



Original research article

Experts, theories, and electric mobility transitions: Toward an integrated conceptual framework for the adoption of electric vehicles

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ABSTRACT

I expand and integrate a theory of mobility (Automobility) with one of science and technology (Actor Network Theory) and one about social acceptance and user adoption (UTAUT). I apply this integrative framework to the diffusion (and non-diffusion) of electric vehicles and the process of electric mobility. I begin by presenting my methods, namely semi-structured qualitative research interviews with social theorists. Then, I present the three theories deemed most relevant by respondents. Automobility holds that, on a cultural or social level, automobiles exist as part of a complex, one that involves hardware and infrastructure—a hybridity between drivers and machines—along with patterns of identity and attitudes about driving pleasure. Actor Network Theory (ANT) involves the concepts of network assemblage, translation, enrollment, and actants and lieutenants. The Unified Theory of Acceptance and Use of Technology, or UTAUT, states that on an individual level, the adoption of new technologies will be predicated on interconnected factors such as performance expectancy, effort expectancy, and other facilitating conditions. Based largely on the original interview data supplemented with peer-reviewed studies, I propose a conceptual framework of user acceptance consisting of motile pleasure, sociality, sociotechnical commensurability, and habitual momentum. I conclude with implications for research and policy.

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1. Introduction

The rise of the coveted automobile is sometimes depicted as one of the great achievements of the twentieth century. During the first half of the last century, the gasoline-powered vehicle evolved from a fragile, cantankerous, and faulty contraption to a streamlined, reliable, fast, luxurious, and widely affordable product [1,2]. These automotive engineering feats were enhanced by the creation of interstate highway systems and urban infrastructure that have offered many people unprecedented mobility [3].

However, the global proliferation of auto-dominated transportation systems and the monopoly of gasoline and diesel transportation fuels have germinated severe social and environmental consequences. These include costly traffic congestion and fatal accidents, deterioration of air quality, greenhouse gas emissions, and susceptibility to interruptions in supply and price volatility of oil [4,5,6]. Yet transitioning away from our existing transportation system, Kemp et al. note [7]: [7: p. xiv], may very well

be “the hardest case” because “there are many stabilizing mechanisms and secular trends that point in the direction of more, not less, mobility.” Moreover, in a meta-analysis about how people think about sustainability and environmental problems, Kormos and Gifford [8] demonstrated considerable unexplained variance between self-reported, objective, and observed behavior. This could lead one to determine that we need better theoretical frameworks concerning transport and mobility to accommodate conflicting or at least confusing data.

To assist with this call for improved theoretical constructs, in this article I connect three theories to create a conceptual framework for electric mobility, a phenomenon brought about by electric vehicles (EVs) in all of their forms, from cars and buses to scooters and motorcycles. Electric mobility has the potential to improve the efficiency, affordability, and sustainability of transport [9,11]. By marrying advanced power electronics and computer controls with conventional and electric drivetrains, vehicles with battery electric motors typically operate more efficiently than those that run on internal combustion engines alone [10]. EVs could, in the extreme, potentially revolutionize our transport system for the better through a combination of improved technologies [11] and improved practices [12]. Turton and Moura [13] argue that EVs offer a potential “paradigm shift” in how we conceive of future markets

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Table 1
Transformative potential for the electric mobility paradigm.

Current paradigm	Electric mobility paradigm
Mechanically driven Powered by internal combustion engine	Electrically driven Powered by electric motors
Energized by petroleum Mechanically controlled Stand-alone operation	Energized by electricity (or hydrogen) Electronically controlled Potential for intelligent operation and interconnected management

Source: Modified from [9].

for energy and mobility. Mitchell et al. [9] go even further to suggest that EVs are “transformative” as they change the “automotive DNA” underlying transport technologies, as Table 1 summarizes. While these claims are debatable (and partly challenged later on), they at least demonstrate that the topic of EVs and electric mobility is one deserving of more systematic, scholastic inquiry.

Based largely on original semi-structured research interviews coupled with an assessment of peer-reviewed studies, in this article, I ask: What do theories of mobility, science and technology, and user adoption tell us about the acceptance of EVs? More importantly, what are the benefits of theoretical unification should it be achieved? I begin by summarizing the key tenets of Automobility (from sociology and geography), Actor Network Theory (ANT) (from science and technology studies), and the Unified Theory of Acceptance and Use of Technology, or UTAUT (from management science and computing), as shown in Table 2. I then selectively draw from these theories to create an integrative framework of user acceptance centered on motile pleasure, sociality, sociomaterial commensurability, and habitual momentum.

To be fair, there are elements of each of these approaches that are incompatible. This is because at one level they have fundamentally different aims and assumptions. Automobility is an approach, or perhaps a concept that also has a critical, political agenda. ANT is concerned with ontology and epistemology, more focused on description and its understanding of how action comes about. The UTAUT is a theory that comes from inferential statistics. It operates with variables, operationalization and regression models and attempts to explain individual behavior. The penultimate section of the paper, however, shows that the three approaches work very well next to each other—each illuminates different aspects and complements isolated weaknesses.

In proceeding on this path, I aim to make three contributions. First and most specifically, I focus my framework around users, an often neglected dimension of Large Technical Systems or sociotechnical systems [14,15]. Much previous work has, for example, focused on “system builders” (entrepreneurial engineers who design and erect electricity networks or sewage systems, see [16–18] as examples) or taken infrastructure or technology as its unit of analysis, such as the “technological innovation systems” approach [19] or the “multi-level perspective” on technical change [20]. By contrast, I look more deeply at how such broader factors interact with users. Indeed, I utilize the term “user” to refer to not only automobile owners, drivers, and passengers but others involved in the broader sociomaterial system including salespersons, traffic police, mechanics, and public officials. I thus attempt to go well beyond the traditional binary of narrowing users to “producers–consumers.”

Second, and more pragmatically, a deeper understanding of the facilitators and impediments facing electric mobility has much relevance to current debates about alternative modes of transport. In this past decade, engineers and regulators have proposed a host of alternative fuels and modes—including natural gas powered cars, hydrogen fuel cells, and second generation biofuels—as necessary to move away from dependence on gasoline and oil in the transport

sector [21,22]. Comprehending the impediments and challenges faced by EVs illuminates how users may accept particular modes of mobility but reject others.

Third, based on interviews with 35 expert social scientists, I integrate aspects of three theoretical approaches—also phrased at times as “conceptual frameworks,” “models,” “theoretical constructs,” “analytical frameworks,” or “concepts”—seldom used together: Automobility, ANT, and the UTAUT. In their exhaustive review of the literature on public attitudes and transport behavior, Anable et al. [23] suggest that approaches such as Schwartz’s Norm Activation Model or Azjen’s Theory of Planned Behavior, which focus on individuals, are used in isolation from broader ones analyzing communities, organizations, or the wider social and cultural environment. Previous research has, for instance, explored individual attributes to the adoption of new vehicles such as personal preferences for convenience [24] or freedom [25]. Axsen and Kurani [26] investigate interpersonal influences such as a desire to inspire others or symbolize environmentalism, whereas Stephenson et al. [27] examine broader external forces such as fuel subsidies. Sheller [28] approaches the topic through the angle of “master frames” of mobility and legitimacy. Rarely, however, are these insights combined. By synthesizing selectively but qualitatively from three theories, I seek to provide an integrated framework—centered on motile pleasure, sociality, commensurability, and momentum—that can explain electric mobility preferences across individual, interpersonal, socioenvironmental and network scales.

2. Research methods

My primary research tool for this study was semi-structured research interviews with knowledgeable experts (“theorists”) about mobility and electric mobility. I interviewed 35 scholars over late 2015 and early 2016 reflecting 18 self-reported disciplines ranging from anthropology and behavioral science to science and technology studies and transport studies, as Appendix 1 indicates. These authors represented 26 separate institutions—mostly universities and a few research institutes—spread across seven countries: Canada ($n=1$), Denmark ($n=1$), Finland ($n=1$), the Netherlands ($n=5$), Norway ($n=1$), United Kingdom ($n=13$), and the United States ($n=13$). This pool of experts was admittedly a convenience sample, but the idea was to approach two different types of scholars: senior and eminent ones well-known within theoretical debates, namely full professors or established researchers with highly cited articles ($n=28$); as well as junior researchers considered cutting edge and pushing concepts in the field ($n=7$).

In terms of the interview process, I asked only two open-ended questions: What theories or concepts are most useful at explaining the adoption of electric vehicles or mobility preferences? And, how can these be integrated, if at all? I asked a follow up question at the end of the interview for supporting articles, reports, books, and other sources of data for further information. To be fair, these questions could also have been directed at non-electric forms of mobility or transport preferences in general—to be candid, they were directed only at EVs for two reasons. One, EVs are distinct from other transport options for having the transformative potential explained in the Introduction. Two, the nature of the grant funding the work (see the Acknowledgments section) dealt only with electric mobility and vehicle-to-grid integration, requiring a focus on EVs.

Interviews ranged from 20 min to 4 h, with a mean time for most of 45 min. With permission, I present quotations from this material below with attribution. I recorded any theory or concept mentioned by participants; the three approaches mentioned more than 20% across all respondents—Automobility, ANT, and the UTAUT—are presented here and summarized by Table 3, and dis-

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