Interrogating the Relation between E-Mobility Recharging Network Design and Drivers' Charging Behaviour

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In this paper we report on research into patterns of electric vehicle (EV) commuters' movement and behavior in a road network. The design of the charging network is a function of its size and the distribution of the charging points within a given urban area. It consists of several spatial design qualities, configuration attributes, travel demand, and users charging patterns. In order to have reliable recharging facilities (RFs), we need to understand the nature of the system and eventually plan and design for the current and potential EV commuters. The recharging experience should not be a worrying matter for EV drivers. Assessing existing systems helps in picking up the main paradigms of EV population and system that need to be considered or even adjusted for a better EV market penetration. This study introduces the spatial configuration of an active e-mobility system through a case study. The paper investigates the correlation between the design characteristics of EV recharging infrastructure and its usability for the given metropolitan area. The usability is a consequential communication corresponds to the system design. We need to explore the variations in individual charging behavior within the EV population to understand the movement patterns in the network. Using data of over 500 EV drivers charging their cars using public charging infrastructure over a three-year time, we clustered the EV population based on the charging patterns. Design configuration analysis is conducted using DepthMap; charging patterns are captured by the infrastructure service provider while been sorted, tabulated and analyzed using SPSS. The study outcomes should give a clear insight of how the use of RFs is affected by the spatial; design features as well as the charging patterns and profiles of EV real users.

Keywords: *Electric Vehicles, Charging Behaviour, Recharging Facilities, Space Syntax*

INTRODUCTION

Electric vehicles are needed to replace the internal combustion engines (ICT) for private cars and small vans. There is a growing momentum of owning a plug-in electric vehicle (PEVs) as it is promising to cut oil use and CO2 emissions. To seize this opportunity and promote the concept of smart and green means of transport, the users charging behavior and viable feedback as well as public awareness need to have more attention. A major impediment to EV mainstream market is the absence of proactive and constructive planning approach for RFs. This is considered as a major issue especially for full electric car passengers due to the sole dependency on batteries as a source of power hence range limits and longer recharging time (Namdeo et al. 2013).

Embracing the system's psychological dynamics is important for developing theoretical frameworks and hypothetical models in order to understand its nature. Due to the differences in technical and economic premises, EV system is not to be treated as a conventional car network system (Lindblad 2012). EV system as the vehicle itself, infrastructure network, technicalities, regulations and standards is a large and complex integrated tapestry that involves multidisciplinary knowledge. EV market stakeholders should partnership to address the hurdles to consumer sales and also jointly work on ensuring a highly satisfactory ownership and driving experience (Accenture 2011).

To fully embrace the EV system and realize its real magnitude, we need to divide and conquer. We need to investigate the dimensions that constitute enablers and disenables of EV adoption and how policies can encourage them (Ozaki and Sevastyanova, 2011). The end users' recognition of the system and perception of its advantages and pitfalls are critical. This includes both the potential users and the early adopters who will be referred to as EV advocates in this context. Studying the charging pattern of different users and correlate it with the design parameters and attributes can show us interesting results.

Sizing and placing RFs problem is such a new topic that recently has been taking some attention. Few important strides have been made to tackle this problem particularly in late 2012 and 2013 (Chen et al. 2013). Several documentations and reports have been published and released containing phased plans, initiatives and long-term development of recharging infrastructure; however, these reports do not share how the presented size and location of RFs were determined (Wirges and Linder 2012). Slim literature releases the previous studies which were conducted to solve the charging stations placement (Lam et al. 2014). This results in the lack of a strategic approach in the design of publically available recharging network which could otherwise increase the market penetration level. By improving the recharging experience, the probability of potential users to shift to EV market and households loyalty to use the EV as their first choice would definitely soar.

Study Aim and Objectives

Spatial configuration analysis is conducted to ultimately help developing design tools for planning authorities and policy makers. The purpose of the study is to explore the users' profiles, test the public awareness of RFs, and investigate the relationship between the design configuration and the user behavior in the road network. The study introduces the spatial configuration of an active e-mobility system through the case study NE1, NE4 and NE8, the inner urban core of Newcastle-Gateshead metropolitan area in the North of England, see figure 1. It analyses the emergent behavior of the crowd and relating and correlating the design characteristics of the network to the usability of the charging points and the design configuration (space syntax measures). This includes a description of administration procedure of data collection, data cleaning and description of the data set. It ends with the use of space syntax as a vehicular movement prediction in the hybrid model.

Figure 1
Newcastle Postal Districts

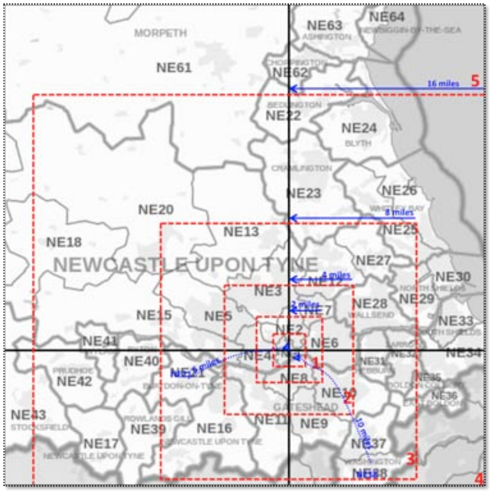
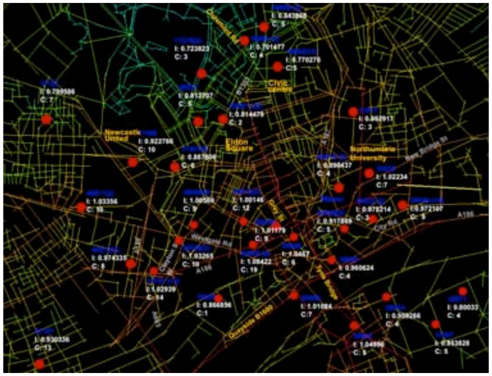


Figure 2
Mapping the Recharging Network



Research Questions

How and to what extent do the spatial configuration and design parameters of the metropolitan urban core impact the charging behavior of EV drivers? Can these factors be identified and quantified?

The paper is structured to start with an introduction of the available data-set and the approach being used to sort and group it. For correlation analysis purpose, all the variables are presented and explained throughout the article; RFs design qualities, emergent charging behavior, public awareness and urban economics attributes. This is followed by the charging behavior profiles of the 500 EV users. Linear regression model is developed followed by interpretations.

Newcastle NE1, NE4 and NE8. Tyne and Wear Metropolitan County contains five metropolitan boroughs: Gateshead, City of Newcastle upon Tyne, North Tyneside, South Tyneside, and City of Sunderland. The case study considers the first two boroughs. In specific, the study area periphery is the inner urban core of their county boroughs which engages three postal districts NE1 (6 KM2), NE4 (14 KM2) and NE8 (16 kM2), see figure 1. All demographic and socioeconomic data and information about EV drivers needed is provided by the city council is provided by the service operator, CYC Company. An axial map has been generated; a total number of active 38 charging points have been mapped, see figure 2.

RECHARGING FACILITIES DESIGN QUALITIES

In last decades, space syntax has been known as an alternative computational language that is used to spatially pattern the modern cites and analyze the topological relationships of settlement spaces (Hillier and Hanson 1984; Hillier 1994). Different shapes of relations and levels of interactions between spaces each other and or with society, have superbly shaped the space syntax notion and its principles in analyzing the spatial patterns of cities (Jiang and Claramunt 2002). Within a given built environment (system) and with its axial representation of roads network, the virtue of space syntax theories and techniques can be used to quantify the properties of the space arrangement and measure its level of integration (see figure 3) accessibility and connectivity and depth (Hillier and Hanson 1984). Attraction theory of vehicular movement is identified as the movement that is seen as being to and from built forms with differing degrees of attraction. In this way, the spatial configuration of the urban grid would be basically the spatial elements through which commuters move; streets, squares, alleys and bridges are linked together to form some kind of global pattern. Movement, configuration and attraction are the three main pillars of a common-sensed movement within the built environment. The movement can be justified by the presence of attraction as well as the configuration properties of the space (Hillier et al. 1993). In this research, another attribute is added which might change the equation, the movement of electric vehicles movement and the associated charging patterns. Figure 3 is the integration and connectivity values represented over the axial map of Newcastle inner urban core.

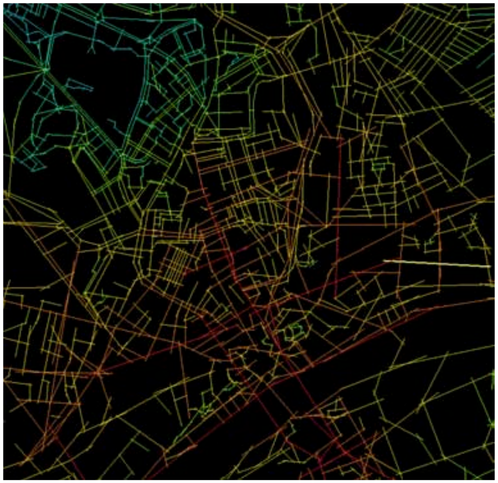
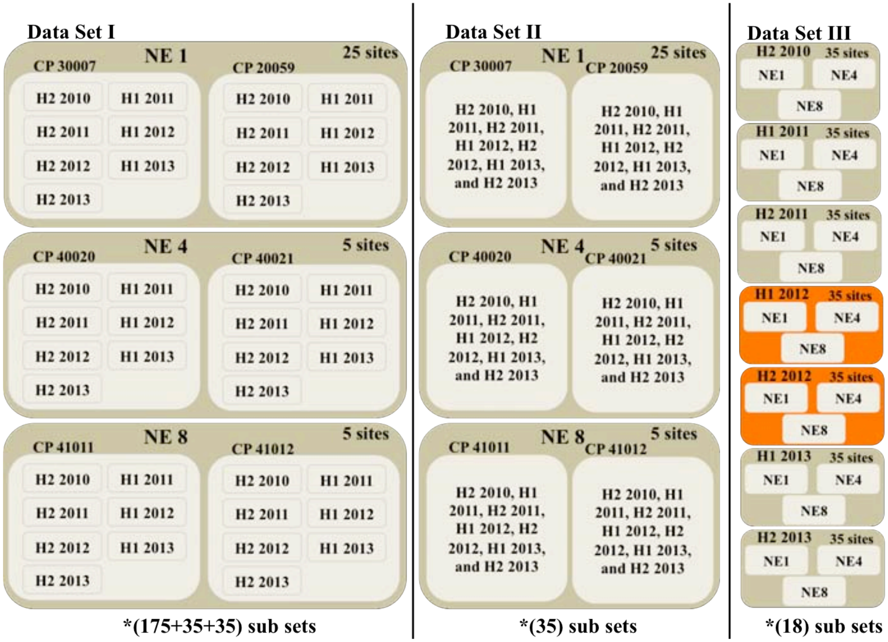


Figure 3
Integration map of Newcastle inner core

Measures of Urban Street Patterns
Streets including curvilinear ones are represented as chains of simple straight-line segments. Street intersections are defined as end points of line segments. Once there is a choice of paths, nodes occur representing an intersection or end of road. Roads can be split into lines at each change in direction and or intersection. This means, a road segment may consist of many line segments (Peponis et al. 2008). Peponis et al. (2008) classified the types of movement in urban street networks into four types: routine movement which denotes the commuter going from familiar origin to familiar destination. Second type is the new path-making to particular, which describes originating from home visiting a new place. The third movement is wandering within a relatively known area and fourth movement is exploratory as it aims at understanding an entirely new environment. Given this format, configuration modeling technique has proven successful in predicting pedestrians and vehicular movement in simulation modeling (Peponis et al. 2008). In this research, the problem we are trying to solve is different as the vehicular movement is associated with other aspects related to EV system. These aspects are related to behavioral layer of the EV population, technical issues, and driving EV history.

Space Syntax Measures
The above axial representation gives the opportunity to measure a particular property of the urban environment; connectivity indexes, control value and integration are some of these morphological properties. Connectivity is the measure of how well an axial line is intersected by others. In principle, there is no non-intersected line in any urban environment, i.e. each space is accessible from every other space in the city. In the mean time, experience tells us that the length of the axial line has some correlation to connectivity indexes, that is, these are more possibilities for lengthy lines to be intersected by others. Integration of a line is by definition a value which indicates the degree to which a line is more integrated, or segregated, from a system as a whole. The measure is actually based on a more basic notion called depth. Depth is more generally a topological distance in a graph. If two lines are directly connected, then the distance between them is equal to one, and the distance of a pair of lines which are not directly connected is the shortest path between them. Integration is a global measure, as the calculation of integration is based on the total depth from the current. However, if a number of depths, instead of all depth, is considered, then the integration is called local integration. Thus, global integration is a global measure describing the relation of each space to the sys-

Figure 4
Datasets and the selected one for the study



tem as a whole, while connectivity and local integration are local measures describing the relationship of each space to its neighbors.

Statistical Analysis

To carry out the spatial statistical analysis, some checks have to take place to ensure consistency and level of detailing. The availability and the quality of the date, identify the possible analysis that can be applied and influence the final conclusion that can be reached. To have meaningful inferences, the worthwhile objectives of the analysis have to be determined (Coe et al. 1994). Data collection process is a time consuming and sometimes costly, we need to make sure that we are benefiting and producing meaningful observations and have rich data that will enable objectives (Marshall 2012).

Various statistical analyses can be carried out to for a given inquiry while using different datasets. These sets may contain the same information in forms of different subsets. Values, attributes or variables regardless their types as continues, categorical, build these sub sets. Hence, sorting, filtering, and needed level of abstraction, design and form the dataset which all depends on the desired objectives. Referring to the research problem, the data sets we are using contain several subsets. These subtests were formed to map all the available data, Figure 4 and decide which data set is being used and which statistical analysis shall be conducted. The analysis cannot satisfy all the objectives at once and even all the time. A cluster analysis may take place to examine the some features of the charging patterns using a set of data. Whereas, analysis of variance shall be carried out to investigate the correlation between the design qualities and the usability of the system using different data set.

The first check is the number we need to identify the employed approach. If we are looking with an optimistic approach, we will hope for the best. To investigate the correlation between the design properties and the usability of the system, we need to consider some factors. There are two approaches to analyze the data: (1) optimistic or (2) Pessimistic. Optimistic approach is to select a single post in each site.

CHARGING BEHAVIOUR PROFILES

There are five charging behavior types which are basically formed in respect to the time spent charging., technical capabilities of the RF, level of awareness and confidence level, willingness to spend time in charging publically and at work and charging pattern of the real users. Interviewing some of the real users also gave some indicators and assisted in forming the following equation which is a function of time, Equation (1):

$$c(t) = \begin{cases} "TheTopUp" & t \leq 20m \\ "GoodEnough" & 20m < t \leq 40m \\ "Superb" & 40m < t \leq 1h \\ "FreeTime" & 1h < t \leq 3h \\ "BeyondCharging" & else \end{cases} \tag{1}$$

The first cluster is "The Top Up". This cluster contains those drivers who are willing to spend up till 20 minutes in charging their cars over the daily road trip. This can be down to 10 minutes which is fair enough to replenish their batteries and let them go home safely. Having said we are scanning the inhabitants and also across-districts commuters, homes are within 20 miles away as a maximum from the city centre; however, the majority is within 12 miles. 91% of this cluster charges their cars for 10 minutes only; which reflects the reliance on domestic and work-place charging. Almost half of the 10-minute users charge at the evening time which means after work and probably on their way home or non-home based trips. The other half charges their cars with a fairly equal distribution over the morning and the afternoon. In a nutshell, this charging pattern tends to form 20% of the total charging events taking place over the years of study (2010-2013). This reflects a low level of awareness that a 10 minute charge can cover your back home trip. Table 1, explains the categories of the two behavioral features of the system.

The second cluster is "The Lucky Charge". This cluster contains those drivers who are willing to spend up to 40 minutes charging their cars throughout their daily road trips. These records were scored throughout the three years. This means that this cluster barely contributes to the overall charging events. The fans of this cluster are those who charge their cars in the mornings and in the afternoon. It is observed that this charging pattern tends to form 10% of the total charging events happening over the years. This reflects another aspect of the behavioral layer of the system. Charging for 40 minutes clearly is not convenient for users to be spent on On-Street RFs; however, if it is possible, this charging pattern shall expand the driving comfort zone of the EV driver.

The third cluster is "The Good Enough". This cluster contains those drivers who are willing to spend up to almost an hour charging their cars throughout their daily road trips. The analysis showed that this cluster forms another 10% of the total charging events over the years of study. This means that this cluster also doesn't represent a majority of the users' charging patterns. The fans of this cluster are those who charge their cars in the mornings and afternoons, mornings more so than afternoons.

The fourth cluster is "The Superb". This cluster con-

Charger Type	7KW	7KW	7KW	7KW	7KW	3KW
Average time Spent	>10 Minutes	>20 minutes	>40 minutes	>1 hour	Full Charge < = 3.5 hours	> 4 hours
Most Freq. time	Morning	Afternoon	Evening			

Table 1
Charging Behaviour

tains those drivers who are willing to fully charge their batteries using RFs. This means that they are so technically oriented and think wisely with respect to electricity. This group is also in luck because this means they tend to have access to workplace chargers which brings easy to their charging process. They save a lot as they probably don't mainly rely on domestic charging, they plan ahead so that they can have full charge which will guarantee a safe daily trip, and also they will ultimately have the longest life time for their batteries. The occurrence of this pattern is relatively high to other patterns; this pattern tends to form 50% of the charging events which mainly represents the workplace charging points. However, in case of having 3KW charging point, this will only replenish a 50 percent of the battery capacity. Yet, still is considered as a high level of dependency and reliance on public charging services. The mapping reflects that the majority of the charging events of this cluster are more often during the day.

The fifth cluster is "Beyond Charging". This cluster contains those drivers who are using 3KW chargers or and have the luxury of fully charging their batteries using it. The charging events of this cluster don't have a pattern. The occurrence of this pattern fluctuates; it mainly forms that last 10% of the charging events. Users tend to charge also in mornings and afternoons while less likely in the evenings.

PUBLIC AWARENESS AND URBAN ECONOMICS ATTRIBUTES

EV passenger acceptance depends on being knowledgeable about EV specifications, capabilities, the benefit of smart transport and how these cars can fit in their daily life. It also depends on the raised awareness about the available charging network and how accessible is the ON street and OFF street charging service. The attitudes of car drivers towards electric vehicles were investigated within a sample visual questionnaire carried out. The aim of the questionnaire was to test the awareness about the available charging points in Newcastle-Gateshead inner core area. The questionnaire was designed to ask 45 potential users about their cognitive skills of remembering or noticing any of the RF in the area of study. The respondents' feedback was collected, tabulated and analyzed. Each charging point got a score that sums up the number of respondents who are familiar with it and have come across. The RFs which got to hit the highest scores of awareness (highlighted in red), Figure 5, are the ones which are highly used by current users. Values of awareness are added as attributes.

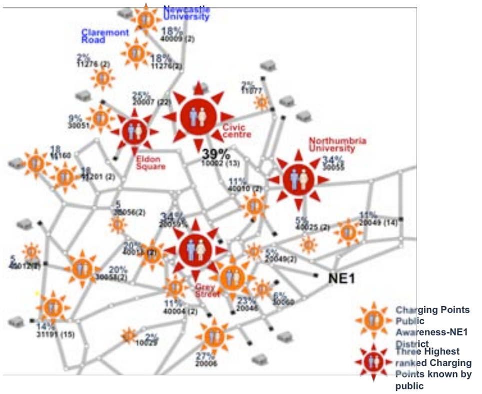


Figure 5
Level of Awareness

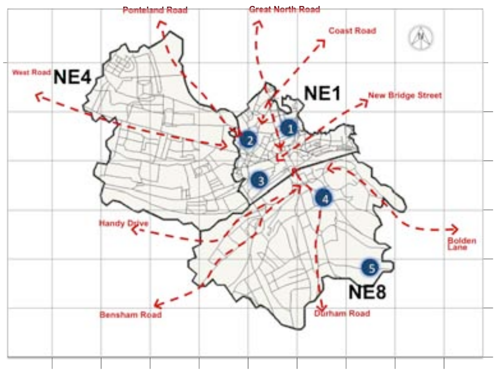


Figure 6
Main corridors and urban cores

Two more independent variables were considered; the level of closeness from the urban cores and the traffic count (travel demand) of the nearest main corridor feeding the RF site.

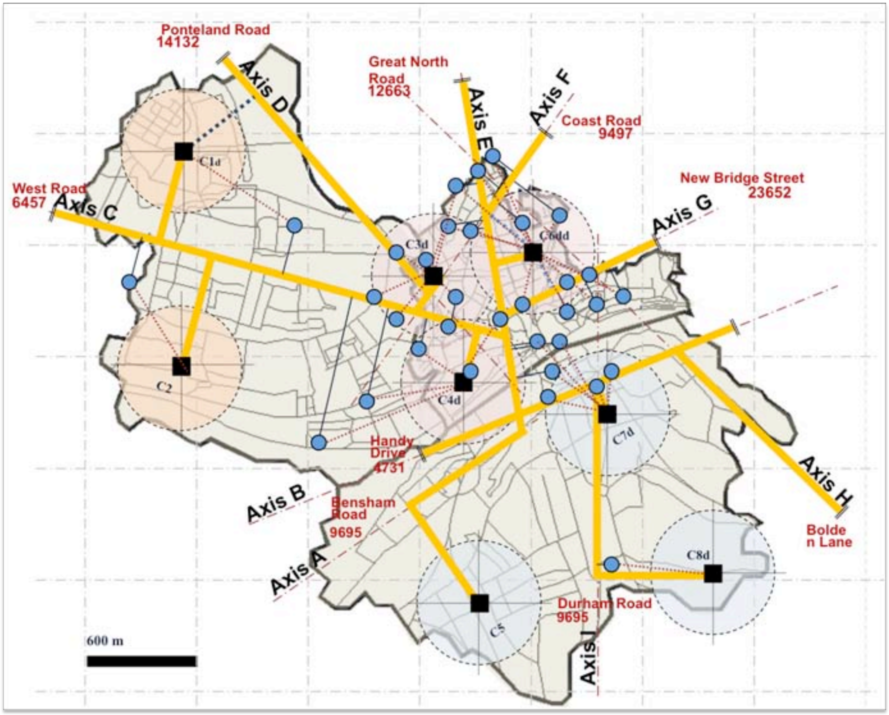


Figure 7
Distances to main roads and cores

From the urban policies, spatial planning reports and demographic records generated by the Government, the urban core areas are mapped, blue numbered circles, see figure 7.

The main corridors are indicated in figure 6. All urban cores and main corridors are plotted as centers and axes respectively in figure 7 alongside the charging points in small circles. Distances to the nearest urban centers are scaled and calculated, see figure 8.

The Unit of UTMC, the real-time traffic and travel information service unit in Newcastle upon Tyne calculates the traffic counts and real time origin-destination matrix of the main corridors.

Factors Affecting Utilities Profitability

To have a profitable business, we need to look into the enablers and disenables that influence the market. The profitability is a function of several related and unrelated factors; these factors are associated behavioral, technical and socioeconomic variables of the EV system. For an example, understanding the rationale behind the willingness to pay and get a new car should be taking high priority in automotive and batteries technologies considerations. The end user's feedback and preference play as significant a role as the automotive and batteries technology in affecting the EV market growth. A better understanding of the social aspect of the system, a clear depiction of the changing behavior of the users and ultimately identify the most influential behavior that affect the usability of the system. The following table summarizes the 12 independent variables (IV) including the dependent variable (DV), the total energy consumed (Λ).

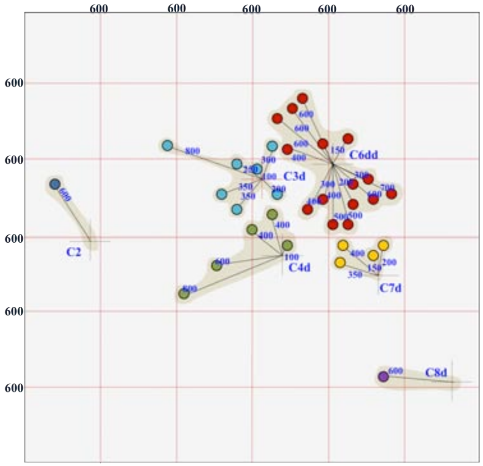


Figure 8
Metric distance to nearest urban centroid

SPATIAL STATISTICAL ANALYSIS

Linear regression is conducted. Dependent variable is the total energy used. The method used is ENTER. This basically means all the variables are entered on the same time whereas other methods like stepwise, remove, backward or forward involved some sort of wise step regression. The Independent Variables (Λ). Highly correlated variables should be excluded as well as a high number of IV in general. After conducting several trials trying to mix and match all the variables and see which set up gives better results, the following composition was selected, see table 5. To run the model, the variables are to be classified into behavioral and spatial elements. Hybrid model is developed into two stages 1a and 1b; different variables are analyzed over 38 levels (observations) in each stage. In the first stage, the spatial parameters (variables) only are entered. As a first check, the regression output tables show some values that specify the model validity, quality and percentage of random error. The model validity can be checked by the significance value (0.049). This means we can carry on working with the model. The second check is the Adjusted R square value. This value indicates the percentage that the model justifies of the total variance of the DI. Table 3 indicates that the five spatial factors explains 17% of the usability variance in a linear correlation, see table 3 model (1). This value is quite low as this means there is over 85% random error if we will use this model to plan for future; however, this is not the final model statistics. In the second stage, the behavior parameters are entered merged with the spatial parameters previously added in the first stage. The Adjusted R square is improved to 0.871, table 3 and the model significance is better, 0.000, see table 4.

DISCUSSION

In the first part of the paper we discussed the different design, behavioral and urban related parameters of EV system that we are investigating in this study. Through Linear regression approach, we developed a hybrid model that coupled the independent behavioral and spatial variables to explore the relation to the total energy consumed by the charging points. Commenting on the regression model output, there are some meaningful interpretations and important outcomes. The coupling process of the variables is fundamental for model validity and reliability. Decoupling behavior and spatial qualities of a system would lead to biased analysis. The model is developed to assist in planning future EV charging network based on real experience and empirical analysis. The depiction of real world population and system has to denote and stimulate at a high level of correlation. In our case, having a system used by human beings, depicting the behavior layer should not be overlooked. Spatial urban structure of EV network does not work independently of charging patterns and behavior of the EV population. Designing for EV charging points is similar to petrol stations location problem, both can not be dealt as facility or location allocation problem. Location allocation problem can be purely based on spatial and metric calculation tabulated in optimization model, which is not the case. Effects and intersections of all factors should be taking into account. To validate this, the random error value has significantly dropped when

	Attributes	Explanation/ Measurement Technique
1	**Public Awareness (P)**	To measure to what extent are the potential users aware of the charging network. This is examined through a spatial questionnaire. Response is collected
2	**On / Off Street (O)**	This value is dummy. Zero for off street charging points, and value of 1 for on street charging point.
3	**Integration (I)**	Space Syntax measure, calculated by DepthMap.
4	**Traffic Counts (T)**	Actual travel demand provided by the Traffic Monitoring Unit in Newcastle (UTMC). The values are for the main corridors feeding the RFs sites
5	**History (H)**	In months, the total number of months the charging point has been installed and used. (CYC data)
6	**No. of users (η)**	The total number of EV drivers used the charging point over 2012 (CYC data)
7	**Distance from centers (ι)**	Metric distance measuring the road length between the charging point and the nearest residential district core.
8	**Transactions (τ)**	The total number of transactions made by the users in 2012 in each charging point. (Point not site)
9	**Average time spent (A)**	In minutes, the average time spent by drivers charging their cars using RF. (CYC data)
10	**Most Frequent Time (M)**	Discreet data, showing the most frequent time of the day the drivers tend to charge their cars using a specific charging point. (Morning = 1, Afternoon =2 and Evening =3)
11	**Total Energy Used (Λ)**	In KW, the total energy spent charging cars by each RF in year 2012. (Dependent variable, Profit indicator)
12	**Weekdays (ω)**	Percentile, the weekday to weekend ratio converted into percentage. This value shows when the RF is being used over the week.

Table 2
Factors affecting EV System

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.532[a]	.283	.171	354.722106
2	.954[b]	.910	.871	139.670909

Table 3
Hybrid Model Summary

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1586825.006	5	317365.001	2.522	.049[b]
	Residual	4026488.725	32	125827.773		
	Total	5613313.731	37			
2	Regression	5106106.697	11	464191.518	23.795	.000[c]
	Residual	507207.034	26	19507.963		
	Total	5613313.731	37			

Table 4
Hybrid Model ANOVA

the behavioral parameters were added in the second stage. The model explains 87% of the RFs' usability variance. This high value reflects that the selection of variables was successful and well studied. In return, this generates a linear equation where the DV is a function of the influential factors that contribute to a utilized and profitable charging network, Equation 1. Out of the eleven factors, there are five most influential variables affect the EV system usability. The equation is a simple linear regression where $y = a + (b1x1 + b2x2 + b3x3 + b4x4 + b5x5)$:

$$
\begin{aligned}
f(\Lambda) = &- 864.049 + \sum_{n=1}^{\infty} (\\
&- .094 \,\text{Public Awareness}\ (P) \\
&- .120 \,\text{TrafficCount}\ (T) \\
&- .220 \,\text{On/off Street}\ (O) \\
&+ .170 \,\text{DistanceFromCentres}\ (\iota) \\
&+ .159 \,\text{Integration}\ (I))
\end{aligned}
\tag{2}
$$

CONCLUSION

EV system is a complex system. It is a function of behavioral, socio-technical and spatiotemporal paradigms. The lack of a strategic approach in the RFs design process affects the market penetration level. By improving the recharging experience, the probability of potential users to shift to EV market and households loyalty to use the EV as their first choice would be definitely raised. A question was raised about the correlation between design parameters of charging network and the charging behavior. In other words, would the influential factors that affect the EV system usability can be identified and quantified? The present study addressed this question by studying technical, socioeconomic, spatial and behavioral aspects of the system.

A multi method approach has been employed to carry out this study. Real users' records spanning three years of operation were analyzed. The analysis showed the charging profiles of the users and how these profiles differ with respect to time of charge and time spent charging features. The design configuration analysis was applied to measure the level of accessibility and integration of the roads containing charging points. 38 charging point were mapped; Integration values were calculated and tabulated. Level of awareness was also considered as variables affecting the public charging network. Through a questionnaire, the level of awareness was quantified. Another urban and travel demand attributes were calculated. The charging patterns of all EV drivers using the NE1, NE4 and NE8 postal districts' RFs in 2012 were analyzed. After several trials finding the charging pattern indicator (Dependent Variable), the total energy consumed in each charging point over the period of study was selected. Linear regression analysis was conducted to investigate the relation between the DI and the design configuration values, level of awareness, and urban and vehicular attributes, Independent Variables (IV).

Statistical model developed reveal that measures of design configuration and spatial qualities, behavior layer, demographic and travel demand attributes are most strongly associated with charging events of EVs when planning for future EV integrated charging network. The study outcomes show that there is correlation between the EV system design parameters and its usability and profitability. It also measured and quantified all factors and identified the most influential ones. Off street charging sites increase the odds of public charging when it is located in workplaces. On Street with high integration values, close to main corridors, distant from urban cores are tend to have high frequency of short charges over the weekdays. Importantly, the results presented here also underscore the significance of the spatial structure of road networks. Integration plays as significant a role as metric accessibility in affecting the proportion of riders walking for transit.

The spatial structure of street network does not work independently of urban and behavioral layers of the given EV system. Based on the standardized coefficients estimated in regression model, On/off Street (O) Distance from centers (ι) and Integration

(I) have comparably high positive impacts on charging network business profit. Traffic count (T) and public awareness (P) come on the second influential set of factors that that contributes to profit.

Overall, the analyses presented here confirm the hypothesis that design configuration values relate to charging preference. Location-related values explain 17% of the variance of total energy consumed of the RFs of the network while adding behavior-related values pulls it up to 78%. The study shows that these measures: ON street and OFF street location, public Awareness, distance from urban centroids, traffic counts of the nearest corridor (s), and integration values are likely to capture only 17% of the EV recharging facilities occupation and usability which is quite a reasonable ratio for a pilot study. Whereas, the charging pattern-related attributes: contribute to 84% and coupling the two categories explains 87% of the system usability. Usability is used in this context to indicate the efficiency of the charging points and indicates the system business model. Hence, selection the total energy consumed is a clear straight indicator of profit in a directly proportional relation. The better we understand the urban parameters, charging behavior and EV technical qualities, the higher chances we are able to positively influence the EV market penetration. Raised awareness of some RFs is affects the usability; whereas, the spatial analysis of the RFs affects the level of awareness. In other words, designing for EV system is such a complex prolonged study that requires high level of coordination between stakeholders, analytical skills, public engagement, and interdisciplinary coordination to embrace the emergent structural properties of the EV system. Future work should allow for more variables and more observations. This study is analyzing year 2012 and specific charging points.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the emobility NSR-North Sea Region Electric Mobility Partnership e-Mobility NSR (NSR, 2011) project for funding the PhD Research. Earlier versions of this paper can be found at https://www.linkedin.com/pub/eiman-el-banhawy/11/316/36a

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