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EMBEDDING ELECTRIC VEHICLES WITHIN A LARGE BUSINESS FLEET: EXPERIMENTAL FINDINGS

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Electric Vehicles have the potential to achieve a sustainable transport system. So far, however, the public acceptance of these vehicles is still low, mainly due to their limited mileage range.

The objective of this research is to analyze a system to maximize the integration of Electric Vehicles into the business infrastructure and managing their use and control. For this purpose, the Edinburgh College zero emission car fleet and their booking and managing system was studied. The data obtained from the booking system include the number of bookings, trips and miles driven with each vehicle and it reports several statistics regarding the use and booking of the electric vehicle fleet.

This information enables the evaluation of the booking system and the identification of peak and low frequency travel times related to different business activities. Furthermore, this information will also be useful for EV related policy and procedure makers to identify the charging patterns of the users.

Keywords: *Electric vehicles; zero emissions; sustainable development; planned behaviour*

LA INTEGRACIÓN DE VEHÍCULOS ELÉCTRICOS EN EL SECTOR EMPRESARIAL

Los vehículos eléctricos tienen el potencial de lograr un sistema de transporte sostenible. Sin embargo, la aceptación pública de estos vehículos sigue siendo baja, principalmente debido a su limitada autonomía.

El objetivo de esta investigación es analizar un sistema para maximizar la integración de los vehículos eléctricos en la infraestructura empresarial y administrar su uso y control. Para ello, se estudiará el sistema de reserva y gestión de la flota de automóviles eléctricos de emisión cero del Edinburgh College. Los datos disponibles de este sistema incluyen el número de reservas, viajes y millas recorridas con cada vehículo, y varios datos estadísticos relacionados con el uso y reserva de la flota de vehículos eléctricos.

Esta información permite la evaluación del sistema de gestión de reservas y la identificación de los tiempos de viaje en horas de alta y baja frecuencia relacionados con diferentes actividades empresariales. Además, estos datos también son útiles para los responsables políticos que desarrollan los procedimientos relacionados con vehículos eléctricos para identificar los patrones de recarga de batería de los usuarios.

Palabras clave: *Vehículos eléctricos; cero emisiones; desarrollo sostenible; conducta planificada*

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1. Introducción

Most of the journeys that take place in Scotland are under the mileage range of Electric Vehicles (EV´s). According to Transport Scotland (2016) 94% of these trips are shorter than 40 km, being the average length around 12 km. Internal Combustion Engines (ICE) emits an average excess of 400 million kg of CO_2 in 22.5 billion kilometers in public sector. It means that 550,000 UK trees whole lifetimes would be needed to compensate these emissions (Office of Government Commerce, 2008).

The objective of the Scottish Government is to reach the 100% non-fossil fuel electricity by 2020 (Committee on Climate Change, 2015) and to eliminate all the internal combustion engines from the road by 2050 (Transport Scotland, 2011). Therefore, among other initiatives, the national transport agency for Scotland (Transport Scotland) plans to install several rapid charges every 80 km at list in primary road network (Alba, 2015). According to Taylor et al. (2010) in trips shorter than 100 km, this would have a significant saving in emissions. The location of these charges needs to find the equilibrium between the installation cost, if they are too close the cost would be too high, and the distance between them, if they are too separated the vehicle might not arrive to the next charger. Furthermore, quick chargers not only improve the charging efficiency but also increases the EV using distances.

The 2010 National Travel Survey found out that the 37% of Scottish homes with access to a vehicle can afford a second car (Transport Scotland, 2014). This means that the lower mileage range of EV´s is not a restriction to make longer journeys, since ICE vehicles could be used for this purpose.

Furthermore, the total cost of ownership (TCO) of EVs which includes the purchasing cost of the vehicle, maintenance costs, reparations, tires and combustible and/or energy consumption for a specific distance in a year (Wu, Inderbitzin, & Bening, 2015), is expected to be similar or lower than fuel driven vehicles by 2025. According to previous studies conducted by Milligan (2017) the TCO is not a crucial fact for the ownership of a new vehicle; preference or tailpipe emissions are more important when purchasing a car.

However, the acceptance of the electric vehicles does not only depend on the initiatives of the government and cost of EVs. The introduction and normalization of electric vehicles depends mainly in the users´ approval (Milligan, 2017; Verhoef, Bliemer, Steg, & van Wee, 2008).The theory of planned behavior (TPB) has been used by many researches to explain the usage and trust on electric vehicles (Kaplan, Gruber, Reinthaler, & Klauenberg, 2016; Lane & Potter, 2007; S. Wang, Fan, Zhao, Yang, & Fu, 2016). This theory suggests that the attitudes, perceived behavioral control and subjective norm affect notoriously in the individual's intention of behavior (Ajzen & Fishbein, 1980; Ajzen & Cote, 2008; Ajzen, 1991; He & Zhan, 2018).

According to Rezvani, Jansson, & Bodin (2015), since electric vehicles can reduce the negative effect on the environment, their adoption is seen as a pro-environmental behavior, which is defined as a conscious act to reduce the hazardous effects of human behavior on the environment (Jensen, 2002; Kollmuss & Agyeman, 2002). As suggested by Royne, Levy, & Martinez (2011) there is a direct relationship between environmental worry and the disposition to pay more, since these consumers consider it worthy to pay more for a more sustainable product (Hansla, Gamble, Juliusson, & Gärling, 2008) if its quality is not compromised (D'Souza, Taghian, Lamb, & Peretiatko, 2006).

Nevertheless, the driving range and security of the car are the key factor for the consumer when buying a new car, therefore, the most critical aspect for the consumer acceptance is the technical performance of the vehicle (N. Wang, Tang, & Pan, 2018). According to Egbue & Long (2012) undeveloped battery technology is the mean constrains to the raise of EVs.

Recent studies show that the lack of confidence on the electric vehicles is caused by the insufficient knowledge and uncertainty towards electric vehicles. A research by Schlüter & Weyer (2019) proved by establishing and analyzing car-sharing services that the acceptance and confidence on EVs increases when the consumers use and get to know the electric vehicles.

2. Objectives

The objective of this research is to demonstrate the possibility of increasing the confidence on the use of electric vehicles and to maximize their integration in the business requirements. As noted by Bayus, Erickson, & Jacobson (2003), it is essential for corporates to have a positive introduction of new goods and to identify primary features to ensure their durability and a successful future. Therefore, the early period of the induction of EV in any business needs to have the support of the workers and its acceptance as part of the company transportation system.

This research analyses the effect of incorporating an electric vehicle fleet to the businesses in order to cover the distances that the employees need to drive in their working day. This way, the users will start driving short distances and gaining trust on the electric vehicles leading to longer distances.

For this purpose, trials were conducted in the electric vehicle fleet of Edinburgh College to evaluate their efficiency and to test if they fully meet the staff´s transportation related needs in all campuses.

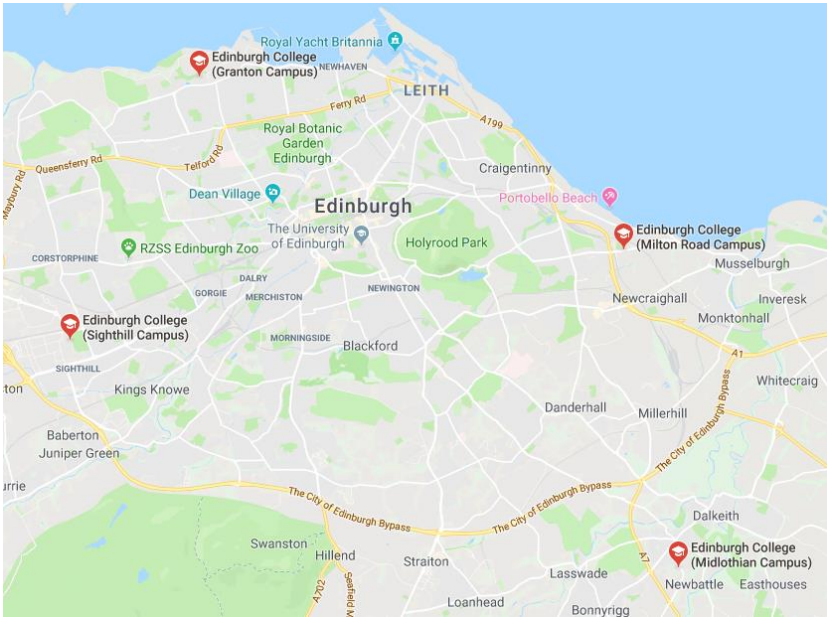
3. Methodology

3.1 Study area: Edinburgh college green fleet

Edinburgh College started to operate a zero-emission vehicle fleet in the year 2011. The first year it functioned as a trial period and since 2012 the college has leased its EV´s to the staff for college business providing a more sustainable, low-cost and low-carbon transportation. The electric vehicle fleet is compound by 10 Nissan, Mitsubishi and BMW electric cars, 4 Nissan vans and an Allied electric minibus.

There are four sites in the Edinburgh College and the figure 1 shows their location in the Edinburgh and Lothian area.

Figure 1: Edinburgh College campus locations (Google maps, 2018)



The distance between the campuses is ideal for electric vehicles (see table 1). There are three charging points in each campus and several easily accessible public chargers between the sites.

Table 1: Distance between campuses

Origin	Destination	Distance (km)
Granton Campus	Sighthill Campus	9.5
	Midlothian Campus	21.1
	Milton Road Campus	11.3
Sighthill Campus	Midlothian Campus	18.4
	Milton Road Campus	24.0
Midlothian Campus	Milton Road Campus	10.3

It is estimated that since this project started, the CO_2 emissions have reduced 50 tonnes and approximately £100,000 in fuel cost (Edincoll, 2017).

The leasing procedure of the electric vehicles in the Edinburgh College works with an easy-to-use booking method. The vehicle reservation program was developed in the college and it is cloud-based. The booking system shows the availability of the electric vehicles and removes them from general availability once they are booked. The program was based in the http://www.bookedscheduler.com/ open software.

The users need to be registered in the college using their email address. The driving license needs to be in place and formation on how to use and charge the vehicles will be shown before the user is allowed to drive electric cars. An identification number will be provided which will be used to access the system account. The users will be able to access to a selected number of EV´s depending on their home campus. Once they have accessed to the

booking system they will be asked to state the date and time that a vehicle will be needed. The screen will show which cars are available and to book a car the applicant only has to click the start button. When this information is entered, the applicant will receive a confirmation email if the application was successful. This email needs to be showed to the staff in the vehicles facilities to get the eCar keys. It is possible to modify or to transfer the booking to other staff member when needed.

3.2 Obtaining data from the booking system

The booking system of the green fleet in the Edinburgh College registers the use of each vehicle available at the campuses. It is important to note that the connections between campuses happen at various times of the day with differing driving and climatic conditions throughout the day and night during the whole academic season. Thus, considering these many different situations and with the purpose of ensuring that the vehicles are fully utilized, the booking programs control system has been analyzed.

Through this program, the following data has been obtained to analyze the efficiency of the electric vehicles and customs of the users.

- Number of bookings.
- Distance travelled per trip.
- Time and date of each booking.
- Re-charging time.
- Usage trends.

Apart from these data, the booking program also reports several statistics regarding the use and booking of the electric vehicles fleet. With this information, the booking management system can also be improved to suit vehicles for the intended journey.

3.3 Users´perception

The electric vehicle booking program enables to access to information regarding to the lengths, origin and destination, time of travel… However, the study does not retrofit the users´ thoughts regarding to the operation of the system. It is a legal requirement to every employer to ensure the safety, health and well-being at work, and this also includes driving their own car to work (Act, 1974).

Therefore, an anonymous survey (Survey Monkey, 2015) was conducted to the staff using the booking program with the objective of identifying the unsuccessful parts of the project and having a perception of key drivers in the system.

The request of the survey was sent to all the authorized EV fleet users in April 2015 for the first time with 8 questions to rate the project between 1 (unacceptable) and 10 (exceptional). The last request was “free text” so the users could write with their own words their perception and opinion on the booking system.

4. Results

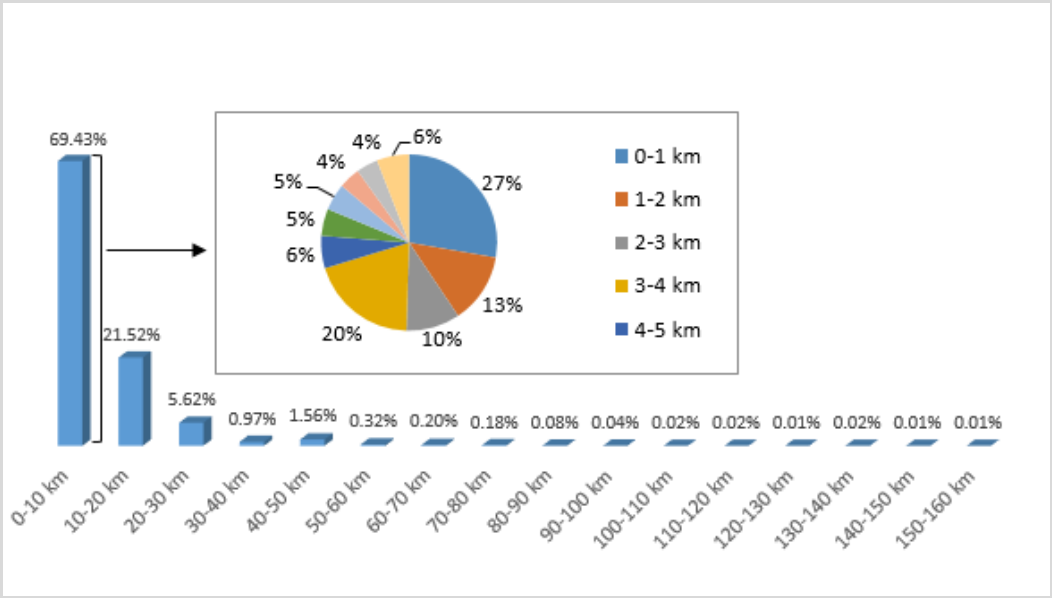
4.1 Booking system

The Edinburgh College electric vehicle fleet data show that 600 staff members are registered and therefore they use the booking system. Since the beginning of the program, over 9,300 bookings, 56,000 trips and more than 250,000 miles have been travelled. Approximately the 85% of the trips are shorter than 16 km since the journeys are commonly between the

campuses. Weiss, Chlond, Heilig, & Vortisch (2014) found out similar results in a previous research.

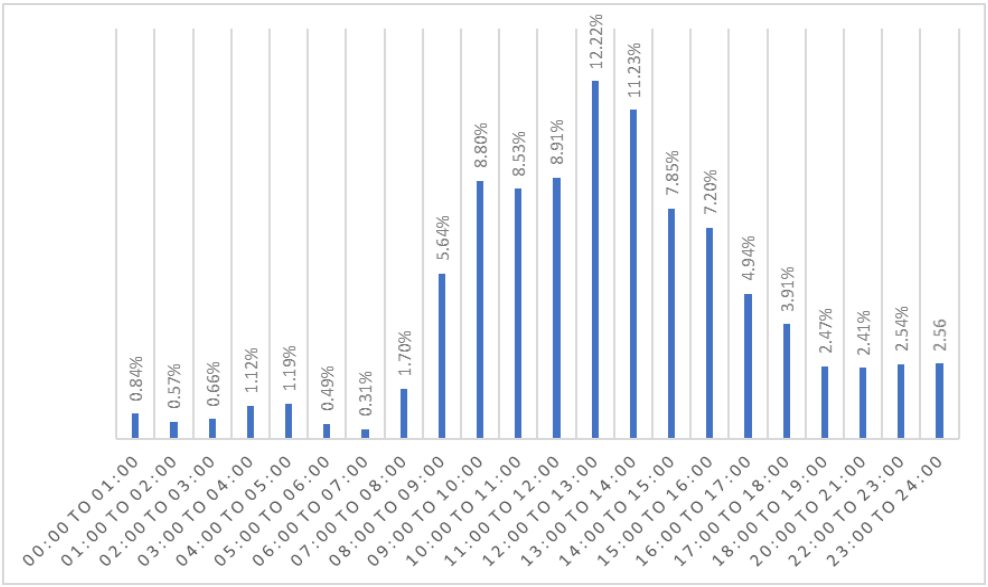
Figure 2 shows the length of the recorded trips for the electric vehicles. The results confirm that most of the trips are short-ranged with less than 10 km.

Figure 2: Percentages of trips vs. km travelled per trip



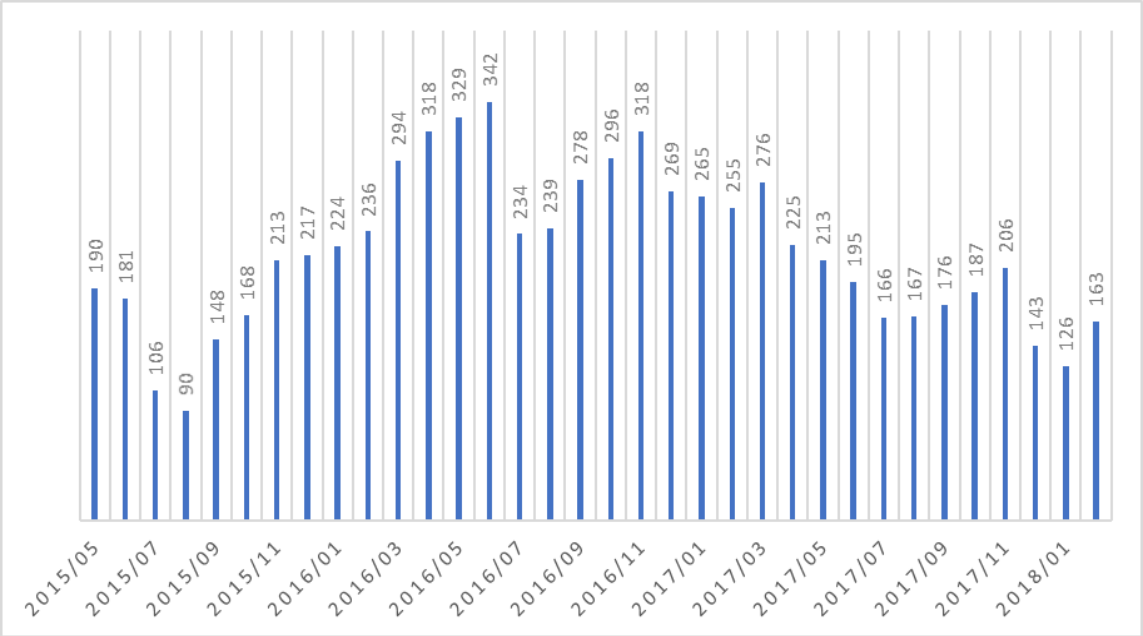
The figure below (figure 3) shows the percentages of the vehicle use at each time frame. The most popular travel period is midday, between 12:00h to 13:00h and 13:00h to 14:00h, with 12.22% and 11.23% of the total vehicle usage respectively. Morning hours are also popular with approximately the 8% of the trips taking place between 9:00h to 10.00h, 10:00h to 11:00h or 11:00 to 12:00h. The use of EVs drops drastically from 0:00h to 8:00h.

Figure 3: Frequency at each time frame



The booking systems also enables to know how many vehicle bookings there have been monthly since the leasing activity started. Figure 4 shows the monthly booking data.

Figure 4: Nº bookings between May 2015 - Jan 2018



It is interesting to note that, there is an increasing mobility in May in every year. Table 2 shows the number of bookings that took place each year compared to number of bookings in May. In all the cases, around 9% of the yearly bookings happened in May.

Table 2: Annual vs. May bookings quantity

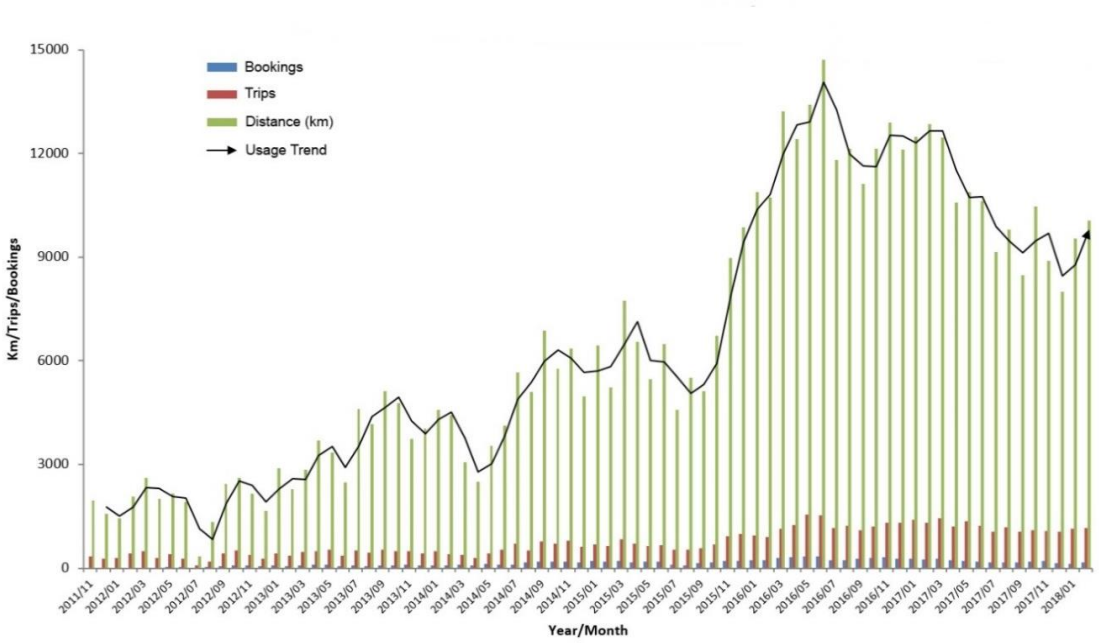
Year	Nº bookings		%
	Annual	May	
2012	285	3	1.05
2013	963	101	10.49
2014	1601	114	7.12
2015	2083	190	9.12
2016	3377	329	9.74
2017	2474	213	8.61

However, it is important to note that there is a decrease in bookings in the year 2017. By the time this study was taking place, 6 members of the staff bought their own EV. Apart from this, improved communications (Skype etc.) and vehicles coming off lease but not immediately replaced also had effect on the mentioned reduction of vehicle bookings during 2017.

Figure 5 gives further information on the annual usage trend including not only the booking quantity but also the number of trips and the distance travelled each month. These results coincide with the research of Pearre, Kempton, Guensler, & Elango (2011) who claimed that

as the number of users increase, the length and frequency of the travels are higher too, as they gain confidence in the EV´s.

Figure 5: Annual usage trend 2011-18



The results also show that there is lower use of the vehicles during winter months. This fact is not caused by reduced technical capacity of the EV. This reduced usage of the vehicles is due to concerns of the users to drive electric vehicles during winter conditions. According to Morrissey, Weldon, & O'Mahony (2016), charging activities of electric vehicles drivers are dependent on the confidence and setting of the recharging facilities. When the remaining driving range is lower than 48 km, drivers usually get nervous, thus the public accessible rapid chargers will help on decreasing this anxiety which induces a growing usage of EV (Anegawa, 2010).

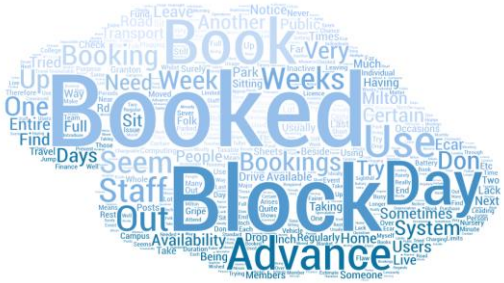
4.2 User´s perception

According to the user´s perception results obtained from the survey, the most repeated concern of the participants was the fact that there were not enough vehicles to fulfill all users needs. This feedback is shown in figure 6. In order to satisfy the users needs, more vehicles were added to the initiative to reinforce the availability through the campuses. The response of the users to this action was very successful. However, the increased quantity of vehicles caused higher number of EV users, therefore the charging infrastructure became the focus of the analysis.

Figure 6: Survey review April 2015

The same questionnaire was send again to all the participants one year later, in April 2016. Figure 7 illustrates the findings of this second survey. The main problem this time was that staff block booking vehicles, so other staff members could not access to the booking. In response to this concern, the booking duration of the vehicles was restricted to optimize the use of the fleet.

Figure 7: Survey review April 2016



Another problem associated to the lack of available vehicles is that the cars may not be returned to their initial campus. In response to this concern, the vehicles are identified with a registration number in one of the campuses, and most of the staff members can only access to a single campus so the vehicles are returned to their origin once they are used.

5. Conclusions

In this study the booking and managing system of the Edinburgh College zero emission vehicle fleet was studied to analyze the potential and users´ perception of embedding electric vehicles to the business infrastructure with the objective of increasing their acceptance and use.

The 6 years study confirms that over 85% of journeys are less than 16 km long, which was also found by many other researchers and reinforces the fact that the autonomy is not a drawback for most of the users in Scotland.

The most common traveling periods are the morning hours, when users drive to work, the midday, which coincides with lunchtime and afternoon, when users finish work. This data provides information that could be shared with electric vehicle related policy and procedure makers, that enables to know when EV´s are expected to be recharging and the effect of grid intensity during this period.

May had the highest frequency of movement mainly due to the increasing number of activities related to the end of the academic year. This data is also useful to identify peak and low frequency travel times related to academic activity and holiday period. However, there is a significant reduction in the usage of the EV in wintertime, proving that the drivers are still concerned about driving these vehicles in winter conditions. This behavior needs to be analyzed and local authorities will have to increase efforts to habituated users.

It is worth mentioning the increasing EV´s usage over the years mainly due to the higher number of available vehicles (multiplied by 2 or 3 depending on the campus since the program started) and driven by an increasing number of accounts in all the campuses. The user´s perception survey also reinforces this fact, the use of electric vehicles increases when the infrastructure improves. It is also important to mention that during 2017 some staff members bought their own electric vehicle causing a lower number of booking and the

results clearly show an increasing trend of EV usage and gaining confidence in the charging infrastructure.

The present research proves that with the introduction of electric vehicles in Edinburgh College, there has certainly been a degree of planned behavior embedded within the staffing complement and the acceptance and use of electric vehicles have improved. It has also been demonstrated that the infrastructure needs to answer users´ needs in order to enhance the trust and acceptance of electric vehicles.

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