Real-Time Electric Mobility Simulation in Metropolitan Areas

A case study: Newcastle-Gateshead

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Abstract. This paper discusses the potential of emerging digital representations of built environments coupled with agent-based modelling (ABM). A new set of urban transportation data is provided as an input which is the electric vehicles (EVs) population of one of the UK metropolitan areas. The study is a part of a PhD research that focuses on investigating computer-aided software to develop a virtual route for electric mobility in the North Sea Region. An overview of agent-based simulation platforms is discussed. Electric mobility system has particular paradigms that differ from conventional urban transport systems; a comparison is presented followed by the recommended approach of integrating the two techniques (visualization and simulation). Finally, the architecture of agents’ algorithm within the EVs network is presented through a case study of virtual Newcastle-Gateshead model.

Keywords. E-mobility; electric vehicles; simulation; agent based modelling; virtual city models.

INTRODUCTION

This paper discusses mainly two computer-based techniques for real-time electric mobility simulation in urban areas: (1) simulation and (2) visualization. In this context, visualization is the digital representation of urban environments from aerial view maps to the more accurate city plans produced to the 3D virtual city models (VCM) (Horne et al., 2007). In the planning context, the advent of computer aided design (CAD) and three-dimensional (3D) modelling shaped the way in which we can better create and simulate metropolises (Thompson and Horne, 2006). Vehicular simulation is one of the simulation applications that depicts mobility system, analyzes, and studies its characteristic to procure reliable realistic results (Paruchuri et al., 2002); its output analysis is a very relevant step in simulation approach (Ali et al., 2007) where it is sometimes integrated with other models e.g. energy, air quality, noise, etc. The world now is approaching green and smart urban transport means to reduce caused Co2 and green house gases (GHG) emissions. Low carbon emissions vehicles, electric and hybrid, are considered to be the optimal means of alternative transport that would eventually reduce the emissions hence save the environment (Logica, 2011); (Strahan, 2012). As any other phenomenon, the electric mobility (e-mobility) pattern has to be studied in order to analyze the current state of the users and determine needs.
and demand for potential future users. Integrated models that combine e-mobility system with other models, have been simulated before for particular marketing and environmental studies e.g. energy model (Acha et al., 2011), market penetration (Zhou et al., 2011), power grid (Kintner-Meyer et al., 2010), customer choice (Mueller and de Haan, 2009). The paper tries to address the following set of questions:

- What are the common and extraordinary paradigms between conventional and electric mobility systems?
- What are the possible approaches to represent micro-dynamic mobility system?
- Is it viable to utilize 3D city models to simulate/present e-mobility system?

ENVIRONMENT AND TRANSPORT SECTOR

Transportation and logistics is the engine for economic growth. It is crucial to move goods, people around the countries, and allow accessing employment, services, leisure activities and socialize with wider communities (HM Government, 2011). It also allows businesses to expand and create wealth and employment. However, it is, the internal combustion engine vehicles (ICVs) type (Herbert, 2011) considered as a major contributor to GHG, and hence has a considerable carbon/environmental footprint emissions. In recent years, the environmental burden of urban road traffic has been worrying governments and authorities of developed countries (OLEV, 2011). A projected look into the future indicates a higher population growth rate, and increasing urbanization trends where the automobile population is growing at a much faster rate (Garling, 2001). Accordingly, researchers, policy makers, and many governments across the OECD countries (IEA, 2011) have focused on low carbon emissions vehicles industry and market considering alternative means of transportation (IMechE, 2000) e.g. hybrid, electric, hydrogen/fuel cell (Herbert, 2011) because of the expected depletion of fuels (Wee et al., 2012).

URBAN DATA VISUALIZATION- 2D PLANS TO 3D CITY MODEL

Urban data has been used before within the two different forms of digital representation: two dimensional (2D) and three dimensional (3D) in numerous applications. With a particular attention to 3D, the extensive available urban settlements data nowadays of developed countries has emerged opening new channels for more applications: town planning, architecture, microclimate investigations or telecommunication (Carneiro, 2008). As per a very recent survey was conducted, there are up to 1036 virtual city models worldwide; this indicates the increasing development of digital representation technology (Morton et al., 2012). The representation of geometry and topology of 3D objects memorizes the shape and configuration of the city. The challenge in visualization is to present it in an uncomplicated way while keeping it on an acceptable level of details and density (Thompson and Horne, 2006). Wang (2005) has mentioned that researchers started managing and presenting geographic information using true 3D representation and forms of analysis of the built environment and present the outcomes.

SIMULATION MODELLING

Simulation modelling has passed through different stages of development to replicate social sciences (Troitzsch, 1997), (Figure 1) shows the present study focus.

Simulation has been widely used in social sciences (Wang, 2005) and the occurrence of its collective phenomena always attached researchers;

For simulating real-time network, simulation solution will better fit due to the occurrence of state changes over time, discrete events and discontinuous equations where by using analytical solutions, the time factor is not considered as outputs functionality depends on the input (Borschev, 2004).

Simulation provides solutions whilst considering a set of rules e.g. equations, mathematical equations/from theories (Lombardo and Petri, 2004), flowcharts (Borschev, 2004) Cellular Automata (CA) (Lombardo and Petri, 2004).
Microscopic simulation provides detailed environment of vehicles movement and facilitates coupling Intelligent Transportation Systems (ITS) (Burghout, 2004).

**Vehicular simulation**

Vehicular simulation as one of the advanced simulation applications that is capable to simulate mobility population, behavioural characteristic, and direct and indirect interactions while allowing a better understanding of astronomical observations (Helbing, 2011). This type of simulation can be achieved via two different approaches: mathematical (centralized) or behavioural (de-centralized) approaches shown in (Figure 1). In centralized approach, car-following laws and scheduling techniques are used which are not generic and can not portray many traffic phenomenon, facets, and behavioural characteristics. On the contrary, de-centralized simulation is more sensible to population behaviour being simulated (Doniec. A, 2008). Hence, the present study falls under this approach by employing agent based modelling (ABM) to develop a spatial intelligent agents (Narzisi, 2008). Agents in such modeling, maintain preference, act differently (Summala, 2005), be opportunistic and anticipate situations (Björklund and Åberg, 2005).

**Agent based modelling-ABM**

Agents sense and act upon their environment, try to fulfil a set of goals in a complex-dynamic environment (Schelhorn, 1999). They involve both goals and constraints forming and emerging the overall complex network (Frank, 2001). Independent perceptions and individual decisions are taken and virtually presented (Li et al., 2006). Agents work together to find the best solution for a problem (Chen, 2009), learn from their experience and adapt to better suit their environment (North, 2010). (Tables 1 and 2) introduce a collection of simple and intuitive ABM platforms.

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**Figure 1**

Present study area of research - dotted line arrow shows the employed approach to simulate new phenomena.
Vehicular simulation using ABM was applied in 1998 by (Trannois et al., 1998) where it was an adoption of the well-known blackboard system for planning agents’ action within the simulation environment. The second significant trial was by (Paruchuri et al., 2002) where they created autonomous agents making own decisions using fine-tuning parameters. According to Doniec at al. (2008), the first model was not presenting autonomous agents’ behaviours and the second one was having limitation due to the supervised and controlled situation by external centralized process. Doniec et al. (2008) developed a more realistic behavioural model by simulating drivers’ behaviour in real simulator depicting their local autonomous behaviours while applying opportunistic and anticipation traits. Our study continues on investigating the appropriate technique to simulate EV population. A hybrid model that combines meso-

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Simulation Technique</th>
<th>Simulation Environment</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASON</td>
<td>Single process-discrete-event, ABM</td>
<td>Layers: 1-Agents and the schedule, 2- Fields</td>
<td>Intensive computational applications (large group)</td>
</tr>
<tr>
<td>VISSIM</td>
<td>Discrete simulation-object oriented programming-OOP</td>
<td>Vehicular model: Blocks: (1) Infrastructure (2) Traffic (Vehicles) (3) Control Pedestrian model: (1) Fixed routes (2) Dynamics routes (3) Dynamic Assignments</td>
<td>Realistic driving and pedestrian behaviour. Microscopic and traffic operation</td>
</tr>
<tr>
<td>Anylogic</td>
<td>Hybrid (ABM, Discrete event - System Dynamics)</td>
<td>Classes: 1- Environment (main), 2- Agent (People)</td>
<td>Several ABM applications: agents can be: consumers, vehicles, equipment, products, or organizations</td>
</tr>
<tr>
<td>Swarm</td>
<td>Agent and individual based modellers</td>
<td>swarms, collections, actions, schedules, observers</td>
<td>RePast, Ascape and MASON creator</td>
</tr>
<tr>
<td>NetLogo</td>
<td>Discrete time steps-multi-agent programming</td>
<td>Layers: 1- Network- Link segments 2- Nodes (intersection) 3- Control Features</td>
<td>Education purposes, short time simulation, local intersection of agents and grid environment</td>
</tr>
<tr>
<td>RePast</td>
<td>Discrete time-OOP, scheduling. Multiple computational agents and personality trait modelling</td>
<td>Environment (main class) and Agents( layers): 1- Properties(Topology) 2- Networks (Transport) 3- Diffusion models (info)</td>
<td>Social network and dynamic models</td>
</tr>
</tbody>
</table>

Table 1: ABM platforms’ techniques, environments, and applications (Railsback et al., 2006); (Luke et al., 2005); (Doniec. A, 2008).
The front price of EV compared to conventional car is one of the considerable barriers by potential users (Garling, 2001); nevertheless, the degree of urban geography, market maturity and infrastructure have their effects on market growth (JATO, 2011) as well. However, the roll out of intelligent infrastructure, creation of innovative service models and changes in consumer behaviour are all positive transformations that indicate that it is a growing market (Bee- ton, 2011) with a positive effect on climate change (Herbert, 2011).

Several factors pertinent to EVs’ battery range appear to influence users’ anxiety during driving; known as Electric Vehicle Range Anxiety- EVRA (Nils- son, 2011). It is believed that this anxiety hinders the EV market expansion (DfT, 2011). EVRA basically exists due to the short full-electric range the EVs have (HMGovernment, 2011). Full-electric range is the maximum distance a vehicle could travel without a need of charge (Eppstein, 2011). Therefore, it can

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASON</td>
<td>Fast execution speed, clever, high complex problems, good user interface, generate graphs and charts</td>
<td>3D display only, non-standard and sometimes has confusing terminologies, problems in interface and programming</td>
</tr>
<tr>
<td>VISSIM</td>
<td>2D and 3D visualization suite, GIS, fast, high complex problems, good functionality of traffic flow, measure of effectiveness (MOE's) reports.</td>
<td>Mathematical models are behind the modelling (check centralized approach)</td>
</tr>
<tr>
<td>Anylogic</td>
<td>Fast, code writer, drag and drop, GIS, high/ medium complex problems</td>
<td>3D display only, poor visualization, medium complex ABM problems</td>
</tr>
<tr>
<td>Swarm</td>
<td>Clever, stable, well organized, clear conceptual basis, clear separation of graphical interfaces and the model.</td>
<td>Medium execution speed, minimum complex problems, incomplete documentation, weak error handling,</td>
</tr>
<tr>
<td>NetLogo</td>
<td>Less programming time and error checker</td>
<td>No 3D, no GIS, slow, minimum complex problems, and no reproducibility</td>
</tr>
<tr>
<td>RePast</td>
<td>Fast, GIS, high complexity, advanced UI, geographic and network function</td>
<td>No 3D, no built-in method to randomize orders among agents</td>
</tr>
</tbody>
</table>

**EV MARKET IN BRIEF**

In Europe and with a particular strategic focus on private and non-commercial electric cars, the total number of registered cars can indicate the level of market penetration. In the first half of 2011, the total EVs registrations were 5,222 (JATO, 2011) which depicts the EV niche market that is in a real need of expansion and creation of conditions for growth for the mass adoption (Graham-Rowe, 2012). The market is hampered by many factors e.g. cost, range, capacity, visual appeal (Graham-Rowe, 2012) speed, and lack of recharging infrastructure integration (Garling, 2001); (Hatton et al., 2009). The higher up-

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*Table 2*  
*ABM platforms pros and cons*  
(Railsback et al., 2006); (Luke et al., 2005); (Doniec. A, 2008).
<table>
<thead>
<tr>
<th>Paradigms</th>
<th>Conventional (non EV) Mobility</th>
<th>E-Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem class</td>
<td>Congestion, traffic management, air quality, noise, and fuel usage, finding solutions to decrease the number of usage</td>
<td>Infrastructure integration, charging habits, energy usage, market penetration (Well-to-wheel studies), EVAR, finding solutions to decrease CO2, increase market uptake</td>
</tr>
<tr>
<td>possible Applications</td>
<td>- Planning and policy makers - Traffic impact assessment -Parking and pedestrian studies - Sensitivity analysis - Traffic safety - Forecasting and controlling traffic - Optimizing traffic flows</td>
<td>- Social and Engineering Sciences -Daily dairies (Charging behavioral characteristic) -Planners and Policy makers -EV and batteries manufacturers, technology providers -Renewable energy, R&amp;D.</td>
</tr>
<tr>
<td>Solution</td>
<td>ABM, CA, both, or geo-simulation (Not analytical)</td>
<td>ABM for IF THEN rules, complex space-time, and computational tasks of collective agents (Not analytical)</td>
</tr>
<tr>
<td>Source of Date</td>
<td>Theories, Artificial Intelligence (AI), interviewed and surveyed persons (driving pattern)</td>
<td>Interviewed and surveyed EVs early adopters and market stakeholders in addition to AI, IF then rules, etc.</td>
</tr>
<tr>
<td>Aim</td>
<td>Shortest path propagation</td>
<td>Nearest charging point</td>
</tr>
<tr>
<td>Market and R&amp;D development</td>
<td>Different platforms, integration of different approaches and applications</td>
<td>Niche market. Little literature focusing on integrating EV simulation with other applications (not urban planning)</td>
</tr>
<tr>
<td>Simulation Environment Layers/Classes</td>
<td>Simulations were conducted with different structure: A- Layers: (1) Physical layer (2) Mental layer (3) Feedback layer (4) Condition layer B- Layers: (1) Reference layer (2) Route feature layer (3) Event layer C-Cellular Automata: (1) Estate (fixed) (2) Agent (non-fixed) D-Classes: (1) Environment(2) Agents</td>
<td>Layers/Classes: (1) Simulation environment (network, city topology and charging points) (2) Autonomous Agents (Vehicles showing battery states) (3) rules (mathematical, activity based or AI)</td>
</tr>
</tbody>
</table>
be said that providing accessible and high visible charging network (hard and soft infrastructure (Beeton, 2011) generates interest amongst consumers and encourages uptake (Element Energy Ltd, 2009). Towards developing a unified ecosystems and smart cities, investigating and predicting the consumers’ response is a significant challenge EV marketers are facing (Beeton, 2011); (Strahan, 2012)

In vehicular simulation (Valverde and Sol'e, 2002) and particularly in the context of EVs, it is very interesting to study and analyse emergent behaviour. This behaviour is a collective macro-scale behaviour coming from the bottom-up (Crooks et al., 2008) and resulting of agents’ coordination (Morton, 2011); (Bonabeau, 2002) (Li et al., 2006). EV patterns or clusters have different nature from normal vehicular patterns. To simulate such pattern, we need to understand its nature and parameters so that we can set the right configuration and have reliable simulation outcomes. A wide range of applications and research studies have focused on the conventional mode of transport and traffic man-

<table>
<thead>
<tr>
<th>Interactions</th>
<th>More direct interaction with agents</th>
<th>More interaction with the environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route Choice</td>
<td>Travel time, distance, and cost</td>
<td>Travel time, distance, and battery state</td>
</tr>
<tr>
<td>Routes of Evolution</td>
<td>1-Theories</td>
<td>Knowledge based findings and IF THEN rules (if required ) to apply more rules related to battery state and availability of charging posts</td>
</tr>
<tr>
<td>Rules</td>
<td>2- Knowledge based findings (Activity based approach)</td>
<td>3-Artificial Intelligence (IF then)</td>
</tr>
<tr>
<td>Routes Type</td>
<td>Real-time path searching-routes/ sub-routes</td>
<td></td>
</tr>
<tr>
<td>Choices and Decisions' Factors</td>
<td>Time, mode, location</td>
<td>O-D matrix, time granted, full-electric range, charging location/time (initial battery state, and power capacity)</td>
</tr>
<tr>
<td>Mobility Mode choice</td>
<td>All modes of vehicles - Battery Capacity is N/A</td>
<td>One mode / simulation: e.g. Private cars with different batteries capacities</td>
</tr>
<tr>
<td>Agents goals</td>
<td>Macro and Micro goals</td>
<td></td>
</tr>
<tr>
<td>Reactive Agent’s brain (key Traits)</td>
<td>Selfish principle in reaching goal, fine-tuned parameters (speed, gap between vehicles, queuing, collision detection, and brake.</td>
<td>Selfish principle in reaching nearest charging within vicinity, check state of battery, charging time, parking lots. Speed, gap, lanes, and brake are N/A.</td>
</tr>
<tr>
<td>Behaviour</td>
<td>Vehicles traits/flow in traffic (route)</td>
<td>Charging behaviour (profile)</td>
</tr>
<tr>
<td>Key Components</td>
<td>Roads, intersections, traffic lights, pedestrians, vehicle’s speed and size</td>
<td>Vehicles and battery type and capacity, no. of users, charging points</td>
</tr>
<tr>
<td>Emerging GIS</td>
<td>Possible, works as repository of the data and user interface</td>
<td></td>
</tr>
<tr>
<td>Visualization</td>
<td>Required for better presentation</td>
<td></td>
</tr>
<tr>
<td>GIS- 3D Visualization</td>
<td>Example: recreational areas visitors’ movement, traffic impact analysis</td>
<td></td>
</tr>
<tr>
<td>ITS Strategies Integration</td>
<td>Message signs, transit signals priority, corridor alternative analysis, control techniques</td>
<td></td>
</tr>
<tr>
<td>Multi Agents</td>
<td>Traffic:1- Network (destinations and roads) 2-Vehicles, 3-Control</td>
<td>EV: 1-Network destinations, roads, and parking lots)2-Charging points,3-Vehicles, 4-Batteries, 5-Drivers</td>
</tr>
</tbody>
</table>
management using micro-scale simulation to present a specific phenomenon. Whereas, little literature was dedicated to EV population and particularly those are focusing on planning and policy making area. An overview of the main paradigms of e-mobility system has to be declared and studied to better understand the system hence better develop the simulation environment and agents’ architecture. The following (Table 3) is considered as one of the main steps of the process of simulating EV population. It summarizes the paradigms of conventional mobility and the extraordinary paradigms of EV mobility systems and it is followed by authors’ observations.

As it can be observed from (Table 3), EV population is not entirely a new type of simulation compared to conventional mobility. They have lots of common and mutual parameters; whereas, the first has some unique parameters that signify its simulation nature. This reflects that EV population is a sub set of the conventional mobility data. The mutual paradigms are clear and recognized e.g. roads network layer, some of the agents’ behaviours and traits, goals scale, visualization and GIS purposes, and the way the ABM is structured. Unique paradigms e.g. battery state, charging preferences, number of destinations, and parking areas exist due to the differences in simulation aims and targets. For an example, both EV and non EV can be typically replicated within a conventional mobility simulation where network and controlling rules will be applied to both similarly. Since the vehicle type is not an influential parameter that may affect the simulation results, the EV will not be recognized as a low carbon vehicle in this particular simulation. However, in other applications pertinent to air quality and noise where the vehicle type affects the study, EV would be recognised as it would completely differ in environmental and acoustical statistics (Hodges and Bell, 2011). The present study targets social scientists, policy makers and planning authorities, who are concerned with the EVs hard and soft infrastructure. In this case, the vehicle type is a major influential factor of the simulation as the outcomes of the simulation would assist in the EV urban planning and infrastructure processes. Drivers’ charging behaviour should be depicted and analysed after running different scenarios (number of users, charging points locations etc); such behavioural characteristic needs distinctive setup. Thus, we can conclude that EV population is a small part of a large group; depends on the application and the end-users’ requirements, the simulation setup changes accordingly.

**INTEGRATING SIMULATION WITH VISUALIZATION FOR E-MOBILITY SYSTEM’S STUDY**

The aim of this study is to investigate the potential integration of simulation and visualization techniques to better represent EV population in metropolitan areas. We are witnessing a long history of the development of simulation, 3D visualization and also geographic information system (GIS) in research and practise. However, the integrative uses of these techniques are still in early stages. For urban environments and transportation systems planning and policy making, the importance of spatial visualization, VCM, lies in its potential for improving the quality of decision-making (Wang, 2005). VCMs help presenting large amount of data, identifying patterns (Ware, 2000) and presenting interdependencies hence better understanding (Helbing et al., 2000). VCM is based on CityGML data format which is a profile of GML3. CityGML implements an interoperable, multi functional, multi-scale and semantic 3D city model. It supports several levels of detail (LoD) as identified by Kolbe et al. (2005) which start from LoD 0, the coarsest level and it contains two and half dimensional digital Terrain (Terrain surface: foremost geographic object and a base of 3D space in VCM (JIN et al., 2005)), to LoD4 which is detailed architectural models including interior and furniture. 2D maps and plans with occasional prospective views and static images presentation technique has been used for urban-planning purpose (Wang, 2005). Planners primarily work on a 2D analytical mode (Pietsch, 2000, Orford et al., 1999). However, for the purpose of the study, a VCM with LoD 2 which presents building textures, networks and infrastructure would perfectly suit.
Towards better spatial planning and micro-dynamic network outputs, the integration of 3D visualization and simulation modelling can represent the dynamics within a realistic visual environment (Figure 2) instead of non-visual approaches such as text and tables (Wang, 2005). In order to represent mobility system, three ways of integrating simulation and visualization techniques can be considered: (1) 2D visualization of ABM simulation, (2) 2D simulation presented in 3D environments (simulation is draped on a 3D Terrain surface) or (3) simulation in a 3D modelling environment.

Since the integration concept has proven its importance and vitality, the guidance in choosing the approach to be employed, is the capability of the simulation platform and how good it would accommodate 3D visualization. Following the evaluation of the platforms presented early this paper, and on the purpose of the present study, the selected platform should be reliable and capable to simulate behavioral characteristics of drivers, give same results with less effort, simplify the simulation environment configuration and provide more flexibility in changing simulation parameters and future situations.

VISSIM platform showed good results in terms of 3D visualization. From literature, it has been utilized before to simulate traffic and it has proven success in merging traffic simulation with 3D modeling (Nomden et al., 2009). However, due to the unique nature of EV population as observed from (Table 3), EVs simulation will not require massive traffic and complex network data as an inputs. A more agent-based oriented platform in modeling would get more credits and higher preference. Anylogic is ABM platform in the first instance, accommodates hybrid problems (if needed), requires less coding (code writer) and has an interactive simulation environment which facilitates having IF THEN rules and AI algorithms via JAVA coding. Built-in logic, state charts options and API (Application Programming interface) would perfectly facilitate modelling EV population with less coding effort. To conclude, integrating simulation outputs with 3D modelling is the recommended approach for simulating EV for urban planning purposes. 2D simulation to be conducted in ABM platform (AnyLogic is recommended for its capabilities), exported, draped in VCM creating spatial dynamic interaction model.

Finally, we can now clearly clarify the five main steps needed to develop the EV Agent (EVA) simulation: (1) understanding the nature of the system, (2) evaluating available platforms and selecting appropriate one for the study focus, (3) developing agent’s architecture, (4) simulating the population using appropriate platform, and finally (5) integrating the simulation with VCM. The setup, configuration, and environment of the simulation is a multi criterion decision:

- Simulate micro-dynamic large-group simulation (vehicular movements).
- Fast execution time, stable, interactive and reliable agent based modelling;
- Requires less coding for adding IF THEN simulation rules.
- Has a 2D and can be coupled to realistic 3D visualization solutions (Figure 2);
- Accepts GIS in case of geo-simulation is required.
- Can simulate societal and behavioural models;
- Has an API collects and extracts real-time information, exports to 3D visualization suite (if needed for visualization purposes).

**CASE STUDY: NEWCASTLE-GATESHEAD AREA**

The chosen focus area is the inner urban core of one of the UK North East metropolitan areas, Newcastle upon Tyne, was selected as the research pilot study. The simulation input data is based on the real information about EV drivers and their usage which is provided by CYC back office (C(harge) Y(our) C(ar), 2011), EV local service provider for the UK North East region. The selection criterion of the case study is based on meeting two conditions: (1) Active in EV market and (2) leading in the 3D visualization techniques. Newcastle has proven success in providing initiatives and schemes for low carbon emissions vehicles. It is leading the North Sea region
in promoting EV market. Since 2009, Built Environment Visualization Centre at the school of the Built and Natural Environment, Northumbria University in collaboration with Newcastle City Council and Gateshead Council has been developing the virtual Newcastle-Gateshead (VNG) to be used for planning and various different applications.

**The artificial brain development of EV drivers’ agents**

The ABM simulates each (EV) battery as an autonomous agent which makes its unique decisions by daily planning (O-D matrix) and finding charging points (Elbanhawy et al., 2012). The following points summarize agent’s attributes and model assumptions:

- Simulation path: EV agent starts defining the Origin-Destination (O-D).
- Update time-interval: On a daily basis.
- Route Choice/Decisions: Daily basis, and at every destination, the agent chooses its path with new destination(s), checks the EV battery hence charging schedule.
- Battery states: 0%, 30%, 50%, 70%, 90% (depends on domestic charging).
- No. of possible destinations: 3 destinations/day (based on average miles/day).
- Charging scenarios: (1) Domestic (2) At work, (3) On and off street (public) (Elbanhawy et al., 2012).

The model outcomes will be calibrated by the information about real-world usage provided by CYC. The correlation factor between the simulation and real Newcastle-Gateshead will be monitored. Eventually, more information is to be added and simulated while validating and calibrating the model before trying different states.

**CONCLUSION**

This study aims at investigating the paradigms of e-mobility system. An overview showed the common and extraordinary parameters and configurations between conventional and e-mobility systems. E-mobility is quite a distinctive pattern to be simulated.
by micro-dynamic ABM where an emergent behaviour to be observed as an output. The simulation has five main stages that start with scanning the market and understanding the EV mobility nature, to selecting appropriate platform, to developing agent’s architecture, to developing the simulation modelling, to finally analyzing it and giving recommendations. Recommendations and observations shall depict the current state of the infrastructure network and individual travelling patterns and charging behaviours. For perfectly fitting the purpose, 2D simulation is to be conducted via ABM platform and to be integrated with 3D city model. This would help presenting the phenomenon hence better analyses opportunities for planners and policy makers.

ACKNOWLEDGEMENT
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