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Infrastructure as social catalyst: Electric vehicle station planning and deployment

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ABSTRACT

Although transportation infrastructure is often recognized as a powerful driver with regard to urban form, it is less frequently recognized for its ability to act as a social and behavioral catalyst. With the demographic shift of people moving to cities and the corresponding increase in competition for the space of transportation infrastructure, as well as the introduction of new technologies to transportation, innovation on how we approach the design of such an important urban component is essential. Here we present a project which responds to the question 'How do you plan and implement an infrastructure for the introduction of a new transportation technology?' This paper describes the planning, design and deployment of a network of electric vehicle (EV) charging stations in British Columbia from a synthetic human-centered design perspective. The project can be used as a reference when discussing holistic approaches to emerging technology based product adoption. In particular, this project focuses on the infrastructure required to support EV uptake and presents a new methodology for planning and deploying EV infrastructure based on a holistic multi-disciplinary approach. Our approach considers that the design of new infrastructure is both a social and cultural undertaking as much as it is a technical one. This view of infrastructure design requires a different design perspective and a pedagogical shift to accompany it. The innovation process in a service sector, such as infrastructure design, precedes the innovation in the product and, as such, a study of a novel process is important (Abernathy et al., 1975, Linton and Walsh., 2003). The methodology we propose for the deployment of a charging stations network is here presented in all its components, reflecting the approach described. We developed the project from a staged network framework built on the technology adoption curve. The framework is adaptable to an evolving deployment, technology and market timeline. The strategies adopted include context specific station phasing, regional network design, station design and branding, and a phased business model. The deployment plan is based on a GIS analysis of urban form which engages predictive analysis to inform where the infrastructure will have the most impact. Ultimately, the case presented demonstrates a complex set of variables involved in the design of infrastructure for emerging technologies, thus contributing to the argument for synthetic design in the study of innovations.

1. Introduction

Technology and product innovation in transportation such as advances in electric vehicles are now having a profound impact on transportation systems and infrastructure. Some current examples of these technologies and products are apps that plan routes by multiple modes of transport, with several layers of information (Google Maps); apps that plan car sharing or hail taxis (Uber); and technologies to support alternative fuel vehicles. Future transportation technologies that are set for the personnel automobile include self-parking and eventually self-driving capabilities in cars which again will change the game for transportation infrastructures. Here we provide the example of the social infrastructure required for massive electric car deployment.

Infrastructure innovation as well as product innovation is required for the electric car deployment. Sussman (2005) identifies innovation as one of the main aspects that new transportation professionals must acknowledge for the transportation industry. The development of new technologies is especially relevant when considering the necessity for mitigating the negative environmental impact of transportation systems while assuring productivity and economic growth (Sussman, 2005). Technologies from Intelligent Transportation Systems (ITS) to Electric Vehicles (EV) to Autonomous Vehicles (AV) may play a relevant role towards the fulfillment of these requirements. They also indicate innovation as an important area of interest inside transportation and infrastructure planning decisions, alongside an understanding of how these innovations relate to the many disciplines concerned with infrastructural impacts (Barras, 1986). Programs such as Management of Technology (MOT) are tasked to assist in the development of innovators that will provide an important bridge and reference in this process.

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Management of Technology and Innovation involves increasing multidisciplinarity and complexity (Yanez et al., 2010). As such, new approaches to the study and deployment of innovation-related infrastructures must also be developed. This paper deals with one such approach. In a first stage, this paper addresses the adoption of EVs by the public, its key relationship with infrastructure, and the need for new T-professionals to engage in the complex challenge of public infrastructure.

Traditional higher education produces subject experts with little understanding of other disciplines. These professionals, termed I-shaped professionals, are valuable in a range of occupations, but they are not adequately educated as innovators. T-shaped professionals also have expertise in specific disciplines (T's "leg"); however they know how their discipline interacts with other fields and disciplines (T's "root") (Karjalainen et al., 2009).

Education, then, must also change in order to teach upcoming new professionals how to approach a complex multidisciplinary problem. Case studies of approaches to these more complex problems are the key to the students' learning. Discussion of approaches in relation to each other is a valuable teaching mechanism by which students can apply higher order thinking processes to the topics. These topics are complex and, as such, rules cannot be established. The teaching process must engage analysis and synthesis of the issues. This type of synthetic thinking can then be applied to other design problems.

The project described in this paper was developed in a project-based learning laboratory which trains T-shaped design professionals. T-shaped design professionals are particularly educated in design thinking. Design thinking is taught in design schools such as architecture and industrial design, but has more recently been adopted by business schools (Brown, 2008) and other disciplines as a way of approaching a multitude of problems which have multi-prong, interdependent criteria. Design thinking approaches innovation activities with a synthetic, human-centered design ethos (Brown, 2008). This becomes more necessary as infrastructure becomes a more contested space with more interrelation to technological innovation and with more complexity in the aspects of its use. It is no longer only a simple engineering exercise but rather a social and cultural balancing act. The project reported in this paper demonstrates the multidisciplinary nature of transportation infrastructure design for emerging technologies, suggesting the need for T-professionals with knowledge of creative design processes to address the critical role of innovation in the field.

We present and expose to students striving to become T-shaped professionals and T-shaped design professionals a new methodology for planning and deploying EV infrastructure based on a holistic view of the problem. The approach is based on design thinking and more specifically the architectural approach taken to infrastructure. This paper presents the underlying construction of a complete framework for station location that has been implemented and is currently being tested in a real world context. The methodological framework was developed with a flexible and interdisciplinary focus which will be discussed throughout the paper.

1.1. The complex problem of EV adoption and EV infrastructural planning

In order to introduce the complex problem of EV adoption and EV infrastructural planning, we separate the discussion in two stages. First we present the discontinuous innovation of the EV by referencing Moore (1991). Second we discuss the societal based infrastructural planning required for massive EV acceptance.

Notably, EVs are considered discontinuous innovations. Moore (1991) himself, when presenting the concept of continuous and discontinuous innovations, classified EVs in the "discontinuous" end of the continuous–discontinuous continuum. According to Moore (1991), discontinuous innovations are new products or services that require a drastic change of the end user's behavior and of the marketplace, in exchange of equally drastic new gains and benefits. Discontinuous products often require modification of other products and services that support them. Furthermore, discontinuous products may lead to cultural changes.

The second part of the discussion, EV infrastructural planning, is a critical aspect of adoption and utilization. Charging infrastructure is the supporting service considered necessary to facilitate the basic functionality of EVs and to enhance public confidence in the technology. One of the main barriers to the uptake of electric vehicles is lack of infrastructure (Klabjan and Sweda, 2011). Currently, there is little financial incentive to install public charging stations and installation costs far outweigh potential profit in the early stages of EV adoption (Weiderer & Philip, 2010, p.45).

However, public charging infrastructure is assumed to play a significant role in counterbalancing the fear, uncertainty and doubt typically associated with new competitive innovations. Among EV users, this trend is demonstrated by the relief of "range anxiety". "Range anxiety" can be described as users' "continual concern and fear of becoming stranded with a discharged battery" (Tate et al., 2008, p.3).

In Japan, a widely cited pilot project by the utility TEPCO (Tokyo Electric Power Company) demonstrated that public charging infrastructure significantly reduced range anxiety, even though the drivers rarely used the public infrastructure (Botsford and Szczepanek, 2009). The change in behavior was significant. Prior to the public fast charging stations being installed, drivers consistently returned to the main office with greater than 50% charge (approximately 70%) remaining; after the public stations were installed, they consistently returned to the main office with less than 50% charge (approximately 30%). From cases like this, it can be concluded that the confidence boost from public fast charging stations is necessary to encourage widespread EV adoption.

Developing public infrastructures facilitate changes and can develop unintended consequences; such as what has happened with the road infrastructure and its adverse effects in the United States. By now, many authors have discussed how infrastructures for transportation technologies have shaped the very form of our cities, as well as have produced multiple unanticipated societal outcomes (Muller, 1995; Marchetti, 1994; Cervero and Gorham, 1995; Frumkin et al., 2004; Fagnant and Kockelman, 2014). The evidence provided by this growing body of literature point towards the need for interdisciplinary discussions around urban infrastructures. T-shaped design professionals are required to successfully integrate the agendas of urban planning, transportation technology and diffusion of innovation. This project is an attempt to demonstrate such an approach as a prototypical project to be studied by students and emulated in future projects.

1.2. A project to bridge multiple perspectives

Transportation infrastructure is a public enterprise. As such, it affects a wide range of people, organizations and interests, although these might not always be involved in the infrastructure's planning. Disruptive transportation technologies need to engage a wider discussion including societal impact, by means of both intrinsic cultural change and infrastructural change. As discussed further on in this paper, the current standard approach for EV charging infrastructure planning does not address these issues thoroughly.

Here the authors have detailed a project conducted from 2011 to 2014 by TIPSlab, which will serve as reference source for assisting in the development of T shaped professionals. TIPSLab (Transportation Infrastructure and Public Space Laboratory), at the University of British Columbia, is an interdisciplinary research group which examines the potential and implications of future technologically related transportation infrastructures. The project was carried out under a series of grants from utilities, federal and provincial agencies in order to plan and install a large network of Fast Charging and Level 2 stations throughout the province of British Columbia, in Canada.

The primary purpose of the infrastructure plan is to encourage adoption of Electric Vehicles in order to reduce greenhouse gas emissions. This project is distinct from other transportation infrastructure projects in that a holistic approach was adopted, considering all aspects of the