NIC Project UKPNEN03 Deliverable D7

Appendix 8
Results of the trial experiments

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Optimise Prime

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

Contents

1 Results of the WS1 home charging experiments ____ 2
2 Results of the WS2 depot charging experiments ____ 6
3 Results of the WS3 mixed charging experiments ____ 13

Deliverable D2 set out a number of experiments for each trial that would, together, meet the project's objectives and answer the key questions. The answers to the key questions are discussed in the final report. This report addresses the initial hypothesis of each of the experiments and gives a brief description on the outcome. A more detailed overview of the outcome of the trials can be found in Appendices 1 and 2.

1 Results of the WS1 home charging experiments

1.1 CEN_Ex_01

Hypothesis: The relative contribution of unmanaged charging of charge-at-home electric vehicles (EVs) to overall home electricity consumption can be predicted using analysis of internal combustion engine vehicle (ICEV) operation

The trial's analysis, based on the study of ICEV data, has found that the charging of EVs is likely to significantly increase electricity consumption at drivers' homes. From this analysis it can be seen that unmanaged charging is likely to result in a peak in charging demand between 17:00 and 20:00. The trials confirmed that unmanaged load peaks during this period. While it was not possible to monitor drivers' home electricity use, this is likely to coincide with peaks in household demand on the grid. The demand profile for a Class 1 domestic customer[1] peaks between 17:00 and 19:00 at around 1kW on a winter weekday. Compared to this, a 7.4kW EV charger would be a very significant load. Taking into account the diversity of load across the fleet the average load per EV is approximately 1.4kW (see Appendix 2 for further details of the load analysis) – even this level of load can potentially more than double the average household load at this time.

The comparison of the use of **ICEVs and EVs** within the British Gas fleet has shown that, while there are some differences, **the overall pattern of use of the vehicles is very similar**. As a result of this, it is believed that **the use of data from existing ICEV fleets should be a good proxy for predicting the operational and charging patterns** of future EV fleets. This was supported by the close correlation of predicted un-managed charging load, and the pattern of charging load observed during the trials.

1.2 CEN_Ex_02

Hypothesis: The relative contribution of smart charging of charge-at-home EVs to overall home electricity consumption can be predicted using analysis of ICEV operation and unmanaged EV charging behaviour

Both unmanaged and smart charging behaviours have been predicted based on the ICEV data.

For smart charging two different models were created – deferred charging, where only the time of charging was altered, and load balancing, where the peak load on the network is minimised.

[1] https://www.elexon.co.uk/operations-settlement/profiling/

The deferred charging scenario was tested during the trials (for more details see Appendix 2). The results were similar to those predicted in the initial analysis of the ICEV data – that load could be shifted away from the evening until after midnight, successfully. A consequence of this – shown both in the initial analysis and the trial results – was the creation of a secondary peak after midnight which was of a higher magnitude than the original peak. In the trials, where all load was delayed until early in the morning, the new peak EV load was 66% higher than the original peak.

1.3 CEN_Ex_03

Hypothesis: EV charging demand will be influenced by weather and seasonal events

The seasonal demand pattern has been studied based on British Gas' ICEV data. It has shown that for this fleet there is a significant variation in seasonal demand as a result of an increased numbers of trips, greater mileage and lower vehicle efficiency in the winter months. Winter EV energy requirements were found to be around 30% higher than in the summer.

Appendix 2 explains the trends found in more detail.

1.4 CEN_Ex_04

Hypothesis: Charge-at-home EV charging causes low magnitude, local constraint on the low voltage (LV) distribution network but poses a more significant effect at higher voltages due to network clustering

Applying Optimise Prime data to the network planning models used by UK Power Networks demonstrates that there is very little difference in terms of thermal reinforcement (LV cables) volume from the baseline forecast. However, a greater impact on power network assets such as distribution transformers can be noticed. It also highlights the additional opportunity from smart charging of fleets in addressing these constraints.

1.5 CEN_Ex_05

Hypothesis: Charge-at-home commercial vehicle electrification has higher DNO cost implications than depot-based vehicle electrification

At present, costs for upgrade of shared assets caused by increased domestic demand is socialised between all customers, while a cost is charged to commercial customers requiring a connection upgrade at their site should reinforcement of shared network asset be necessary.

From April 2023 the charging methodology will change, with commercial customers not being responsible for shared network upgrade costs, only for extension assets that serve their site. As a result of this change the cost absorbed by network customers through the DNO will become similar for both home and depot electrification.

1.6 CEN_Ex_06

Hypothesis: In the absence of an industry solution to the separation of commercial load on a domestic connection, software solutions based on data from charge points (CPs) and telematics can provide an effective alternative, saving money for the driver and fleet

Centrica has shown through the project that it is possible to manage reimbursement of charges for a commercial load through a software solution.

Implementation of such a solution saves money for the fleet operator, as the cost of manually reimbursing electricity use would likely be resource intensive and more prone to error. Centrica has also developed functionality to participate in the project's flexibility events and charge to a tariff, potentially reducing costs further.

There is no direct financial impact on the driver, as they are reimbursed for the power at cost. There could potentially be scope for any savings from flexibility or smart charging to be shared with the driver as an incentive.

Despite this, it has become clear through the project that an industry solution, with separate metering and billing of commercial load, could potentially provide additional benefits to both parties, for example:

- The driver would not have to be part of the reimbursement process – the usage wouldn't appear on their bills and they would not have to settle the account. This would remove potential worry over budgeting and ensuring they are being paid correctly.
- Centrica would be able to choose the tariff and supplier for its commercial load. This would make it easier to utilise time of use tariffs, allow negotiation of commercial rates and simplify the payment process.

Following the implementation of this initial process, Centrica has trialled a commercial solution that solves the first of these two issues by reimbursing the customer's electricity account directly. More details of the solutions trialled by Centrica can be found in Appendix 9.

1.7 CEN_Ex_07

Hypothesis: The Total Cost of Ownership (TCO) of charge-at-home EVs will be higher than ICEVs due to higher upfront costs

In the short term this is correct, although this can vary depending on the fleet. Analysis based on the British Gas fleet found that EV TCO is currently higher, with the cost of leasing/purchase being the main driver of this difference. Vehicles which travel further will have a more favourable TCO, as the running costs of EVs are lower, offsetting the higher purchase cost.

It is anticipated that the cost of commercial EVs will decrease over time as production ramps up, however during the project prices have not declined due to continued shortage of supply in the market. This has also resulted in extended waiting lists for vehicles, which have limited the growth of EV fleets. More detail on fleet TCOs can be found in Appendix 4.

1.8 CEN_Ex_08

Hypothesis: Distribution network constraints caused by charge-at-home commercial EVs will be minimised through combination of smart charging and time of use (ToU) tariffs

Smart charging behaviour has been predicted based on the ICEV data. Modelling shows that smart charging could have a significant impact on power demand, although the type of smart charging implemented must be chosen carefully. Simply shifting the demand later may result in higher peak demand if charging events that were more spread out during the day/evening were shifted to start simultaneously, in the form of a secondary peak. Smart charging that is based on load spreading or balancing over the time the vehicle is plugged in could reduce peaks in EV demand significantly.

The trials with the British Gas fleet validated this modelling. Smart charging, simulating a tariff, was very successful in reducing demand at the network peak time in the early evening but created a higher peak in the early morning, since the cost-based control results in all vehicles starting charging at similar times.

In practice there are still barriers to fleets taking up this type of smart charging, as the cost of charging is based on the driver's choice of tariff and most tariffs are not time of use. Without time of use tariffs there is little incentive to implement this type of smart charging. Further details of smart charging load can be found in Appendix 2.

1.9 CEN_Ex_09

Hypothesis: Reliance solely on home-based charging is not suitable for vehicles with reactive operational behaviour, travelling large distances or carrying heavy loads

The study of the usage of the British Gas ICEV fleet has identified that the majority of journeys that are currently performed by British Gas drivers should be possible with the EV model that has been chosen for British Gas, using at-home charging. Drivers undertaking reactive work, outside of normal hours or schedules have been found to generally drive shorter than average distances, so this mode of work is unlikely to be a barrier to electrification. However, at this stage in the rollout relatively few reactive schedules are being operated by EVs – this may be due to driver perceptions affecting the decision to convert to EV or the seasonality of reactive work.

There are some longer trips taken, in the range of 140-200 miles, that might require top-up charging in order to be carried out by current generation of EV vans. However, these trips are very few in number. British Gas provide drivers with access to public EV charging networks for this purpose. Analysis of trips has shown EVs and ICEVs are both completing longer journeys. There is also no difference in loading weight between EV and ICEV operations. The limitations of home-based charging arise more from the home itself than from the vehicle; many drivers do not have access to a suitable off-street location for a home charger to be installed, and even those that have space do not always have suitable electrical infrastructure. More information on the analysis of the operational patterns of the fleets can be found in Appendix 2.

1.10 CEN_Ex_10

Hypothesis: The availability for charge-at-home EVs to be utilised for flexibility services can be predicted from smart and unmanaged charging experiments

Centrica found that the predictability of their fleet’s ability to provide flexibility services was high, especially on weekdays, where there was a 95% confidence. At weekends, predicting available flexibility was more challenging due to fewer drivers working at this time. Details of the outcomes of the flexibility trials can be found in Appendix 1.

1.11 CEN_Ex_11

Hypothesis: Flexibility from charge-at-home EVs will be best suited to long-term weekend contracts or short-term over-night contracts

Trials with Centrica found that home charging on weekdays was relatively predictable, and as a result, flexibility could be offered on longer term contracts. The peak time for charging is in the early evening, making this the most reliable time for flexibility provision.

Weekends were much less predictable, due to most drivers not working at this time, and would be less suited to flexibility provision. The volume of charging was also lower at weekends. Overnight periods are more difficult to flex, as there is limited time afterwards to charge before the vehicles are needed. This is unlikely to be an issue as there is low demand for flexibility at this time.

1.12 CEN_Ex_12

Hypothesis:
a) Drivers’ opinions of EVs and related smart technologies will become more positive with an increased exposure/experience.
b) External factors rather than organisational factors are seen as main barriers to EV transition by corporate management.
c) Smart charging needs to offer clear benefit to both the drivers and the fleet operator in order to be accepted.

The Centrica driver surveys resulted in the following key conclusions:

a) **Drivers generally have positive opinions of EVs**. Experience of EV use reduces some concerns over range and capability of vehicles, though the charging experience becomes more of a concern. Overall there was a clear improvement in the extent to which British Gas drivers would promote the adoption of EVs and related technologies in their organisation between the two survey rounds.
b) **Managers view the availability of appropriate vehicles** as the key barrier to timely adoption of EVs. Acceptance by drivers is generally not a major issue, although increasing electricity costs have made some drivers wary of charging at home.
c) There is a mixed perception towards smart charging amongst British Gas drivers. While **there was overall support (70% amongst EV drivers) for smart charging**, and a commonly held belief it can save the business money, there was also a **significant degree of perceived risk that it might not guarantee enough charge**. **Communication of the benefits is likely to be necessary** to ensure ongoing support from drivers.

More details of the behavioural findings can be found in Appendix 5.

1.13 CEN_Ex_13

Hypothesis: Centrica as a fleet operator will prioritise TCO minimisation above operational aspects

Centrica takes both cost and operational impact into account when deciding when to change to EV, for example Centrica:

- Waited until an EV was available that was practical for the majority of workload
- Does not necessarily require EV to be TCO neutral/positive. Significant value is also gained from the environmental and public image benefits of operating an EV fleet.

1.14 CEN_Ex_14

Hypothesis: Charge-at-home commercial EV fleets are not attractive to aggregators for flexibility provision

The trials have shown that the charge-at-home EV fleet is likely to be of interest to aggregators. This is because the charge-at-home EV fleet has proven to be predictable, reliable, and available at a time which provides a benefit to the network.

Interviews with aggregators in Deliverable D5 have shown a strong appetite for providing flexibility from electric vehicles. However, a number of key barriers to doing so exist at present including the limited number of EVs currently able to provide flexibility and the need for increased standardisation/automation in order to bring down the costs of delivering flexibility.

2 Results of the WS2 depot charging experiments

2.1 RM_Ex_01

Hypothesis: The impact of unmanaged EV charging on Royal Mail depot electricity demand can be predicted using analysis of ICEV operation

The operational schedules of fleets have to be taken into account when electrifying, since vehicle distance travelled and depot leave/return times are critical to predicting EV energy requirements and CP plug-in/plug-out times.

The Royal Mail operational schedules analysed varied by depot and varied depending on vehicle type (EVs/ICEVs). This highlights the need to consider each depot separately when planning, and not apply models developed based on other locations.

Overall, the ICEV schedules were found to be useful in predicting overall electricity demand. However, some specific circumstances need to be considered:

- Care should be taken with regard to interpreting when load will occur, as there is often a lag between vehicles arriving back at the depot and plugging in.
- Seasonal changes were found within the EV operations, highlighting the need to use a significant amount of data (preferably at least a year) to estimate the maximum load.
- Vehicle efficiency is lower in the winter and this needs to be considered when sizing demand.
- Operational differences, such as having more than one EV per CP, or having shifts where EVs return to the depot in the middle of the day can impact on the predictability of EV load.

More information about operational factors can be found in Appendix 1.

2.2 RM_Ex_02

Hypothesis: The impact of smart charging on Royal Mail depot electricity demand can be predicted using analysis of ICEV operation and unmanaged EV charging behaviour

The simulations of smart charging based on ICEV data showed that peak load minimisation and cost minimisation could be achieved at Royal Mail depots. The modelling indicated that smart charging schedules could yield cost savings for Royal Mail and other depot-based fleet operators by managing charging load to avoid peak energy cost times. The same technique should also alleviate pressure on the distribution network at times when it is most constrained. In addition to reducing costs from peak energy usage, estimates of connection costs for the full electrification of several Royal Mail sites was carried out. In all of the sites studied, it was found that connection costs could be avoided or significantly reduced if peak load was reduced through peak load minimisation-based optimisation.

The modelled findings were supported by the practical trials: implementation of smart charging control successfully reduced the amount of energy delivered at times when electricity was most expensive and reduced the maximum peak in load at the depot. However, the magnitude of savings in both cases was less than predicted by the models, due to the implementation of measures to limit risk to operations. A floor charge rate of 6A minimum was imposed on all CPs to ensure that vehicles would always receive a full charge by the next day. This limited ability to move load to cheaper tariff times of day, as vehicles in some cases were already fully charged, even at the minimum charge rate, before the cheaper tariff time period started.

2.3 RM_Ex_03

Hypothesis: EV charging demand will be influenced by external factors such as weather and seasonal events

Charging demand at Royal Mail sites was found to vary seasonally, with several drivers of demand:

- Efficiency of vehicles was lower during winter, likely in part due to use of heating – vehicles at Mount Pleasant depot used 20% more energy per mile travelled
- Vehicles travelled slightly further, on average, in the winter at most depots
- The timing of demand also changed seasonally; plug-in times were generally later in the winter due to longer shifts

As a result the peak demand from unmanaged charging was 33% higher in winter compared to summer at the largest depot, and 41% higher when considering all days in the trial.

There was some variation between depots, with one depot experiencing a higher average load in the winter but a higher peak load in the summer, because load was more concentrated in a shorter period of time.

2.4 RM_Ex_04

Hypothesis: The load profile of Royal Mail depots can be predicted based on the degree of electrification of the fleet and the charging mode adopted (unmanaged or smart)

As part of the modelling of different load scenarios for RM_Ex_01 and RM_Ex_02, expected load profiles were produced and different charging scenarios were trialled at each of the Royal Mail depots.

The load at smaller depots (or depots with a smaller number of EVs) was found to be more difficult to predict, as relatively small changes can result in large changes in load patterns. This was a particular issue when making bids for flexibility services, as discussed in Appendix 1. The load predictions for depots with more EVs were more successful.

The load shift resulting from time of use smart charging can be predicted to an extent, but restrictions such as the minimum charge rate, and the relationship between the time of use bands and the unmanaged charging pattern needs to be considered, as these can reduce the scale of the response.

2.5 RM_Ex_05

Hypothesis: The impact of installation of other LCTs on the load profiles of electrified depots can be predicted

The project made a prediction of the potential for on-site generation from LCTs at two Royal Mail depots. Details of this analysis can be found in Appendix 2. While the output of LCTs does vary, it can be predicted relatively accurately and is not likely to change significantly. If the load of the site, including EVs is known, this can be used with the LCT output calculation to demonstrate the impact of the LCTs on EV load.

2.6 RM_Ex_06

Hypothesis: The need for network reinforcement resulting from depot fleet electrification can be mitigated through profiled connections

Profiled connections have been simulated and trialled at the Royal Mail sites. Trials of the profiled connection systems have shown that it is possible to control overall load in line with a profile at some sites through the use of EVs.

There is however a need for a minimum volume of EV load, in proportion to background site load, for the EV load to be able to be controlled without background load breaching the profile. This is explained further in RM_Ex_10.

Use of the profiled connection load profile in the strategic forecasting system showed an ability to reduce peak load on specific substations and create a saving on network reinforcement overall versus an unmanaged case. While investment in reinforcing the network may be reduced, deferred or avoided in specific locations it is unlikely to be entirely mitigated.

Eight Royal Mail sites which are being considered for future electrification were analysed with the site planning tool to evaluate how load could be managed with smart charging and profiled connections. The cost of upgrades needed to accommodate the resulting load profiles were analysed by the UK Power Networks connections team. This showed that in the majority of cases network reinforcement could be either avoided or reduced, resulting in potential cost savings of up to £95,000 per site and reduced time to connect.

More detail on the profiled connection trials can be found in Appendix 1.

2.7 RM_Ex_07

Hypothesis: LV distribution network impacts resulting from depot EV charging can be predicted

Applying Optimise Prime data to the network planning models used by UK Power Networks demonstrates that there is a greater impact on power network assets such as transformers, and the impact on LV cables was minimal. It also highlights the additional opportunity from smart charging of fleets in addressing these constraints.

2.8 RM_Ex_08

Hypothesis: High voltage (HV) distribution network impacts resulting from depot EV charging can be predicted

Applying Optimise Prime data to the network planning models used by UK Power Networks demonstrates that there is a bigger impact on the higher power network assets such as transformers. It also highlights the additional opportunity from smart charging of fleets in addressing these constraints.

2.9 RM_Ex_09

Hypothesis: Depot vehicle electrification has lower DNO cost implications than return-to-home vehicle electrification

At present, costs for the upgrade of shared assets caused by increased domestic demand is socialised between all customers, while for commercial sites requiring a connection upgrade, a cost is charged should reinforcement of shared network asset be necessary.

From April 2023 the charging methodology will change, with commercial customers not being responsible for shared network upgrade costs, only for extension assets that serve their site. As a result of this change the cost absorbed by network customers through the DNO will become similar for both home and depot electrification.

2.10 RM_Ex_10

Hypothesis: EV load shifting can enable adherence to a profiled connection without exposing the DNO to unacceptable risks

The ability of EV load shifting to manage adherence to a profiled connection was tested in the Optimise Prime trials. A key determinant of whether EV load can be used to maintain the profile is the size of the controllable EV load relative to background load. If the EV load is less than the variation in non-controllable load, then it may not be effectively controlling the peak load of the site.

If profiled connections are set close to predicted demand there may be a risk that the connection capacity for a site is breached by load that cannot be controlled. It is recommended that profiled connections are based on a significant amount of historical load data, and if this is not available, they are initially set with a buffer and refined as more data becomes available.

If a connection upgrade is required solely for adding electric vehicles to a site, then it should be possible to control the additional EV load within the profile. However if an upgrade is needed also due to increases in uncontrollable load, or if the profile requires a reduction of load at some times, the ability of the EVs to enable adherence needs to be considered.

2.11 RM_Ex_11

Hypothesis: Profiled connection agreements are financially advantageous to both depot operator and DNO

The trials have shown that use of smart charging to limit load (potentially, but not necessarily linked to a profiled connection) can reduce the costs of connection for some Royal Mail depots, with savings of up to £100,000 when installation of a sole use transformer can be avoided.

Changes to charging methodologies from April 2023 will alleviate the risk of the fleet being responsible for shared network asset reinforcement, with the majority of costs now being met by the DNO. As a result of this, the DNO, and network customers could potentially benefit more from profiled connections, if they can defer network reinforcement. However, there may be less incentive for customers to accept such an agreement if there is limited financial incentive.

2.12 RM_Ex_12

Hypothesis: Profiled connection agreements and flexibility services reduce fleet TCO

The trials have shown that use of smart charging to limit load (potentially, but not necessarily linked to a profiled connection) can reduce the costs of connection for some Royal Mail depots. Revenue can also be created from flexibility services.

The impact of both of these has a relatively small impact on the overall TCO when compared to vehicle purchase and running costs. However, with many TCO cases finely balanced the savings could tip the balance in favour of electrification, and as the cost of vehicles reduces over time, the relative importance of these savings to the TCO could increase.

2.13 RM_Ex_13

Hypothesis: Profiled connection agreements reduce lead time and costs to electrify fleets

Where there is limited capacity for expansion, profiled connections can reduce lead times by avoiding the need for upgrades higher up in the network. Use of the Site Planning Tool has also found that there is often scope for businesses to manage charging within their existing connection capacity by managing charging or making alterations to electrification plans.

2.14 RM_Ex_14

Hypothesis: Smart electrification strategies (load balancing, flexibility and profiled connections) reduce DNO costs

In general, smart electrification strategies reduce DNO costs versus an unmanaged scenario. Modelling has shown that cost differences were most prominent in the requirement for upgraded transformers.

Analysis of the different strategies trialled showed limited difference between the strategies, which result in similar outcomes.

2.15 RM_Ex_15

Hypothesis: Optimisation of depot LCTs with the EV fleet creates additional benefits

While there are limited LCTs, such as solar panels, installed at some of the Royal Mail depots it was not possible to measure their impact on site load during the trial.

Optimise Prime has however analysed the potential for solar power and battery energy storage systems at two Royal Mail depots – Dartford and Premier Park – and compared it to the load at these sites. It was not possible to do this for all depots, as some had complex layouts/roof structures which made estimating the potential for solar installation difficult without a full survey.

The sites were found to be very compatible with solar generation, able to utilise the majority of generation on-site at the time of generation resulting in a relatively short payback period on the investment. Analysis of the future load of the wider Royal Mail fleet (Appendix 2) has shown that load is likely to coincide with solar generation throughout their UK estate. Battery storage was found not to be necessary or cost effective at the sites studied due the high proportion of energy self-consumed without a battery, though this may vary for depots with less daytime load.

Results from this analysis are summarised in Appendix 2.

2.16 RM_Ex_16

Hypothesis: The availability for depot-based EVs to be utilised for flexibility services can be predicted from smart and unmanaged charging experiments

In broad terms, the availability for depot based EVs to be utilised for flexibility can be predicted from unmanaged and smart charging. However, the exact behaviour of vehicles can vary from day to day or over time. As a result some margin of error needs to be kept, either when making bids for services or evaluating performance. The Royal Mail trials found a number of factors that impact ability to provide flexibility:

- Smaller depots are more susceptible to changes in vehicle routines.
- Charging schedules can shift over time, for example when Royal Mail delivery volumes are lighter in the summer, vehicles return earlier and plug in earlier. This type of behaviour may require a longer learning period to predict.
- While the load for a vehicle may be predictable, the number of vehicles charging at a site may vary over time and changes in the fleet need to be considered when making long term connection or flexibility commitments.
- Where vehicles share CPs, timing of load can be harder to predict.

The trials also offered flexibility alongside time of use smart charging and were similarly successful in offering flexibility. Depending on how the smart charging is implemented it may limit the amount of flexibility that can be offered at a specific time, so the details of the tariff need to be considered when making a bid.

2.17 RM_Ex_17

Hypothesis: Standard connection agreements allow for higher availability of cheaper flexibility compared to profiled connection agreements

The requirements of flexibility, a profiled connection or time of use tariff are likely to overlap, as all three take price signals from network constraints to some extent. As a result of the limitations put in place by a profiled connection, the customer may have lower levels of load at peak times and/or less scope to move load to other times.

However, profiled connections allow the DNO to manage capacity in a local area on a long-term basis, while the flexibility request may be for a temporary additional constraint or wider network requirements. Due to this the requirements of different products will not necessarily overlap. Where they do coincide, the profiled connection will be reducing the need for the DNO to procure flexibility.

In any case, the ability to provide flexibility will be dictated by the amount of flexible load, how actively it’s being controlled and the margin within the profile to reallocate it to another time. The DNO could choose to offer extra capacity within the profile or allow connection breaches to provide flexibility if this provides a net benefit.

2.18 RM_Ex_18

Hypothesis: Flexibility will only be a viable option to depots if procured on long-term contracts for weekend or over-night periods

This is not the case in the trial depots. To be reliable, flexibility provision times must be aligned with the times when EVs are charging in their unmanaged state. This will vary by fleet, but at Royal Mail this usually occurs in the afternoon and evening. Weekend demand is lower and as a result is more difficult to accurately predict and offer reliable flexibility.

This is positive, as requirements for flexibility at the weekend and overnight is generally low.

Availability of flexibility does vary over time, with significant seasonal variation seen at Royal Mail depots. As a result, very long-term contracts may not be appropriate unless they allow the fleet to revise the amount of flexibility available closer to delivery, as this is when more accurate forecasts can be made.

2.19 RM_Ex_19

Hypothesis: DNO current flexibility requirements are unlikely to be met by depot based EVs

In terms of timing, the trials have found that flexible EV demand is most reliably available on weekday evenings, when network demand is highest. The availability (both in terms of timing, duration and volume of flexibility) varies significantly by depot however due to differences in scale and routes at each location. For example, some Royal Mail depots experience demand peaks in the early afternoon, while at others this peak was in the late evening. Analysis of the UK-wide Royal Mail fleet has shown that unmanaged demand at most depots will peak in the early afternoon.

In terms of volume, depot based EVs are likely to form part of a wider portfolio of assets. In Optimise Prime each depot was treated as a separate flexible unit, however this has shown that for smaller depots it is difficult to offer a meaningful quantity of flexibility reliably. This localised approach may however be useful to the DNO in order to solve very localised network constraints, but alone may not offer the reliability the DNO requires.

2.20 RM_Ex_20

Hypothesis:
a) Drivers' opinions of EVs and related technologies will become more positive with an increased exposure/experience.
b) Depot managers are largely supportive of the switch to EVs, despite some operational challenges.
c) External factors rather than organisational factors are seen as main barriers to EV transition by corporate management.
d) Corporate managers are largely in favour of smart charging, while depot managers (operational level) are sceptical.

Two rounds of surveys were carried out with Royal Mail drivers and managers, this allowed the project to analyse changes in opinions over time. Full details of the behavioural surveys can be found in Appendix 5.

Overall there was a high acceptance of EVs from those surveyed and this was maintained through both rounds of the survey.
a) **Drivers were very positive towards EVs** in the first round of the survey. In round two, there was little difference overall, though **some specific depots showed a less positive response**, possibly due to a **belief that the number of vehicles was outpacing the available charging infrastructure**
b) Around **80% of depot managers viewed the EV transition favourably**, despite some concerns over range being sufficient
c) **Corporate managers** identified **vehicle availability as the factor that most impacted the EV transition**, followed by financial pressures, connection and charger availability.
d) While **Royal Mail managers** were found to be **aware of smart charging, no strong opinions were expressed**.

3 Results of the WS3 mixed charging experiments

3.1 Ub_Ex_01

Hypothesis: The time, location and magnitude of electric private hire vehicles (PHVs) charge events can be estimated from Uber trip data

The trials have successfully developed a model of the charge events that would occur based on Uber data. The resulting data gives an indication of where Uber drivers are likely to be charging, or would like to charge if there was sufficient infrastructure.

A range of techniques have been used to identify when charge events could occur, and, based on several factors when drivers charged during the day. Where charging during the shift was found to be unlikely, the charging was ascribed to an estimated home location. The magnitude of actual charge events was then modelled, based on drivers using the most optimal public CP for their journey. For both on-shift and off-shift charging the load on the network is likely to peak in the evening, as vehicle batteries become depleted and daytime drivers return home.

The project has successfully estimated the load coming from PHV charging, based on journeys made on the Uber platform.

3.2 Ub_Ex_02

Hypothesis: The time, location and magnitude of electric PHVs charge events will be influenced by external factors such as weather and large public events

Weather and time have been studied as potential influencers on charging patterns. It was found that weather has very little impact on EV trip volumes, and hence on the level of charging that is being modelled.

It is possible however that weather affects the efficiency of vehicles – this impact cannot be estimated from the Uber trip data alone. The telematics data from WS1 could be used to estimate the impact from operating in colder weather – 7% more energy was found to be required for every 10ºC decline in temperature in this trial.

Time was found to have a greater influence than weather on trip and charging patterns. There are definite patterns in daily and day-to-day trips, and this impacts upon when shifts end, when drivers need to, and are able to, charge their EVs.

3.3 Ub_Ex_03

Hypothesis: Existing EV uptake models can be improved using data on actual uptake of electric PHVs within the trial

Optimise Prime has provided summary outcomes from the trial data analysis to help improve UK Power Networks' current modelling of the impact of PHVs on future network load.

This has resulted in some significant changes versus the previous models. EV load at network peak times was significantly lower using the Optimise Prime data for a number of reasons:

- Unmanaged peak charging time for PHVs was later than the normal network peak, unlike some other fleets
- Each EV travelled slightly less on average and was more efficient than predicted in the existing models.

3.4 Ub_Ex_04

Hypothesis: Locations lacking adequate charging infrastructure (current and future) can be inferred from Uber trip data

The trials have mapped both where drivers actually charged (as in Ub_Ex_01) and where drivers were when they decided they needed to charge. Based on this the project was able to develop a range of indicators of the adequacy of charging infrastructure.

There are several locations where drivers have to travel a significant distance in order to charge. LSOAs were ranked on the frequency and distance that drivers had to travel from them in order to charge. Central London areas in the City of London and City of Westminster ranked highly in both of these counts due to the low number of rapid CPs and the high volume of journeys undertaken.

Individual CPs were also studied and based on the optimal CP modelling, the most popular CPs in London are utilised way beyond their capacity, suggesting drivers will have to queue in order to charge when they are at their busiest, or travel further in order to use non-optimal CPs. For on-shift charging, CPs in and around the City of London and City of Westminster were identified as the locations with the highest modelled utilisation, so adding to the charging infrastructure there is recommended. CPs that were added in these areas, particularly in Westminster, during the project were very successful in accommodating Uber EV demand.

For off-shift charging, where long charge events will not impact on abilities of drivers to earn, drivers can more easily utilise the larger number of slow and fast CPs. Nevertheless, proximity to a CP is a key consideration, as drivers are unlikely to want to travel far from where they live to charge, particularly if charging the vehicle on a slow CP while parked for an extended period between shifts.

Future demand has also been forecast. While demand for charging infrastructure is expected to continue to grow, it is expected that patterns of charging will change as the fleet changes:

- The locations of drivers' homes will change, as the home locations of all Uber drivers does not directly correspond with those of current EV drivers
- The importance of on-shift charging will start to decline; as the average range of vehicles increase, more vehicles will be able to complete a full day shift without having to top up. More chargers are likely to be needed in outer areas, at or near drivers' homes, to allow charging at the end of the shift or overnight.

3.5 Ub_Ex_05

Hypothesis: Electric PHVs charging causes low magnitude, local stress on the distribution network at present, but will pose a more significant threat in the next 10 years

Initial work on distribution network impact has involved overlaying the current charging demand in each LSOA on substation capacity, in order to develop heatmaps of areas where constraints may be encountered in the future.

This initial analysis has shown that there is significant variation across the Greater London, although Central London, where on-shift charging takes place is likely in a better position to accept additional demand than the suburban areas of the London where drivers live. Given the expected greater reliance on off-shift charging in future, lower capacity in the more suburban areas could present a barrier to fleet electrification.

Use of data from the Uber fleet in the strategic forecasting system has further confirmed the above, with load from PHVs only resulting in a low reinforcement requirement in the LV across the London Power Networks area. As shown in Appendix 2 Section 3, some more suburban areas have less available capacity, and are likely to face higher demand from off-shift charging, potentially leading to higher reinforcement requirements by 2035.

3.6 Ub_Ex_06

Hypothesis: DNO costs are unlikely to be affected by electric PHV charging in the short term

PHVs are likely to be one of the most rapid adopters of EVs, with Uber aiming to transition all vehicles by the end of 2025, and other PHV operators needing to meet the requirements of regulators such as Transport for London and other local authorities.

There will be costs involved in providing a significant amount of network infrastructure over this time, however analysis of network load has shown that the amount of network investment driven by PHVs in the short term is relatively low, compared to the impact from other vehicles (such as vans), with the peak of investment in replacement cables and transformers coming in the 2030s as other technologies electrify.

This is partly due to the peak load from PHVs generally not coinciding with the network’s peak load – the project’s forecasts expect peak load from EVs to occur in the early hours of the morning, even if smart charging is not used.

3.7 Ub_Ex_07

Hypothesis: Electric PHV fleet operators are unlikely to be significant flexibility providers

The operators themselves are unlikely to be flexibility providers as they do not generally own the vehicles and are not responsible for charging them – drivers would have to choose to offer flexibility.

Operators could promote such services through partners if it were commercially viable.

3.8 Ub_Ex_08

Hypothesis: The value available from flexibility provision is insufficient to alter driver behaviour

There is a clear distinction between off-shift and on-shift charging and the potential for flexibility.

On shift, there is a very clear opportunity cost for charging, as drivers could be earning around £25 per hour by taking trips. Flexibility services that prevent drivers taking trips (e.g. by prolonging charging sessions or pushing them into busy periods) would need to offset this opportunity cost. As an hour of opportunity cost is equivalent to the cost of charging with a rapid charger on a per minute basis it is unlikely that a flexibility payment of sufficient value could be offered. Drivers are also likely to charge as needed, and so are not able to plan around flexibility events.

Off shift, there is potentially greater opportunities for shifting charging, as vehicles will be plugged in for a longer period of time. An aggregated model similar to that trialled with the British Gas fleet could be adopted.

There are, however, a number of factors that may limit the amount and value of flex available from the PHV fleet:

- Vehicles generally plug-in later, with relatively few charging during the evening network peak. Flexibility at other times may, however, become more valuable as demand changes over time.

- A relatively small proportion of PHVs are expected to charge at home because many drivers lack off-street parking. Providing flexibility via on-street infrastructure is likely to be more complicated, and less certain, as drivers may plug in at different locations.
- Use of automated smart charging at homes may reduce the benefits that can be gained from flexibility.

3.9 UB_Ex_09

Hypothesis: Charging infrastructure costs could be reduced using profiled connections across aggregated CPs

Profiled connections are primarily designed to manage aggregated EV load on the distribution network. Because of this, aggregated dispersed load is unlikely to be suitable for a profiled connection, as it will be connected to the network in different places.

Public sites with multiple CPs could potentially benefit from profiled connections, however operating in this way would limit the charge speed attainable by customers at the site and may not be acceptable to customers, especially PHV drivers who could otherwise be earning revenue.