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Assessing the Viability of Electric Vehicles in Daily Life: A Longitudinal Assessment (2008-2012)

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Abstract

The UK's Technology Strategy Board, with central and regional government support, funded the world's largest multi-site demonstration trial of ultra-low carbon passenger cars. 349 cars were deployed supported by the installation of approximately 500 electrical charging points. The trial has contributed to the UK Government's newly published ultra-low emission vehicle strategy. It has also helped vehicle manufacturers and energy suppliers understand how people use these cars and how they feel about them.

Eight project teams comprising at least one vehicle manufacturer, an energy supplier, a local authority, infrastructure provider and a university have gained funding. The trial included two separate research activities:

1. Usage patterns – including time and duration of journeys, energy used and charging location.
2. User perception – questionnaires and interviews with users before, during and after the trail to help understand their feelings about the car and their behaviour with the car.

The first 65 cars were handed over to users on 13th December 2009. By December 2011, 349 vehicles from 19 manufacturers had been deployed over a mix of private domestic, company pool or fleet vehicles. The vehicles have undertaken over 276,000 trips covering over 1,500,000 miles, and have charged over 51,000 times. The vehicle models included the plug-in electric Tata Indica, Mercedes Smart ForTwo, Nissan Leaf, Ford Transit Connect; BMW Mini-E, Mitsubishi i-MiEV, Allied conversions of the Peugeot Tepee MPVs; the hydrogen fuelled Microcab; and performance electric sports cars including the Ecotricity conversion of the Lotus Exige. The fleet also included plug-in versions of the diesel hybrid Land Rover Range-E and the petrol hybrid Toyota Prius. This paper provides details of the programme and results of the research to date, focusing especially on vehicle usage and perception data from 12 months of usage.

Keywords: Battery electric vehicle (BEV), passenger car

1 Introduction

The UK Government (through the Depts. of Transport, Business Innovation and Skills, and Climate Change and Energy) delivered the Technology Strategy Board (TSB) Ultra Low Carbon Vehicle (ULCV) Demonstrator Trial to provide a multi-manufacturer real-world test of vehicles that aimed to assess EV technology, reduce carbon emissions, and accelerate the introduction of EVs to market. Our research groups were responsible for designing methods and analysing data related to private and corporate drivers' experiences of driving their EV. This work marks a comprehensive assessment of both vehicle-related and driver-related factors that contribute to successful integration of EVs into the national fleet.

In total, 349 low carbon vehicles were deployed. Over 90% were pure EVs, with the remaining being plug-in hybrid electric vehicles and fuel-cell vehicles. Collectively, the vehicles completed over 276,000 individual trips covering over 1.5 million miles and recorded over 51,000 charging events.

2 Overview of Data Collection

The vehicle and driver information were collected and analysed by Cenex and Oxford Brookes University on behalf of the TSB and OLEV. Questionnaires and interviews were conducted with over 350 drivers at the pre-trial and three-month trial stage. The drivers, vehicles and their usage patterns were selected by the individual consortia for the purposes of their own projects. The eight consortia were typically made up of OEMs, energy suppliers, universities and local authorities.

3 Drivers and Adaptation

3.1 EV Users

The view that EVs are the domain of those who are solely environmentally motivated was shown to be outdated. The majority of the drivers were Corporate drivers who did not contribute financially to operating the vehicles, whereas 30% were Private drivers who paid for the lease of their vehicles. The vehicles were either issued to, and mainly used by, just one individual driver, or vehicles were available to a Pool of drivers. Drivers did not want to compromise their daily routine and commonly stated that the car needed to fit their lives rather than visa versa.

3.2 Adaptation

Drivers showed immediate *Primary Adaptation* whereby the EV was seen as simple to drive and unfamiliar components such as regenerative braking were adapted to within the first trip. Drivers' sense of having to plan their journeys more carefully was reduced with experience of the vehicle.

3.3 Judgements of Performance

Old performance stereotypes associated with previous generation EVs were successfully countered. The current EVs were seen as fun to drive, smooth, and rated very highly on acceleration from standing and when the car was already moving. Over a third of drivers stated that their EV had *superior* performance to their normal car. The drivers' perception of an EV's flexibility and their ease of use increased over the first 3 months.

4 Journey Patterns

4.1 Distance Travelled

The average trip and daily mileages between user groups were similar. However the EVs were used more often by Private users, allowing them to achieve 37.5% more monthly mileage than Corporate drivers, and 92% more than Pool car drivers.

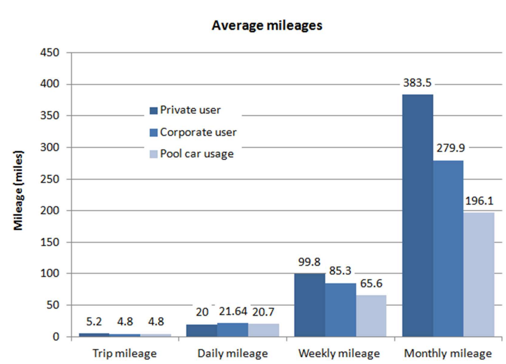

Figure 1: Journey patterns by user group

4.2 Journey Times

The EVs were used mainly during the working day with 71.5% of trips commencing between 8am and 6pm. Corporate users were responsible for 75% of daytime trips and Private users were responsible for 66%.

5 Range and Anxiety

5.1 State of Charge Use

Few drivers experienced range anxiety because they deliberately did not drive at a state of charge that would actually cause concern. The EVs generally had much more battery capacity than was used, with most users driving with a sizeable safety buffer. Private drivers utilised lower battery SoC areas marginally more than Corporate drivers, with Private drivers achieving 21.4% of journeys ending at less than 50% SoC compared with 18.7% from Corporate users.

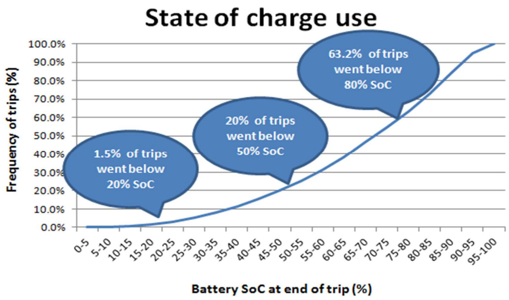

Figure 2: State of charge by trip

5.2 Vehicle Range and Energy Consumption

The average energy consumption across all EVs was 1.5% SoC/mile which extrapolates to a theoretical range of 66.7 miles. The energy consumption of a trip was related to the trip's distance. There was a higher rate of energy consumption per mile and a larger variation in energy consumption for shorter duration trips where users can confidently adopt any driving style in the knowledge that the vehicle has the range to complete its journey. The data suggested that drivers adopted their driving style dependent on the journey length. With longer trips having a lower rate of energy consumption. This was observed across all EVs independent of the vehicles battery capacity.

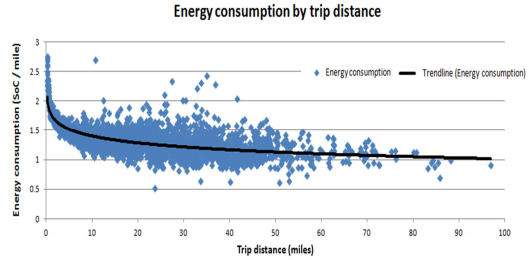

Figure 3: Energy consumption by distance

5.3 Judging Remaining Range

Drivers who actually did challenge the range (or accidentally found themselves in circumstances where they may have run out of charge) achieved *Secondary Adaptation*. This involved being aware of the inter-connected nature of driving style, regenerative braking, route selection, state of charge, and the information fed back from the displays. Drivers who achieved this could drive with a significantly lower safety buffer.

5.4 Judgements of Adequate and Ideal Range

Private drivers said they required a lower range (approximately 83 miles) for their day-to-day driving compared to Corporate drivers who stated that they required a higher range (approximately 109 miles). However, Private drivers required a greater range in order to accommodate all their journeys. A 230 mile range would be ideal to satisfy both groups of drivers.

6 Charging

6.1 Charge Start Times

83% of charge events occurred during weekdays where morning, afternoon and evening peaks occurred at circa 8am, 2pm and 9pm. The 9pm charge peak showed that smart infrastructure was an effective method of transferring the charging load of EVs outside peak electricity use hours where 27% of charges commenced between the hours of 9pm to 1am, this compared to 5.9% of journeys that ended within the same time period.

6.2 Distance Between Charges

Pool drivers adopted good practise in frequently charging the EVs leaving a full charge for the next user. In contrast, Individual drivers had the freedom to plan charging with their anticipated vehicle use. This feature was also observed in the average distance drivers travelled between charging, with Pool drivers travelling 22.3 miles compared to Individual drivers whom achieved an average of 28.7 miles.

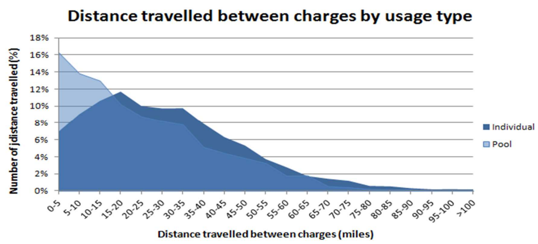

Figure 4: Distance travelled between charges

Distances travelled between charging steadily rose by an average of 14.9% over the first 6 months of vehicle ownership. Since average trip length did not increase over the same period this showed that drivers were gradually becoming more confident undertaking more journeys between charge events.

6.3 State of Charge Transferred

On average the EVs were placed on charge 3.5 times per week. Corporate drivers charged more frequently at 3.7 times per week compared to 3.3 times for Private drivers.

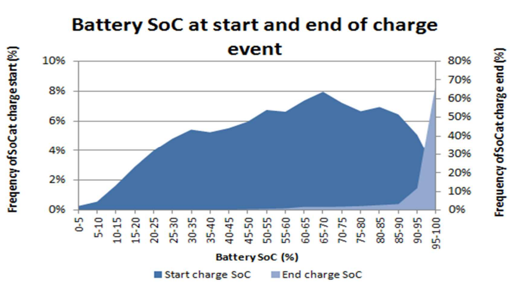

Figure 5: State of charge during charging

The graph above shows the SoC at charge commencement was broadly distributed between 25% and 90%. The EVs were mostly charged until full with the majority of charging (>70%) ending at over 95% SoC. Throughout the loans the drivers gradually increased the average SoC being transferred from 29.0%, 33.2% to 34.3% during months 1, 3 and 6 respectively.

7 Concluding Statements

EVs were positively received by drivers in the trial and were showed to be viable for everyday life. Typical stereotypes of EVs (e.g. owners being purely environmentally focused and EVs having lower drive performance than conventional vehicles) were shown to be outdated. The drivers in this trial drivers were mainly car enthusiasts, interested in assessing EV practicality, and had a desire to advance driving technology.

The majority of drivers whom took part in the trial clearly had access to another vehicle and tended to use the EVs for regular and repeatable journeys. In fact, drivers entered the trial with the intention of using the EV in conjunction with their normal vehicle, and not as the sole vehicle available for use.

The drivers were quick to adapt and there was little range anxiety experienced as most drivers got nowhere near the potential range capability of the EVs.

Over the first 6 months the distances travelled between charging steadily rose by an average of 14.9% showing that drivers were gradually becoming more confident undertaking more journeys between charge events.

There were different levels of adaptation (primary and secondary), with primary adaptors quickly gaining a satisfying level of comfort, performance and routine from the EV. Secondary adaptors attempted a more thorough integration of the EV within their lives and continued to investigate range and performance boundaries. There was limited secondary adaption within the trial. Training, and encouraging users to break down comfort zones, can be used to enhance secondary adaptation, especially with Corporate vehicles users.

Drivers expressed a need for better range prediction from the vehicle and better feedback from the effect of factors linked to range e.g. regenerative braking, driving style, ambient temperate and on-board features. Improvement in this area would also increase the range potential of the vehicles.

These findings have informed the UK Government in designing the newly published strategy for ultra-low emission vehicles in the UK [1,2]. This has enabled construction of policy to support integration of EVs into the national fleet and to understand the degree to which successful integration can be anticipated. In addition, our work has informed energy suppliers of what is required to support drivers in their attempts to charge their vehicles both at home and also away from home as part of a wider public charging infrastructure.

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