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Functional, symbolic and societal frames for automobility: Implications for sustainability transitions

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ABSTRACT

Automobility refers to the continued, self-perpetuating dominance of privately-owned, gasoline-powered vehicles used primarily by single occupants—a system which clearly has broad environmental and societal impacts. Despite increasing societal interest in transitions to more sustainable transportation technologies, there has been little consideration of how such innovations might challenge, maintain or support different aspects of automobility, and what that means for technology deployment, transport policy, and user practices. To bring attention to the complexity and apparent durability of the automobility system, in this paper we develop a conceptual framework that explores automobility through a categorization of frames, or shared cultural meanings. This framework moves beyond the typical focus on private, functional considerations of user choice, financial costs and time use to also consider symbolic and societal frames of automobility that exist among users, non-users, industry, policymakers and other relevant social groups. We illustrate this framework with eight particular frames of automobility that fall into four broad categories: private-functional frames such as (1) cocooning and fortressing and (2) mobile digital offices; private-symbolic frames such as (3) gender identity and (4) social status; societal-functional frames such as (5) environmental stewardship and (6) suburbanization; and societal-symbolic frames such as (7) self-sufficiency and (8) innovativeness. Finally, we start the process of discussing several transportation innovations in light of these automobility frames, namely electrified, autonomous and shared mobility—examining early evidence for which frames would be challenged or supported by such transitions. We believe that appreciation of the complex and varied frames of automobility can enrich discussion of transitions and policy relating to sustainable transportation.

1. Introduction

The continued dominance of privately-owned, gasoline-powered vehicles used primarily by single occupants is a major contributor to several societal problems, including climate change, air pollution, excessive traffic congestion, and negative land-use impacts. This self-perpetuating system has been referred to as automobility, a term that covers the full breadth of actors, materials, technologies, policies and practices that make up and reinforce private vehicle usage (Urry, 2000, 2004; Kirsch, 2000; Sheller and

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Urry, 2006, 2016). Many policymakers and other stakeholders have explored and supported efforts to transition towards more sustainable forms of mobility, such as more efficient vehicles, vehicles powered by low-carbon fuels, and promoting mode switching (walking, cycling, and transit) through improved urban density and infrastructure changes—though to date none of these efforts have substantially improved the sustainability of global transportation systems.

Like other sectors, societal interest in transportation alternatives has followed successive cycles of "hype and disappointment" over the last few decades (Melton et al., 2016), with the most recent hypes including electric mobility, autonomous vehicles and shared mobility. However, there has been little consideration of how such innovations might challenge, maintain or support different aspects of automobility, and what that means for deployment. Moreover, discussion of sustainable mobility transitions often flow from a constrained view of consumer perceptions, assuming that alternative forms of mobility need only to replicate the functions of automobility (e.g., a means to get somewhere at an affordable cost) in a way that is either similar to or better than the status quo in order to succeed. While the concept of automobility and related discussions of the "new mobilities" paradigm have generated insights regarding new, sustainable transportation patterns (Sheller and Urry, 2006, 2016), most academic and policy discourse of such transitions continues to unduly focus on the role of personal choice and, in particular, "rational" consumers motivated primarily or even solely by financial costs or their valuation of travel time (Shove, 2010).

We thus start from the position that modes of transportation, especially automobiles, are more than just functional technologies (Schuitema et al., 2013). They are means of identification; items of conspicuous consumption; possible abodes of privacy, solitude, and ritual; instruments of aggression and skill; ceremonial initiations into adulthood; and potential hobbies (Fagen, 1983; Kent, 2014). Passenger vehicles are polysemiotic, that is, they signify multiple ideas. The development of particular modes of transport are thus deeply altered and affected by social and cultural patterns of courtship, residence, socialization, work habits, education, leisure, and suburbanization (Flink, 1980). Cars provide status and emotional affect through their speed, security, safety, link to sexuality and career achievement, and facilitation of freedom (Sheller, 2004: 221-242).

In this paper, we introduce and develop a framework to discuss the broader complexity of the meanings of automobility in modern society, which holds important implications for the consideration of alternative mobility forms and policy pathways. Specifically, we examine automobility using the concept of "frames"—what Lakoff (2004, p. xv) terms "mental structures that shape … the way we see the world, the goals we seek, the plans we make, the way we act, and what counts as a good or bad outcome." A large body of research has explored the role of frames concerning technologies, science, policies and social issues, which both reflect and shape perceptions among different social groups and public decision making (Fischer, 2003; Pal, 2014). Frames also have a subconscious undercurrent in creating and circulating the myths that guide our collective lives (Strauss et al., 2013). Thus, automobility can evoke or be interpreted through multiple frames—frames cut to the underlying nature of how people interact with transport modes and resulting mobility practices. Moreover, examining automobility through frames recognizes functional but also symbolic, cultural, and psychological elements of modern cars (Sachs, 1992; Hard and Knie, 2001; Stephenson et al., 2015; Sheller, 2012).

In effect, we develop a conceptual framework exploring automobility through a categorization of frames that extends from such private, functional dimensions to more seriously consider symbolic and societal dimensions—at the same time moving beyond the individual user to also consider the broader system of automobility. We seek to illustrate how appreciation of the complex and varied frames of automobility can enrich discussion of transitions to sustainable transportation. We draw from a variety of literatures in doing so, providing evidence for the framework and its application. As part of this, we apply our framework to three current innovations in sustainable transport, namely electrified, autonomous and shared mobility—increasingly referred to as the "three revolutions" of transportation (Sperling, 2018). For the quantitative-minded reader, this process is exploratory and meant to be hypothesis generating rather than hypothesis testing. The main contributions of this paper are conceptual. First, we integrate insights from two approaches—automobility and frames—to create a conceptual framework that we believe can improve further research on and discussion of transitions within or beyond automobility. Second, we identify and discuss eight examples to illustrate the breadth of this framework, while not meaning to be exhaustive . Finally, we start the process of discussing these three transportation innovations in light of automobility frames—a perspective that is largely absent from literatures on all three technologies. This conceptual framework and approach are guided by the authors, informed by our collective and varied experience in transportation and social science research. With this process and these novelties, we aim to motivate increased attention to the broader sociality of automobility, moving beyond an often exclusive focus on user choice guided by financial and functional considerations.

2. Conceptual framework: automobility and frames

We begin by further defining the two main aspects of our framework. First, we draw from Sheller and Urry's (2000) definition of automobility as a complex, self-reinforcing socio-material system that is strongly intertwined with technology, culture, norms, and practices in most modern countries. Automobility is about far more than the car: it encompasses the broader system that supports car use, including industry and supply chains, users and non-users, social practices and cultural expectations, as well as politics and policy. One needs to look at this full system to understand the present dominance of privately owned passenger vehicles over other modes of transportation, a dominance that has proven exceptionally resilient over the past century, and across space, spreading to most regions in developed and developing countries alike. While earlier patterns of human settlement were shaped by stagecoaches, locomotives and street trolleys, automobiles become the key influence in most developed countries by the mid-1900s (Sovacool, 2009). Indeed, Sheller and Urry (2004, p. 31) describe modern societies as being "irreversibly locked in" to the usage of fossil-fuel based cars due to, among other things: the development of supportive long-lived infrastructure such as roads, buildings and automobile-centric suburbs; the inertia and political clout of incumbent industry; and the corresponding shaping of cultural expectations

about social practices and the organization of time and space. In short, automobility describes the complexity and durability of private, fossil-fuel powered vehicles as systemic in nature, involving a broad range of social groups, technologies and practices.

The second aspect of our framework is frames, a term which helps to bring the comprehensive, but sometimes vague, notion of automobility into focus via specific examples of shared cultural meaning. In the broadest sense, a frame is simply a way of organizing experience (Goffman, 1974). The notion of a frame has been influential across a variety of disciplines, from artificial intelligence and communication theory to psychology, innovation studies, and public policy. Berkout (2006: 302) notes that a frame is seen both as "functional to interpretation, sense-making and problem-solving by social agents, and to establishment and maintenance of cohesion and order of social groups" as well as "a means for reconciling experience with knowledge, while at the same time being grounded in the social and institutional frames within which agents act." Thus, one can have individual cognitive frames, policy frames, media frames, and even technological frames (Valentine et al., 2017; Brown and Sovacool, 2017).

Our use of frames is in line with the social construction of technology literature, where a "technological frame" refers to "all elements that influence the interactions within relevant social groups and lead to the attribution of meanings to technical artifacts" (Bijker, 1997, p. 123). Put in simpler terms, a technological frame refers to a shared cognitive worldview that binds different stakeholders together, meaning it is beyond any individual or group. A given frame can often have a positive or negative element, emphasizing the benefits or risks of a given technology (Stephens et al., 2008). Klein and Kleinman (2002, p. 31) add that a frame can deeply penetrate stakeholder perceptions of technology, structuring their thinking, influencing problem solving, shaping the formulation of strategy, and even altering design specifications. Despite the dominance and apparent stability of automobility, it can still be seen as a contested social space populated by overlapping competing and complementary frames, a finding that holds true for many other technological artifacts and sociotechnical systems (Stoknes, 2014; Goldthau and Sovacool, in press; Pinch and Bijker, 1984; Bruun and Hukkinen, 2003). As we will explore in this article, some frames can support or challenge the status quo of automobility, potentially in a contradictory way – for example, electric vehicles can both support the dominance of privately-owned vehicles (maintaining many environmental impacts), while supporting a movement against fossil fuel usage (reducing many environmental impacts).

Essentially, automobility describes the dominance, and self-reinforcing nature of cars, while frames can describe the changing, flexible nature of how aspects of automobility can be interpreted in different ways by different groups over time. To bring together these broad concepts of automobility and frames, we establish a general categorization of frames using a two-by-two typology developed by Axsen and Kurani (2012). Starting from the position that much of the transportation literature has continued with a focus on private-functional frames, this typology emphasizes that automobility can fulfill symbolic as well as functional attributes across private and societal dimensions. This typology was originally developed to categorize consumer perception of the potential benefits of plug-in hybrid vehicles, and has since been used to categorize consumer perceptions of alternative energy and alternative fuel vehicles (Matthews et al., 2017; Noppers et al., 2015, 2014). Starting in Section 3, we will extend this framework to categorize broader societal frames of automobility—not just the perceptions of a vehicle owner, driver, or passenger, but also to the broader range of system users such as cyclists or pedestrians, industrial researchers, government and urban planners, writers for the mass media, and members of civil society (to name a few).

Axsen and Kurani (2012) proposed that consumer perceptions of automobile benefits can be divided into a two-by-two dimensional typology depicted in Table 1: functional versus symbolic, and private versus societal. The functional aspects of automobiles are important, where consumers may want a passenger vehicle to be practical, to be reliable, to save money or minimize costs, or improve performance. These are examples of private-functional benefits, which are often the sole focus of research and societal discussion of present transportation technologies, as well as discussions of the strengths and weaknesses of new, more sustainable transportation technologies and practices. However, several streams of research indicate that consumer perceptions are more complex and amorphous than a purely functional focus allows. For instance, the assumption of the rational, cost-minimizing car purchaser or user desiring to save time has been found to be inconsistent with empirical research (Turrentine and Kurani, 2007; Gärling and Steg, 2007; Kent, 2014). To move beyond the private-functional frames often rooted in engineering or neoclassical economics, some transport researchers are drawing from disciplines such as sociology, psychology, and history, as well as interdisciplinary frameworks (Sovacool, 2017).

In this vein, Axsen and Kurani's (2012) framework describes consumer perceptions of private-symbolic benefits, covering the

Table 1
Conceptualization of the benefits of plug-in hybrid electric vehicles (illustrative examples). (*Source:* Adapted from Axsen and Kurani (2012))

	Functional	Symbolic
Private	The functional benefit to the consumer, e.g.	The symbolic benefits to the consumer, e.g.
	• Save money • Reliable • Improved performance	• Expression of self-identity • Convey personal status • Attain group membership
Societal	The functional benefit to society, e.g.	The symbolic benefit to society, e.g.
	• Reduce air pollution • Reduce global warming • Reduce oil use	• Inspire other consumers • Send message to automakers, • government, oil companies

symbolic meanings that are found to be highly intertwined with vehicle use (Steg, 2005; Steg et al., 2001), where automobiles can express self-identity, convey personal status, or signal membership in a particular group. Such symbolic frames have been found to be particularly important for alternative-fuel vehicles, for example where one study of hybrid vehicle owners found that their vehicles embodied meanings that were not previously provided by conventional automobiles (Heffner et al., 2007). In more recent research, specific makes and models of electric vehicles have been found to be associated with different symbolic frames, for example with the Nissan Leaf being seen as more "pro-environmental", and Tesla models being instead associated with being "exotic" and "successful" (Axsen et al., 2015, 2017). More generally, one sees such frames embodied in popular television shows such as "Pimp my ride!," which show how the customization and personalization of cars can convey symbols to others. Thus, alternative forms of mobility can be innovative not just because of improvements to technical performance, but also because they convey a "different social meaning" than conventional transportation technologies and practices (Hirschman, 1981).

Moving to another dimension of Table 1, while the above examples focus on the potential benefits to be realized by the vehicle owner or user, consumers can also perceive benefits to society more broadly. Passenger vehicles are private goods in practice (Canzler, 1999), though their production and usage inevitably impact society more broadly, in what economists describe as negative externalities such as air pollution, greenhouse gas emissions, fossil fuel dependence, congestion and land-use impacts (e.g. sub-urbanization), noise, visual pollution, the dissection of ecosystems, roadkill, and impairment to human health, to name a few (Douglas et al., 2011; Calthrop and Proost, 1998; Hohmeyer et al., 1997). In that sense, new, more sustainable mobility technologies can provide a public good by reducing these environmental and societal impacts. For this reason, passenger vehicles can be perceived as "mixed goods" that have aspects of private and public (societal) goods (Brown, 2001; Green, 1992), especially for alternative fuel vehicles and transportation practices where reduced environmental impact is often the primary benefit. Of course such public good benefits suffer the classic market failure of being under-provided by market forces—as the costs are borne by the car buyer, and benefits are spread across society more broadly.

Following Axsen and Kurani (2012), we employ the terms "societal" as a broad category of collective benefits, including reductions in environmental impacts, national impacts (e.g. reduced oil dependence) and land-use impacts. This dimension distinguishes between two types of societal benefits. Functional-societal benefits relate the vehicle's direct impacts on the environment, energy security or land use patterns. In contrast, symbolic-societal benefits relate to the vehicle's ability to inspire other users, companies and governments to engage in activities that in turn impact society more broadly, which could maintain or strengthen existing negative impacts (e.g. supporting current gasoline use), or reverse them (e.g. transition to low-carbon fuels).

As noted above, while this framework was developed for consumer perceptions of potential automobile benefits, we believe it also can help to categorize broader frames of automobility—frames that are constructed, maintained and contested among a broad range of relevant social groups. Next, we identify eight illustrative examples of such broader frames—two for each cell of Table 1.

3. Eight illustrative frames of automobility

Following our conceptual framework, one would expect automobiles (and supporting infrastructure) to be polysemiotic for drivers and other actors, and to relate to functional, symbolic, private and societal dimensions. In this section of the paper, we identify eight frames connected to automobility (Table 2). The eight frames are meant to be illustrative rather than exhaustive, and to extend beyond the more conventional (functional) interpretation of automobiles as access (to destinations), as convenience (ability to choose when to access such destinations) or as a means of rationally saving or minimizing costs. Continuing with Bijker's (1997) notion of a technological frame also having "relevant social groups" attached to it, we have sketched a few possible stakeholder groups that may subscribe to each frame.

We proceed to discuss each frame in turn, before applying these frames to several examples of potential mobility transitions (Section 4). We note that these frames are largely presented in a positive way, thus focusing on the forces of automobility that self-perpetuate. Of course, there are many potential negative frames of automobility among certain social groups, which can be seen to challenge or contest the status quo. However, instead of focusing on such frames of contestation, we instead focus on dominating frames, and how several mobility transitions might support or challenge them. The final section of the paper offers insights and contributions from our typology of frames for both scholars and policymakers.

3.1. Private-functional frames: the automobile as cocoon, fortress, and isolated enclave, or as a digital office

First is the category of private-functional frames, which, as noted, emphasize individual and fairly utilitarian dimensions of mobility. These include frames relating to user perceptions of convenience, cost and travel time. Because such frames dominate the literature in this field, here we provide two alternate examples from this category: cocooning and the digital office.

In our first frame example, passenger vehicles provide users a sanctuary, a zone of protection between their inhabitants and the dangerous world of other vehicles moving towards and beside one at high speeds on the "killing fields" of modern roads (Urry, 2004). The driver is "cocooned" in an iron cage separated from many risks, strapped into a comfortable if constraining armchair and surrounded by micro-electronic informational sources, controls and sources of affect such as pleasant smells, colors, and sounds (Wells and Xenias, 2015). The automobile becomes less a mode of transport and more a mutable habitat similar to a mobile living room or "sonic envelope" where one can relax, listen to music, and engage in other leisure activities (Bull, 2001, 2004). This frame includes a safety aspect, such as how the drivers of sport-utility vehicles perceive them to be safer than other vehicles (Thomas and Walton, 2008) even though they are demonstrably less safe for other drivers or pedestrians. Such perceptions of "bigger as safer" have created a sort of self-perpetuating "arms-race", with families buying larger vehicles to keep themselves "safe" from the other larger

Table 2
Summary of eight illustrative automobility frames.
Source: Authors

Frame	Type	Dimension	Relevant social group	Explanation
Cocooning and fortressing	Private-functional	What cars do for individual drivers	Individuals seeking solitude or comfort	The car acts as a cocoon, fortress, or isolated enclave where drivers are isolated from the harsh realities of the world and can listen to music, relax, and even engage in sexual activities
Mobile digital offices	Private-functional	What cars do for individual drivers	Employees and office workers	The car acts as a moving office away from work where users can engage in conference calls or check electronic mail
Expression of gender identity	Private-symbolic	What cars represent for drivers	Individuals with feminine or masculine identities	The car acts as a signifier for masculinity (large cars, sports cars, pickup trucks) or femininity (small cars, quiet cars, early generation electric cars)
Expression of class and wealth	Private-symbolic	What cars represent for drivers	Middle and upper class drivers	The car signifies socioeconomic status (luxury cars for the rich, economy or used cars for the poor)
Environmental stewardship	Societal-functional	What cars do for society	Environmentalists, climate activists	The car is more efficient or uses low-carbon fuels that can avoid climate change and air pollution (or the inverse)
Suburbanizing	Societal-functional	What cars do for society	City planners, transport planners, policymakers, commuters	The car facilitates both longer traveling distances and sprawl which make possible commuting to work and suburbanization
Self-sufficiency	Societal-symbolic	What cars say to society	Environmentalists, engineers, climate activists	The car can signal to the petroleum industry that a driver (of an alternative car run by biofuel, hydrogen, or electricity) seeks to be independent of transnational fuel suppliers
Innovativeness	Societal-symbolic	What cars say to society	Early adopters and innovative consumers, grassroots entrepreneurs	The purchase of some cars can signal to automotive manufacturers that they need to produce new products to satisfy evolving user tastes

vehicles.

Another example of a private-functional frame is how cars might be seen as useful mobile offices, an extension of the growth and further development of "co-offices" as sites for meetings and itinerant work. Organizations are already facilitating informal spaces where spontaneous meetings takes place amongst casual coworkers (Garside, 2014). Many users of passenger vehicles already do precarious things like apply cosmetics, conduct conference calls, text, check email, or read while driving a car (Telemaque and Madueke, 2015)—this frame encapsulates these aspirations. Our later discussion of autonomous vehicles will elaborate on the potential for even more extreme versions of this frame.

3.2. Private-symbolic frames: The car as expressions of gender or class

Moving to the private-symbolic category of frames, Steg (2005) found that a variety of non-instrumental motives played important roles in how drivers experienced vehicles in the Netherlands, where "people can express themselves by means of their car." We focus on two particular frame examples here: gender and class.

First, passenger vehicles can be seen as an extension of users' gender identity (Tyfield et al., 2014; Gartman, 2005; Sheller and Urry, 2000; Butler, 1999; Scharff, 1992), which has arguably played a role since the early development of automobility in the rural US (Kline and Pinch, 1996). As Solá (2016: p. 34) writes, "differences between women and men are found in several dimensions of mobility, and … the magnitude of gender differences can shift between dimensions." One stream of research emphasizes gendered travel patterns or a "gap" in travel, with men more likely to travel further but less frequently, with with fewer destinations , and women traveling more frequently with children, and/or walking (Kawgan-Kagan, 2015; Mahadevia and Advani, 2016; Zheng et al., 2016). Others advance a "Gender Socialization Theory" which suggests that "females tend to be socialized toward a feminine identity stressing attachment, empathy, and care" (McCright et al., 2016), the implication being that they will choose vehicles more amenable to protecting their children or minimizing environmental degradation.

Relatedly, manufacturers have long exploited prevailing gender norms when they tried to frame cars as masculine, including the notions of control and mastery (Oldenziel, 1997; Franz, 2005), as well as automotive design that emphasize aggression and noise. For example, Campbell (2005) has noted how sport-utility vehicles came to be masculinized by their association with jeeps and military technology and a sweeping emergence of "cultural militarism" and a "re-masculinization" of American identity and heroes after the American defeat in the Vietnam War. According to Campbell, early sport-utility vehicle drivers, mostly male, would have given up dreams of becoming air force pilots and firefighters, but purchasing and using the vehicle enabled them to feel carefree and adventurous.

To this day we continue to see significant gender-based differences in travel patterns, model sales, marketing efforts, and openness to new technologies. Further, preferences for greener or more efficient cars can be associated with gender, though the direction of the relationship seems to vary across contexts (Sovacool et al., 2018). Some stated preference literature finds that women prefer smaller cars, or more fuel-efficient cars compared to men, or tend to cycle more (Fan, 2017; Kronsell et al., 2016; Aldred et al., 2017), with cleaner vehicles being seem as more feminine and "unmanly" (Brough et al., 2016). In a Swedish study, more women similarly value the environmental benefits of electric vehicles compared to men (Vassileva and Campillo, 2017). On the other hand, a survey in Canada finds that early electric vehicle buyers are overwhelmingly male (81%), especially Tesla owners, though among conventional vehicle owners, females are somewhat more likely to express interest in being the "next" purchaser (Axsen et al., 2016). A focus group study found that woman were more likely than men to emphasize the practical attributes of electric vehicles (Caperello et al., 2014). The potential gender symbolism of electric vehicles is further illustrated in Fig. 1, recently photographed in the United Kingdom, where one owner put flowers on it and also noted on the back that "going green is sexy!."

Second, cars can also reflect symbols of class and luxury (Walker et al., 2000) or as a "status symbol" (Steg, 2005). Indeed, the development of automobility is described as being driven by the upper class from its early days, where passenger vehicles were

Fig. 1. An electric vehicle "Feminized" with flowers in London, United Kingdom, 2016.
Source: Authors

framed as a “race-travel-limousine” to meet the goals of prestige and luxury (Canzler, 1999). Katz (2000) also suggests that in the modern era, automobiles have replaced jewelry and watches as possessions that best display identity to the masses. Research suggests that the safety features of passenger vehicles can further reinforce class symbolism, with high-income individuals more likely to purchase safer vehicles (Girasek and Taylor, 2010). Perhaps most obviously, one might simply look at the marketing strategies applied to luxury-class vehicles, and the resulting significant market share, to see that the symbolic conveyance of class remains a strong part of automobility.

3.3. Societal-functional frames: The car as environmental steward or harbinger of suburbanization

This societal-functional frame category relates to the broader social and environmental impacts of automobility, which can be seen as positive and negative. Of course, automobility can be objectively described as causing significant negative environmental impacts. The average petroleum-powered vehicle emits prodigious amounts of carbon dioxide per liter of gasoline burned, making the transportation sector responsible for about one-quarter of greenhouse gas emissions in the United States and Europe and one-sixth of global emissions (Tran et al., 2012; IPCC, 2014). Conventional automobiles are also major sources of particulate matter which is associated with heart disease, cardiopulmonary disease, atherosclerosis development, cystic fibrosis, chronic lung disease, and some forms of cancer (National Center for Environmental Assessment, 2006; Pope et al., 2009). Admittedly, the actual environmental impacts of alternative fueled and electric vehicles can vary considerably by context, with estimated greenhouse gas reductions varying from 10–24% (Hawkins et al., 2013) to 62–65% (Addison et al., 2010), and even more uncertainty in estimations of related pollution flows in other areas of manufacturing and disposal (e.g. water, metal depletion). We note, however, that the notion of frames is concerned with cultural perceptions of automobility and its variants, which may or may not correspond with more rigorous measures of impacts (e.g. lifecycle analysis).

Our first example frame emphasizes the positive environmental attributes of some vehicles, namely those that are more fuel-efficient or that rely on alternative fuels, leading to the notion of “green cars” as a symbol that is present throughout modern culture, including media and films. Some car buyers have stated they prefer electric vehicles because they believe they offer the potential to reduce tailpipe pollution and to curtail greenhouse gas emissions (Axsen et al., 2016; Carley et al., 2013; Egbue and Long, 2012). As said by one “typical” driver of an electric vehicle, “They’ve got a short battery life but apart from that I really like them. I like doing my bit for the planet and I like to convey the image of an eco-conscious social worker!” (quoted in Dijk, 2016: 80). Others have shown that electric vehicle drivers learn to become more sustainable in other aspects of their life beyond transport, such as coming to learn more about reducing waste or advocating solar panels for the home, escaping “technological unconsciousness” (Ryghaug and Toftaker, 2014). More generally speaking, many users of cleaner cars associate their vehicles with “greenness”, further expressed via social media and interpersonal networks (Axsen et al., 2012; Jensen et al., 2013; TyreeHageman et al., 2014; Axsen et al., 2016). Fig. 2 provides two visual examples of how automobility (top panel), or alternatives to the automobile (bottom panel), can be connected to air pollution and human health.

Our second example of a societal-functional frame views cars as a facilitator of suburbanization or longer distance commuting from home to work, which is perhaps the strongest example of automobility “lock-in” and durability. Early suburbs were made possible by public forms of transport, in North America known as "streetcar suburbs" (Glaeser, 2011). Later the spreading of suburbs worldwide was realized through car-based commuting along roads built for cars. The urban environment as it exists today has been deeply influenced by perceptions of the car as a harbinger of the suburbs, as well as the gradual erosion of investments in public transport and rail. Glaab and Brown (1967) compellingly showed how engineers perfected (and planners adopted) various devices that were part of a high speed system of motorized transportation—grade separation of highway from city street, traffic circles, divided dual highways, and synchronized stop lights. Changes in transportation altered urban form, and urban form in turn almost deterministically reinforced city functions as being centered on the automobile. Rogers (1997: 35) summarizes the drastic influence of this shift: "it is the car which has played the critical role in undermining the cohesive social structure of the city…they have eroded the quality of public spaces and have encouraged suburban sprawl… the car has made viable the whole concept of dividing everyday activities into compartments, segregating offices, shops and homes".

3.4. Societal-symbolic frames: The car as a statement of oil independence or innovativeness

Our final category considers the societal-symbolic frames of automobility, where our examples relate to intentional pro-societal messages that challenge aspects of automobility via oil independence and innovativeness. One frame views cars as a public statement about the perils of oil dependence—particularly cleaner, more efficient cars that signify frustration with oil producers or cartels such as the Organization of Petroleum Exporting Countries, or opposition to war and conflict in the Middle East and elsewhere (Heffner et al., 2007). Articulators of this frame may point to the fact that oil and gas suppliers have consistently employed private security firms to protect their operations and suppress dissent. In Afghanistan, Indonesia, Myanmar, Nigeria, and Peru, some firms selling oil and gas have denied free speech, employed torture, supported slavery and forced labor, sanctioned extrajudicial killings, and ordered executions (Sovacool and Dworkin, 2014; Watts, 2005).

Thus, for some consumers and social groups, driving smaller cars, more efficient cars, cars with electric motors, or cars fueled with alternative fuel such as ethanol or biodiesel can be in a way a social statement to oil producers and cartels that drivers are angry at them for a pernicious set of social and environmental consequences. Historical public opinion polls going back to the 1970s in the United States have found that many drivers “blame” oil companies or OPEC for gas prices and want to hold such organizations accountable, which potentially can be done by driving less or switching to petroleum free modes of transport such as walking or

cycling (Citizen, 2012; Lacey, 2011; Belk et al., 1981; Hummel et al., 1978). Similarly, Lefrancois (1998) finds that driving more efficient or smaller cars can for some represent self-sufficiency and independence as well as other ways of regaining control over one's life, a sentiment that some new vehicle buyers also associate with the usage of electric vehicles and "green" electricity (Axsen and Kurani, 2013a, 2013b). Such sentiments can lead some to believe that their forms of automobility reflect broader social protests against things like oil markets or international conflict, as Fig. 3 underscores.

Our second societal-symbolic frame example is signaling to external groups or organizations such as automotive manufacturers or incumbents, especially when they have been perceived (rightly or wrongly) as dismissive or hostile to innovations threatening their core business strategy (Geels, 2014; Penna and Geels, 2015; Sovacool et al., 2017). Buying a different type of car can therefore be a social indictment of traditional engineering principles and automotive manufacturing practices (Heffner et al., 2007). Electric vehicles, for instance, often use different materials and advanced electric motors, power controllers, batteries, and regenerative braking systems (Dyerson and Pilkington, 2005; Andersen et al., 2009; Christensen et al., 2012; Kley et al., 2011). Further, Tesla has emerged as an automotive brand that directly symbolizes a challenge to the structure and strategy of incumbent automakers (Sprei, 2018), in particular by focusing exclusively on high-end, pure electric vehicles, as well as through other pro-innovation behavior such as making its patents freely available or "open source". Buying or driving a car produced from these "alternative" principles and models can be seen as part of a social movement, sending messages to automakers and other suppliers that more innovation activity and technological progress needs to be channeled towards sustainable mobility transitions. Automobility becomes an expression of innovativeness.

3.5. Complexity within the framework

Although the eight frames we identify above are not meant to be fully comprehensive, they do capture a reasonable approximation of the breadth of frames that interact with automobility. Put simply: automobility can evoke or be interpreted through the multiple frames depicted in Fig. 4, which can compete with or complement one another. A single user can operate within and between multiple frames at once. Conversely, different social groups—ranging from car owners and employers to environmentalists and city planners—can also adopt similar frames. While we treat each frame distinctly for ease of identification, some may interconnect into bundles of frames or meta-frames. Snow et al. (1986) termed this "systems of frames" or "frame alignment" and "resonance," when individual frames become linked in congruent and complementary ways. For instance, expression of identity can affect the innovations frame, because car manufactures will have to take feminine and masculine attributes in the development of

Fig. 2. Transportation campaigns connecting automobility, pollution, and health. (a) Top panel: Mayor of London Clean Air Campaign, December 2017. (b) Bottom panel: Singapore Mass Rapid Transit campaign, Summer, 2010.

Fig. 2. (*continued*)

new products, and the latter can also impact expression of class and wealth. As another example, cocooning and fortressing along with mobile digital offices can impact suburbanizing, and vice versa.

Furthermore, as automobiles and practices of mobility can cut across private and societal as well as functional and symbolic dimensions, frames can be active across multiple levels of actors, from individuals (such as drivers or passengers) to organizations (such as automotive manufacturers and dealers). For example, vehicle manufacturers and other vested interests may seek (and may succeed) to frame particular innovations (such as electric mobility) on traditional industry terms. Some frames may support traditional incumbent or established actors (such as automakers, petrol stations, car dealerships, etc.) whereas others may seek to disrupt incumbency and promote an anti-establishment paradigm (such as new entrants like Tesla and the lesser known Th!nk and Buddy).

Different groups may also have contested views of a particular frame. If employees frame automobiles as mobile digital offices, so too may their employers—but to different ends. The employee may be thinking how to use travel time to accomplish work functions so they can spend less real time "at work". The employer's interpretation of mobile digital offices may be for work to colonize the automobile, making the employee's availability ubiquitous, extending spatially outside the workplace and temporally outside of normal office hours. Cocooning as a private-functional search for safety can lead to a social-functional arms race in which drivers seek larger, heavier cars to make them "safe" but only at the expense of others. But, in shaping cars to be bigger and safer, the dangers of vehicles have been significantly externalized unto non-drivers, including cyclists, pedestrians, and especially children (Desapriya et al., 2010). Thus, even single frames may provoke contested reactions. Such tensions between the broader versus individualized

Fig. 3. A statement about mobility and oil wars, Toronto, Canada, 2009.

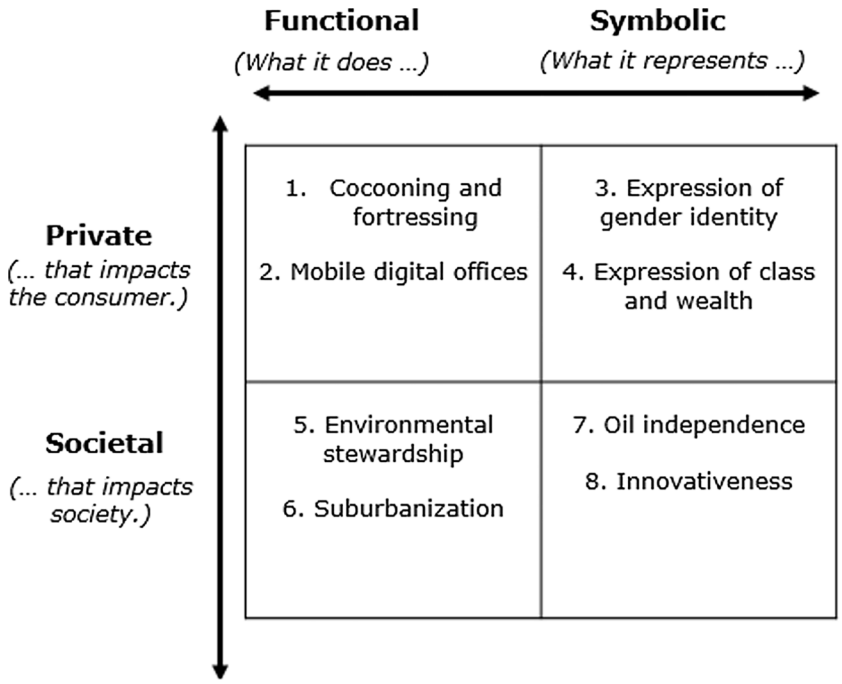

Fig. 4. Eight functional-symbolic and private-societal frames of automobility.

nature of a frame can by informed by Heffner et al.'s (2007) explanation of differences between symbolic denotations as widely accepted social meanings (in line with the broader frames we outline), compared to connotations or more personalized meanings (the more specific version taken on or appropriated by an individual or social group).

4. Application: implications for mobility transitions and transport policy

In addition to illustrating the complexity of present day automobility, our frames illustrate the importance of framing in mobility transitions—that is, moving away from privately owned, petroleum-powered passenger vehicles, ideally towards a more sustainable set of technologies or practices. Specifically, we consider three emerging transport innovations that could individually, or in combination, transform passenger transportation as we know it: electric mobility, autonomous vehicles and shared mobility. Sperling (2018) goes so far as to call these innovations "three revolutions" that could significantly impact the future of transportation and mobility. Each can be considered in terms of how such a transition would weaken, maintain or strengthen any frame, especially our eight frames of (1) cocooning and fortressing, (2) mobile digital offices, (3) expression of gender identity, (4) expression of class and wealth, (5) environmental stewardship, (6) suburbanizing, (7) oil-independence, and (8) innovativeness. Table 3 offers a useful but admittedly oversimplified characterization. The table provides a crude indicator of "evidence" for each of our evaluations (that is, weakening, maintaining or strengthening that automobility frame), ranging from "no evidence" to "substantial evidence". By "evidence" we include references with actual observations of the market (where they exist) as well as insights from exploratory research and stated preference studies

4.1. Electric vehicles

First, electric mobility is the idea of substantially transitioning to passenger vehicles powered by electricity, including plug-in hybrid vehicles and "pure" battery electric vehicles—which we'll collectively refer to as electric vehicles (EVs). EVs are often mentioned as holding potential to play a strong role in decarbonizing the transportation sector. For example, in scenarios produced by the International Energy Agency (2010) to achieve long term climate goals, EVs need to achieve a 40% new vehicle market share by 2040. Here, we consider the example of an EV transition as relatively incremental to automobility—essentially swapping out a petroleum drivetrain for one powered by electricity—while acknowledging that visons of electric mobility can include other technologies such as e-bikes, as well as integration with the autonomous and shared mobility pathways discussed next.

While there is much research and discussion of the potential purchase costs and performance characteristics of EVs (Hidrue et al., 2011; Plötz et al., 2014), here we focus on the implications for the current automobility frames we identify. Because EVs can continue the use of privately-owned vehicles, such a transition could maintain many frames of automobility, including cocooning/fortressing, mobile digital offices, and suburbanization. And as a wider variety of EV makes and models emerge (size, power, and style), purchase and use of these different models could continue to communicate different symbols of gender identity, wealth and other aspects of status, as already seen among the "early" EV buyers (Axsen et al., 2015), as well as focus groups with mainstream car buyers

Table 3
Illustrative mapping of different mobility transitions onto existing frames (with asterisks indicating the degree of evidence).
Source: Authors

Frame	Type	Electric vehicles (EVs)	Autonomous vehicles (AVs)	Car sharing
Cocooning and fortressing	Private-functional	Maintained[b]	Strengthened[b]	Weakened[b]
Mobile digital offices	Private-functional	Maintained	Strengthened[a]	Weakened[a]
Expression of gender identity	Private-symbolic	Maintained[c]	Maintained[b]	Likely weakened[a]
Expression of class and wealth	Private-symbolic	Maintained[c] (with sufficient diversity of models)	Maintained, perhaps strengthened[a]	Weakened[b]
Environmental stewardship	Societal-functional	Strengthened[c]	Maintained or weakened[b] (if it leads to increased energy use)	Strengthened[b]
Suburbanizing	Societal-functional	Maintained[b]	Strengthened[b] (if it leads to longer commute distances)	Weakened[b] (in supporting urban density)
Oil independence	Societal-symbolic	Strengthened[c]	Perhaps weakened[a]	Strengthened[b]
Innovativeness	Societal-symbolic	Strengthened[c]	Strengthened[b]	Strengthened[a] (social innovation, "try" new drivetrains)

[a] No evidence.
[b] Some evidence.
[c] Substantial evidence.

(Caperello et al., 2014). Further, a transition to electric mobility could strengthen several automobility frames, namely environmental stewardship, oil independence, and innovativeness—symbols that have also been communicated by early buyers and potential mainstream buyers of hybrids and EVs (Axsen et al., 2015; Heffner et al., 2007). An interesting future line of inquiry could examine how an EV transition might induce a re-ordering of frame priorities among certain individuals or social groups—for example where exploratory research finds that for consumers that become strongly motivated by the environmental and pro-societal attributes of an EV, previously dominant frames such as safety and cocooning can fall to a lower priority level (Axsen et al., 2013).

Taken as a whole, an EV transition seems most likely to maintain or even strengthen our eight illustrative frames of automobility. Some see this as a limitation of EVs; for example, UK-based researchers have critiqued policy documents that tend to frame EVs as supporting technological progress and consumer choice and being necessary in an auto-dependent world (Bergman et al., 2017; Bergman, 2017). Others might argue that, for these same reasons, a transition to EVs can be viewed as a more politically acceptable and thus a more feasible or probable low-carbon transition pathway (with lower social welfare costs).

4.2. Autonomous vehicles (AVs)

Our second example is autonomous vehicles (AVs), which are increasingly attracting attention from automakers, transportation researchers and policymakers. Here we consider the potential for fully autonomous vehicles ("Level 4" and "Level 5"autonomy, according to the *Society of Automotive Engineers* classification) that can perform all driving functions (urban and highway driving, parking) without any human driver supervision in most (or all) circumstances. Such vehicles are not currently available for sale, though automakers have announced plans to release AV models, and a growing body of research continues to explore several aspects of such a transition. Widespread AV uptake could profoundly impact society through changes in traffic patterns and user costs, residence location and land use, and energy use and pollution (Milakis et al., 2017), not to mention the ethical considerations of AV safety protocols (Sparrow and Howard, 2017). The ultimate societal effects of a full transition to AVs are largely uncertain; one study of boundary conditions illustrates that AVs could lead to a halving or doubling of energy usage and greenhouse gas emissions, depending on the assumptions used (Wadud et al., 2016).

Early research and logic suggests that AVs only—without shared ownership models—would likely maintain or strengthen several frames of automobility. First, AVs could strengthen the mobile digital office frame. Business meetings could begin to occur within AVs while people are on the move (Laurier and Dant, 2012). AVs could reduce fatigue in long-haul commutes and at the same time enable commuters to make their travel time more productive (Sharon, 1983). Similarly, privately-owned AVs could support the cocooning/fortressing frame, where surveys of citizens indicate positive perceptions of the safety improvements in AVs as well as potential reductions in impaired driving incidents (Payre et al., 2014; Bansal et al., 2016). And with longer commute times, potentially resulting as a "rebound" from cheaper travel in a private AV, there could be even more free time for the "driver" in a protected, private space. Early evidence also suggests that patterns of AV interest and usage may support gender differences, for example where

men have tended to state higher acceptance of and trust in AV technology (Hohenberger et al., 2016). AVs could strengthen the suburbanization frame, where increasingly productive commute times could facilitate further suburban sprawl and greater distances between homes, workplaces and amenities (Milakis et al., 2017). Further, early adoption of AV technology is likely to be associated with the innovativeness frame, in supporting broader industry movement towards AV technology (Bansal et al., 2016; Haboucha et al., 2017).

On the other hand, one can imagine scenarios where some private frames of automobility might be weakened, e.g. if AVs de-emphasize the importance of high-performance, masculine vehicles—for example, some drivers worry about losing the enjoyment of manual driving (Kyriakidis et al., 2015). Further, in terms of societal frames, AVs could potentially weaken the oil-independence frame in that drivers could become even more dependent on oil companies if these vehicles are still powered by petroleum and used more intensively, especially if consumers feel they become "locked-in" to even longer, more time-consuming commute distances. Finally, impacts on the environmental stewardship frame are unclear, as are the eventual net impacts of AVs on air pollution and GHGs.

While the future of AVs is highly uncertain, Table 3 suggests that they—in absence of electrification or shared ownership models—are likely to maintain or strengthen most of our eight illustrative frames of automobility. In particular, Sperling (2018) and others describe the potential for a "nightmare" transportation scenario in 2040, where increased AV usage only leads to more vehicle usage, more urban sprawl, declining transit use, privacy violations and increased inequity. It seems that policymakers and stakeholders targeting environmental goals and transitions to transportation sustainability will want to pay particular attention to advancements in AV technology in order to avoid the potential negative effects of further reinforcing automobility.

4.3. Shared mobility

A third innovation example is shared mobility, which can include various forms of ride-hailing, sharing, or carpooling, as well as shared fleets that might be electric and/or autonomous. For simplicity, we focus here on what are becoming more conventional car share models (or "car clubs" in the UK and Europe) that allow members to use different vehicles on trips as needed (Cervero et al., 2007), including round-trip and free-floating programs. Similar to AVs, the net environmental and societal impacts of car sharing are uncertain, though car sharing is often considered as a pathway to reduce vehicle use in general, with associated reductions in greenhouse gas emissions, air pollution and traffic congestion (Baptista et al., 2014; Firnkorn and Müller, 2011).

Increasing the usage of car sharing could maintain or strengthen several automobility frames; for example, current car-share members are found to be motivated by the private-functional concerns of convenience and saving money (Lane, 2005; Vancity, 2018). Nielsen et al. (2015) found that in Denmark, ridesharing was almost entirely framed in economic and social terms but not in enviornmental terms. However, more than half of car share members in a survey based in Vancouver, Canada mentioned the importance of environmental motives, where car share use could be broadly perceived as reducing vehicle travel as well as the need to manufacture and dispose of private vehicles. Further, car share users report feelings of "freedom and peace of mind" that might support the oil independence frame (Vancity, 2018). Similarly, because more recent advances in car sharing are largely linked to the improved sophistication of related software and connectivity between the internet, phones and cars, engagement in a car share program could be associated with the innovativeness frame—linking with aspects of a "technology-oriented" lifestyle or identity (Axsen et al., 2012). Though, others have noted that in some policy contexts, car sharing programs have not been associated with technology development or progress, in contrast with EVs (Bergman, 2017).

On the other hand, car sharing could weaken several frames of automobility, including the frame of cocooning/fortressing given the lack of a privately owned vehicle and the associated notions of providing a safe, personalized domain, as well the mobile digital offices frame. Further, the lack of consistent access to or use of a single vehicle model might weaken the ability to signal aspects of self, such as gender and class—the latter especially so given car share users' focus on cost savings (Vancity, 2018), which might obstruct or confuse other signaling. The frame of suburbanization is weakened in that most car share programs work best in regions of urban density. Finally, impact on the environmental stewardship frame is unclear, where the net impacts of car sharing are uncertain and might be framed more as means to reduce vehicle ownership rather than total travel and energy use (Mishra et al., 2015; Bergman et al., 2017).

Despite some potential alignment with our automobility frames, Table 3 suggests that, among our examples, a transition to car sharing could represent the most substantial shift away from current automobility—or at least the eight illustrative frames. However, to be clear, despite the potential for car sharing programs to challenge some frames of automobility—currently there is no evidence that such programs will seriously threaten or change automobility systems more generally.

4.4. Applications to mobility and transport policy

Furthering this application exercise, we briefly consider how these eight frames of automobility can inform policy design and analysis, where the crafting of climate, energy and transport policy can also weaken, maintain or strengthen automobility frames. In one particular example that relates most to EV-supportive policy, Brown (2001) explains how California's 1990 enactment of a zero-emissions vehicle (ZEV) mandate—which required companies to sell a minimum market share of EVs by 1998—was initially envisioned as a policy to shape societal perceptions by prioritizing an environmental stewardship frame within the passenger vehicle market. However, the policy was later weakened and reframed to instead prioritize other, private-functional frames of the vehicle, notably how consumer choice is and should be driven by considerations of cost and performance (Brown, 2001). Brown argues that a more significant EV transition—and pro-societal transition–could have occurred if the original intent (and framing) of the policy were

maintained.

More generally speaking, climate policies for transportation are often discussed as taking one of two paths. The first path targets reduced vehicle usage directly—including carbon or fuel taxes, shifts towards more dense and diverse urban planning, and investment in infrastructure to support transit, cycling and pedestrians—all of which would weaken many automobility frames, including most of the private frames as well as suburbanization. The second path instead targets a technological transition by switching towards more efficient vehicles and low-carbon fuels, which arguably maintains most existing automobility frames while potentially strengthening frames of environmental stewardship, self-sufficiency and innovativeness. As an example, California and several other regions have enacted policies that relate to both pathways, but heavily lean towards a technological transition focus (Sperling and Eggert, 2014). Similarly, the strongest GHG mitigation policies in the rest of the North America and much of Europe and China address light-duty vehicle efficiency, as well as the carbon content of fuels—not travel demand. Essentially, it seems that many governments prefer to enact climate policies that maintain or strengthen automobility frames (e.g. a low-carbon fuel standard or zero-emissions vehicle mandate) rather than enact policies that threaten or weaken existing automobility frames (e.g. a carbon tax, fuel tax or changing zoning rules to stop suburbanization). Such preferences could be interpreted as a degree of political self-preservation, as research demonstrates how carbon pricing in particular can be the most likely climate policy to incite political opposition among citizens (Rhodes et al., 2014, 2015), as well as the incumbents of automobility.

In sum, this typology of automobility frames can help to inform policy analyses of which policy designs are likely to be more acceptable, and transformative, in terms of how they weaken, maintain or strengthen automobility frames. Some policies attempt to weaken or change automobility, while others attempt to work with it or even to further entrench it. This finding resonates with conceptual frameworks in the policy sciences community such as the Multiple Streams Approach—suggesting that policymakers facing uncertainty will often seek to reframe a policy problem in a way they see as advantageous (Kingdon, 1984; Zahariadis, 2007, p. 66). Similarly, literature on the Narrative Policy Framework suggests that the narratives attached to particular polices are socially constructed, malleable, and variable across different scales (individuals, groups, institutions, cultures) (Jones and Radaelli, 2015). Frames can also be transferable across geographic space—as we have seen with automobility as a system–and perhaps policies that challenge frames in one region might be successful in other jurisdictions and at other times.

5. Conclusions

In sum, we integrate concepts of automobility and frames in effort to recognize that passenger vehicles (and the broader system around them) fulfill complex, and dynamically evolving, roles that cut across private, societal, functional and symbolic dimensions. Passenger vehicles, in other words, remain perpetually polysemiotic. Automobility reinforces the notion of cars acting as a cocoon, fortress or isolated enclave where drivers can relax and listen to music, and they can become movable offices offering a digital conduit to the online world. Automobiles can signify masculinity and femininity or social and economic status. Moving out to broader societal implications, automobiles can represent environmental benefits, commuting and suburbanization, or statements to oil suppliers and automotive manufacturers as well as other users and non-users. The automobile reminds us that cars not only mark the physical landscape but the mind. Perhaps more salient, such frames have been and continue to be adapted and contested across social groups and contexts, but at the same time have remained highly durable over the past century of automobility. With this cultural and cognitive complexity of vehicles in mind, we offer six conclusions.

First is recognition of the sheer complexity of the automobility system, including the many frames that it both shapes and is shaped by. Despite more than a century of design, development, diffusion and use, there remains no single consensus about what a passenger vehicle “is,” “does” and “represents”—though it is clear that automobility embodies frames that extend far beyond the basic notions of rational consumer choice and private-functional considerations of cost, performance and convenience. The vehicle (or car or automobile) is highly diverse in what it is and can be. Automobility frames—such as the eight examples we describe and apply—can mold how users and society more generally conceptualize vehicles as well as alternative forms of mobility, what variables of analysis are important, how resources are valued, and indeed, what merits attention as a problem. Some frames, perhaps paradoxically, also contradict—framing some vehicles as reducing environmental impacts seems to contradict the notion of automobiles as resource intensive harbingers of suburbanization; similarly, the frame of cars providing solitude and anonymous cocoons can contrast with notions of trying to publicly signal one’s identity or make social statements to oil and automotive companies. There is continued heterogeneity in the frames automobility, which itself aligns with the notion of vehicles as individual and customizable. Of course, there are likely many additional frames beyond the ones we identify here. Recognition of this complexity lends support to the framework we present, and the conversations we start in terms of how new innovations and policies might weaken or support different aspects of the automobility system.

Second, despite this complexity and heterogeneity of meaning, consideration of a frames perspective also helps to recognize the durability of automobility, echoing Sheller and Urry’s (2004) description of automobility being irreversibly locked-in. We see how several of our automobility frames have been present in a broad sense throughout much of the last century of automobility, including cocooning, conveyance of gender roles and status, suburbanization, and innovativeness. Such frames have proven remarkably adaptive, as some have persevered through drastic changes in technology, production practices and user groups. This durability is also evidenced in how policymaker framings of new mobility options, such as EVs and car sharing, tends to be aligned with the status quo frames of automobility (Bergman, 2017).

Third, given automobility is itself polysemiotic, we should expect sustainable mobility transitions–which must in some way transform automobility as presently constituted–will be too, and thus will be viewed from multiple frames, some complementary and some competing. As Clark (1990) astutely noted many years ago, energy, climate, and transport policy is a domain of conflict, not

cooperation, and it envelopes nexuses of differing interests. As a result, consensus on future mobility options should neither be expected nor sought. Put another way, no "master frame" may exist. Such underlying interpretive tensions, because they are about identity and society rather than purely technology or functionality, will likely remain with us even if our desire for vehicles and the types, nature, and delivery of automobility alters.

Fourth, in our exploratory consideration of how different types of sustainable transportation innovations entrench or challenge automobility, we provide an indication of which automobility frames might be weakened, maintained or strengthened by electric vehicles, autonomous vehicles, and shared mobility. In particular, it seems that the self-reinforcing nature of automobility will lead to continued emphasis of related frames. On this note, it is possible that some of these frames might shift to align with new mobility services in ways that we don't foresee here, where consumer preferences, business models, industry activities and policy might co-evolve towards a new equilibrium that is substantively different from the automobility frames we see today. That said, given the resilience that automobility has demonstrated so far, a significant transition away from the status quo seems to be difficult.

Fifth, despite such inevitable contestation and uncertainty, our framework can yield implications for policymakers, transport planners and practitioners. If one accepts that automobiles are chosen and used for reasons extending beyond the "rational," "technical," or "functional," then policies aimed at guiding our transportation systems—the scope and extent of research and innovation activity, the nature and duration of subsidies and other incentives, the design and stringency of technology-forcing policies—must consider such complexity and adapt. The socio-material and cultural dimensions of automobility imply that purely technical perspectives will remain insufficient to facilitate broad social acceptance. In short, frames are just as important as improved tires, better fuel economy, longer lasting batteries, and tougher and lighter materials in why people embrace particular forms of mobility.

Finally, given these insights, we offer a short list of recommendations for researchers in this field of sustainable transportation technologies, including those exploring the potential for electric, autonomous and shared forms of mobility:

- wherever possible, consider motives, preferences and frames beyond the private-functional benefits of convenience and cost;
- more seriously pursue interdisciplinary research projects, especially in complementing the dominant perspectives of engineering and economics with insights from fields such as psychology, sociology, history, anthropology, innovation studies, and public policy as well as the arts and humanities;
- place more focus on stakeholders beyond consumers or obvious users in terms of their roles in maintaining or challenging automobility, including automakers, fuel providers, policymakers, planners, investors, NGOs and mass media; and
- consider, acknowledge and explore this diversity of automobility frames (positive and negative, among a breadth of stakeholders), even when quantitative data is not yet available (i.e. drawing from qualitative methods as needed).

These suggestions will help enhance and deepen our understanding of the processes by which automobility operates, self-perpetuates, and adapts to (and influences) social and technological change. The resulting interdisciplinary insights could also uncover additional frames of automobility. Such understanding will only improve our ability to anticipate the pace and scope of sustainability transitions, and to effectively support such transitions.

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