptake	Enumerate incidences of inadequate charge	Understanding of driver perspectives on electric vehicles and how they change throughout the project is achieved At least 10 drivers from each depot surveyed quarterly
RM193		Survey drivers throughout trial gauging attitude towards EVs at quarterly intervals throughout project duration	
RM194	Evaluate the satisfaction of depot operators with EV uptake	Survey depot operators throughout trial gauging attitude towards EVs at quarterly intervals throughout project duration	Understanding of depot operator perspectives on electric vehicles and how they change throughout the project is achieved At least one depot manager surveyed quarterly
RM195		Survey depot operators throughout trial gauging attitude towards space availability before and after implementation of EVs	
RM196		Enumerate routes which were deemed inappropriate for EV operation	
RM197		Enumerate incidences of vehicles out for maintenance for both ICE vehicles and EVs	
RM198	Evaluate the satisfaction of depot operators with smart software systems	Survey depot operators throughout trial gauging attitude towards optimisation software at quarterly intervals throughout project duration	Interaction between optimisation systems and operability of the fleet understood At least one operator from each depot surveyed quarterly
RM199		Enumerate incidences of incompatibility in end to end testing and document their resolution	
RM200		Enumerate incidences of depot operator over-riding charging schedules	

10.3 Mixed trial activities

10.3.1 Objective 1

Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment

Table 47 – Mixed trial objective 1 activities

Activity ID	Sub-objective	Activity	Outputs
UB001	Understand the variation in trips taken by PH electric vehicles	Validate trip data received for quality control (sense checking long/lat, time-stamps)	Clean data-set is available for processing
UB002		Generate estimated trip data from existing data (mileage, specific routes)	Approximate route maps for private hire EVs are visible
UB003		Produce a heat-map showing density of trips (by borough)	Ability to attach energy consumption to private hire EV routes Understanding of areas of use for private hire EVs
UB004		Produce a heat-map showing number of miles driven (by borough)	
UB005		Identify patterns in trips taken (impact of weather, large public events, transport strikes, public holidays, time of day, day of the week, season)	
UB006		Create 'Trip Profiles' by comparing trips (inner city, night shift, long distance, outer suburb to inner city)	Classification of PH driver behaviour into groups of similar behaviour complete
UB007		Create 'Vehicle Profiles' including make, model, average region of operation (miles, minutes) and 'Trip Profiles'	Grouping of vehicles into distinct categories with similar performance and behaviour complete, allowing for analysis and predictions based on indicative category averages

Activity ID	Sub-objective	Activity	Outputs
UB008	Analyse the charging requirements of private hire EVs	Generate estimated ‘between-trip’ (journeys made without passengers) data from existing data (mileage, specific routes)	Approximations of charge locations for on-street charging
UB009		Identify 'wait zones' between trips (location, duration)	
UB010		Produce a heat-map showing time spent in 'wait-zones'	
UB011		Map existing public charging infrastructure (incl. charge-point speed, charge-point operator) from available data, assume average London charge-point power rating if data unavailable	
UB012		Assess overlap of 'wait zones' with charging infrastructure locations and define as ‘charge event zones’	
UB013	Analyse the charging requirements of private hire EVs	Estimate daily start location of each EV	Assigned battery percentage along the routes taken by the private hire EVs
UB014		Estimate battery consumption for vehicle profile (based on mileage, weather, duration of trip, driving behaviour, route profile)	
UB015		Approximate EV SoC along the trip routes	
UB016	Analyse the charging requirements of private hire EVs	Iteratively change individual EV start battery charge-level, assess whether low battery SoC zones (geographical regions of incidences of low charge-level) are associated with assumed charge event zones, if not, update EV start SoC	Approximations of charge locations for charge-at home EVs
UB017		Identify vehicles which are likely to be charged off-street (high percentage start, no wait times on route etc.) and define as ‘home-charging’ private hire EVs	
UB018		Assign ‘home-charging’ private hire EVs with charge-event zones by analysis of common working day start/end location	
UB019		Assess model predictions of home charging private hire EV location by comparing with availability of off-street parking	
UB020		Include ‘home-charging’ and ‘street charging’ as categories in ‘Vehicle profiles’	

Activity ID	Sub-objective	Activity	Outputs
UB021	Analyse the charging requirements of private hire EVs	Model load profiles for each EV charging based on time and location of assumed charge, assuming 'un-managed' charging utilised (speed defined by speed of estimate public charge-point used, off street parking assumed 7kW charging)	Approximations of time and magnitude of charge events
UB022		Build indicative load profiles for each private hire EV category (charge type, trip type) with functionality on weather, public events, time of day, day of week	
UB023		Determine kWh requirements and relationship to weather, season, events etc.	
UB024		Produce a heatmap of kWh charging requirements (by borough) for a given week	
UB025		Produce a heatmap of kWh charging requirements in peak hours (4-6pm week days) (by borough) for a given week	
UB026		Determine average charge location for each EV and add to 'Vehicle Profile'	
UB027		Update charging requirements, heat maps as vehicles join the trial	
UB028	Model the effect of private hire EV charging loads on distribution network infrastructure	Associate 'charge event zones' with distribution network infrastructure	Profiles for associated distribution network infrastructure (load, voltage, etc.) Understanding of current level of strain on distribution network Knowledge of locations of the distribution network with large volumes of spare capacity
UB029		Gather historical network capacity data (headroom capacity, load factor)	
UB030		Produce a heatmap of distribution network capacity availability given EV uptake levels prior to trial	
UB031		Update capacity heatmaps throughout the trial	
UB032		Given monitoring from Royal Mail and Centrica trials, assume times of day/week/year at which constraints appear on the network	
UB033		Calculate contribution of private hire EV charging in these constrained times	
UB034		Determine 'vehicle profiles' that are most likely contribute to network constraints	

Activity ID	Sub-objective	Activity	Outputs
UB035		Run sensitivity analysis on 'vehicle profiles' (mileage, charge event location, charger speeds) and consider impact on network capacity headroom and load factor	
UB036	Develop private hire EV uptake models	Monitor EV 'vehicle profiles' over trial duration	Forecasts for EV growth as a precursor to predicting future EV charging requirements
UB037		Determine trends in private hire EV uptake into the trial (monthly EV number growth, average region of operation, average charge locations)	
UB038		Compare trial data with publicly available EV uptake models	
UB039		Predict private hire EV uptake for each borough (home location) until 2030	
UB040		Predict private hire EV activity in each borough (minutes/miles of operation) until 2030	
UB041	Identify potential charging infrastructure requirements	Compare EV routes for charge at home EVs versus public charging EVs (average regions of operation for same 'category' of vehicle, heat-map of miles/minutes in each borough)	Location and charge-point rating recommendations for new/refurbished infrastructure.
UB042		Determine whether public charging private hire EV drivers manipulate their route due to charge-point location	
UB043		Survey EV drivers for perspective on charge-point deficient regions	
UB044		Identify 'wait zones' between trips (location, duration) for charge at home EVs	
UB045		Iteratively change the starting battery SoC for charge at home EVs, simulating the removal of the home charging event, and map incidences of low charge	
UB046		Generate potential locations for charging infrastructure based on convergence of 'wait zones' and energy requirements for EV data	
UB047		Generate potential locations for charging infrastructure based on convergence of routes and energy requirements for diesel vehicle data	
UB048		Produce a heatmap of kWh charging requirements (by borough) for a given week for future EV uptake scenarios	

Activity ID	Sub-objective	Activity	Outputs
UB049		Produce a heatmap of kWh charging requirements in peak hours (4-6pm Week Days) (by borough) for a given week for future EV uptake scenarios	
UB050		Generate specifications for charging infrastructure required due to future EV growth (location, speed)	
UB051	Predict the impact of private hire EVs charging on the network in the future	Model network effects resultant of private hire EV charging given future uptake scenarios (assume charging locations do not change)	Vision of future private hire EV impact on network Variable model that can take in inputs which represent different potential scenarios (legislation, public opinion, etc.)
UB052		Model network effects resultant of private hire EVs charging given future uptake scenarios (assume suggested charging infrastructure installed)	
UB053		Produce a heatmap of distribution network capacity availability erosion for high percentage EV penetration levels	
UB054		Perform sensitivity analysis on network effects with regards to charger rating at each predicted charge location (kW)	
UB055		Predict incidents of clustered private hire EV charging and estimate impact (headroom erosion) on local distribution network infrastructure	
UB056		Explore the impact of future legislation on EV usage/charging requirements	
UB057	Translate simulated and measured network effects into infrastructure upgrade requirements[21]	Determine private hire EV numbers required to consume spare capacity on relevant distribution network infrastructure	Understanding of implications of private hire EV uptake to DNO
UB058		Use private hire EV uptake models to develop scenarios that result in the requirement for infrastructure reinforcement in the next 10 years	
UB059	Translate anticipated upgrade requirements into DNO costs[22]	Apply DNO costing method for bringing reinforcements forwards/delaying reinforcements to evaluate network benefits/costs associated with un-managed/smart charging of EVs	

[21] Activities under this sub-objective are additional learnings and will be carried out subject to time and resources being available.
[22] Activities under this sub-objective are additional learnings and will be carried out subject to time and resources being available.

10.3.2 Objective 4

Assess the ability of EV fleets to provide flexibility services to the DNO

Table 48 – Mixed trial objective 4 activities

Activity ID	Sub-objective	Activity	Outputs
UB060	Consider DNO future flexibility needs	Given future EV uptake scenarios, determine charging infrastructure (existing or suggested) that exist on a constrained network (less than 10% capacity headroom)	Understanding of the extent of overlap between DNO flexibility needs and flexibility available from private hire EV charging is achieved Driver costs for different types of flexibility provision is calculated
UB061		Given future EV uptake scenarios, determine patterns in peak loads on relevant network infrastructure (magnitude, times of day, day of week, season, etc.)	
UB062	Determine operational feasibility of private hire EV operators providing flexibility services to DNOs	Determine whether incentivising drivers to charge at a different location (location shifting) can be used to alleviate predicted constraints	
UB063		Calculate driver diversion (minutes, miles) from route from location shifting	
UB064		Associate a cost to driver diversion for location shifting	
UB065		Determine whether pre-emptive/delayed charging can be used to alleviate predicted constraints	
UB066		Calculate driver diversion (minutes, miles) from route due to pre-emptive charging	
UB067		Associate a cost to driver diversion for pre-emptive charging	
UB068		Determine the magnitude of plugged-in flexibility availability at any one time throughout the trial duration	
UB069		Simulate the magnitude of plugged-in flexibility availability at any one time given EV uptake and charger rating scenarios	
UB070		Simulate provision of flexibility from on-street rapid charging based on network needs	
UB071		Estimate time and financial implications of rapid on-street flexibility provision to the driver	

Activity ID	Sub-objective	Activity	Outputs
UB072		Create aggregated load profiles for charge-at-home private hire EVs for present and future scenarios (assuming ‘un-managed’ charging)	
UB073		Determine potential value from aggregation of charge-at-home private hire EVs for use in providing flexibility services to the DNO	
UB074		Assess potential for ‘profiled connection’ at clustered vehicle sites (duration of charge-events, predictability of charge-events)	
UB075	Develop business models for private hire EV flexibility provision	Consider connection costs for suggested charging infrastructure based on basic connection application	General speculations as to potential market mechanisms are made
UB076		Consider connection costs for suggested charging infrastructure based on a profiled connection application	
UB077		Consider how lower connection costs may benefit PHV operators	