Towards a prospective transition framework. A co-evolutionary model of socio-technical transitions and an application to car sharing in The Netherlands

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31 October 2013

Paper to present at a seminar at CIRCLE (Lund University), 6 November 2013

--- First and preliminary version ---

Abstract: This paper develops a new, prospective framework of socio-technical transitions based on Nelson’s model of the co-evolution of technology, industry structure and supporting institutions. This model is refined by integrating more specific theories about increasing returns, Schumpeterian competition and institutional work. As a case study, the framework is applied to car sharing in The Netherlands. It is concluded that car sharing may well become a new mobility regime, even if it is unlikely to replace private car ownership altogether.

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1. Introduction

During the past decade, many studies have been devoted to the understanding of the emergence of radically new technologies, in particular, in the realm of sustainable energy and transportation (Geels and Schot 2007; Hekkert and Negro 2009; Markard et al. 2012). These studies have been particularly concerned with historical case studies analyzing the conditions under which a niche technology succeeds in overthrowing an existing socio-technical regime (Geels 2002), as well as the monitoring of current emerging technologies in terms of buildup of a supportive innovation system (Hekkert et al. 2007). Hitherto, however, transition scholars have not attempted to engage in prospective analysis regarding the future of emerging technologies. Indeed, in evolutionary theorizing about innovation, the whole notion of prediction seems at odds with the fundamental contingent, uncertain and self-reinforcing nature of technical change (Arthur 1989; Allen 1990).

Notwithstanding the inherent uncertainty regarding the future course of technical change, taking stock of the recent body of transition research allows us to gauge the future potential of emerging technologies in a qualitative manner. The prospective transition framework developed here is meant as a heuristic device to assess the future potential of a radical innovation that potentially may grow out into a new regime through large scale diffusion. It differs from technological forecasting exercises based on simulation modeling in that the framework is qualitative in nature, and does not pretend to give precise predictions regarding.

2 Two exceptions are important to mention. First, Elzen et al. (2004) and Hofman et al. (2004) developed a new, sociotechnical approach to derive scenarios in which innovations emerge from trends, recombinations and policies, as opposed to traditional scenarios methodologies where innovations are exogenous to social, economic and political developments. Second, Markard et al. (2009) proposed a prospective framework to identify transition options in a particular technological domain. They do so by analyzing the coherence of options in socio-technical and organizational terms. In both cases, the framework helps stakeholders to envisage alternative futures, and derive implications of innovation policy for such futures. Thus both frameworks are prospective regarding socio-technical transitions, but differ from our approach in that we aim to analyze the likelihood that a particular transition will occur in the foreseeable future.
the rate and speed of diffusion. Furthermore, the analysis is also meant to identify endogenous factors that support innovation diffusion as well as critical barriers that may hinder innovation diffusion. Thus, our aim is more modest in that we want to provide a qualitative prediction regarding the future potential of radical innovation, that is, to assess an innovation in terms of more or less likely to diffuse at a small or larger scale.

The prospective transition framework is based on the co-evolutionary model by Nelson (1994), which analyses technological development as the outcome of the complex interplay between technology, industry and institutions. This triple framework is further elaborated by highlighting three respective dynamics supportive of socio-technical transitions: increasing returns (Arthur 1989), Schumpeterian competition (Cohen and Klepper 1996) and institutional work (Lawrence et al. 2009). As an illustrative case study, we use the framework to assess the future potential of car sharing. We will analyze the potential of car sharing by looking at the through the lens of our proposed framework highlighting increasing returns in the adoption of car sharing services, the Schumpeterian competition dynamics in the car sharing segment, and the legitimation dynamics supportive of institutional work that are currently unfolding. The conclusion holds that that are no serious barriers to the widespread diffusion of car sharing, even if the institution of private car ownership is expected to erode only slowly. Or, to put it in a more precise manner, we cannot identify any particular reason why not to expect that car sharing will grow out to become a new mobility regime, even if it is unlikely to replace private car ownership altogether.

We will proceed as follows. The next section introduces the prospective transition framework based on the co-evolutionary model by Nelson (1994) and extends his model to include more specific theories about increasing returns, Schumpeterian competition and institutional work.
Section 3 shortly introduces the characteristics of car sharing and the basis for its current success as a niche. We then apply the prospective framework to car sharing in Section 4. The final section concludes.

2. A prospective transition framework

As a basis of our prospective framework, we turn to Nelson’s (1994) co-evolutionary model of economic development, which understands the fate of radical innovations as determined by the complex interplay between technology, industry structure and institutions. The prospect of a new technology or service arises when it becomes regarded as promising, thus triggering investments. Typically, following the product lifecycle model (Abernathy and Utterback 1978), an extensive period of exploration precedes the emergence of a dominant design (in case of artefacts) or business model (in case of services). In most cases, the dominant design emerges from increasing returns to adoption. Such returns tend to increase both for producers (e.g., through experience curves and innovation in supplier and infrastructural industries) and for users (e.g., through network externalities and learning effects). This self-reinforcing technological dynamic leads to higher value for users, which in turn supports the further diffusion of the dominant design in question (Arthur 1989). This also holds for service industries where business models compete, and users generally benefit the highest increasing returns by joining the most dominant business model. Such advantages stem primarily due to the central role of economies of scale and scope in the provision of services (Miles 1993).
Particularly important in passing the threshold of widespread diffusion is the state of substitute technological systems. In some cases, substantial switching costs are involved for adopters that change from one system to the next. These costs need to be compensated by a larger user base yielding higher network externalities. Consequently, the higher the switching costs, the more actors have an incentive to wait for others to adopt first (Shy 1996; Zeppini et al. 2013). Switching costs are not given, but to a large extent depend on firm strategies and government regulations. In particular, if the new technology can be made compatible with existing standards, infrastructures and regulations, switching costs are generally low. Furthermore, if user practices can remain largely unchanged while adopting the next technology as an alternative to the old one, costs for consumers become more acceptable.

Though increasing returns are often highlighted to explain the emergence of a dominant design (M urmann and Frenken 2006), another effect of increasing returns holds that it accelerates widespread diffusion in two ways. At the supply side, increasing returns bring down costs, mainly through experience curves, which translate into lower prices. At the demand side, increasing returns increase the utility of adoption the innovation, which increases people’s willingness-to-pay.

With prices going down and mass markets opening up, and a dominant design in place, the emphasis in innovation shifts from product to process innovation (Abernathy and Utterback 1978). As a result, the average size of firms quickly goes up, and the number of firms active in the industry typically goes down. The resulting Schumpeterian dynamics between large firms spurs process innovation and mass production, as well as incremental product innovations as to further refine and differentiate the dominant design. Indeed, larger firms have more incentive to invest in R&D as they can spread their fixed costs over a larger
number of products compared to small firms. These innovations, in turns, further decrease prices and improve quality, accelerating diffusion.

Technological and industrial dynamics are intertwined, that is, co-evolving (Nelson 1994). Technological standardization spurs the growth of firms and the emergence of an oligopolistic market structure, while this market structure, in turn, spurs process innovation and further standardization of the dominant design. This does not, however, imply that product innovation halts altogether. Rather, product variations are being introduced to differentiate the standard product for different consumers, but within the framework defined by the dominant design (or “socio-technical regime”) as to continue to profit from economies of standardization (Murmann and Frenken 2006).

As a third dimension in this co-evolutionary process, Nelson (1994) emphasizes the critical role played by institutional innovations supportive of the further development and diffusion of the new technology (Van den Belt and Rip 1987). As new technologies have their specific physical and social properties, institutions generally need to be adapted, or even invented, to solve specific problems or conflicts that arise. These may concern de jure standards and regulations, property rights, university-industry interaction, labor markets and user practices. In this context, the concept of a technological innovation system that is built to support the development of a new technology is relevant as well (Hekkert et al. 2007; Bergek et al. 2008). Without dedicated institutions that support R&D, market formation and legitimacy with the public, most new technologies fail to diffuse widely.

The differential diffusion of technology across regions and countries, the competitive advantages stemming from it, is often caused by different institutional policies at the national
level (Nelson 1995; Murmann 2003), but also at the regional and transnational levels (Coenen and Truffer 2012; Raven et al. 2012). That is, the spatial location of new industries is to some extent indeterminate, because a crucial location factor concerns newly created or adapted institutions that support its further development. Hence, the windows of locational opportunity for firms can be said to be open initially, and progressively close over time (Boschma 1997; Boschma and Frenken 2009). What is more, in case the new industry is (partially) substituting services already provided by incumbent regimes, actors with vested interests in older technologies may block institutional reform, causing particular regions or countries to fall behind (Lazonick 1990; Grabher 1993; Wenting and Frenken 2011).

The question becomes under what conditions institutions are changed, and adapted in a way that they support the further development and diffusion of emerging technologies. Institutional sociologists have approached this question by focusing on dynamics that increase the social legitimacy of an innovation, or more generally, a new practice in society. Only when the new practice is considered as a legitimate activity, investors will start to back entrepreneurs, regulators will adjust laws and rules, and clients become willing to buy (Aldrich and Fiol 1994; Zimmerman and Zeitz 2002). That is, without social legitimacy, economic uncertainty regarding about future markets and technologies remains.

Building social legitimacy requires “institutional work”, typically carried out by institutional entrepreneurs, or groups of individuals, who actively seek to change existing and build new institutions (DiMaggio 1988; Lawrence et al. 2009). Typically, though not necessarily, such institutional entrepreneurs coincide with the entrepreneurs exploiting the innovation in question. The prospects of a new technology, hence, depend on the conditions that allow

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3 This need not be a newly created firm; radical innovations can also be exploited by diversifying firms.
actors to engage in institutional work leading to institutional change. Battilana et al. (2009) discuss three such conditions. First, in times of crises, actors are more open to institutional change stemming from a common sense of urgency. This is in line with Geels’ (2002) Multi-Level Perspective where landscape developments can trigger changes in socio-technical regimes, provided that a technology is already well developed in niches. Second, in case the existing institutions in an industry are multiple and heterogeneous, there is more opportunity to establish new institutions that can solve some of the contradictions and conflict arisen in the past. In that context, institutional work stems from discontent regarding existing institutions, but may eventually lead to a whole new set replacing the initial institutions. Third, if the industry is only weakly institutionalized in the past, there is more room for individuals to experiment with new institutions. Again, this is in line with Geels’ multi-level perspective on socio-technical transitions, which emphasizes the ‘resistance’ exerted by prevailing institutions of incumbent socio-technical regimes. Among the barriers stemming from existing technologies are the prevailing technical standards, labor laws, public policies, taxes knowledge bases, infrastructures, use practices, and cultural values (Geels 2002; Smith and Raven 2012). Hence, to analyze the prospects of a new radical innovation, it is important to understand the current barriers and their resistance.

In summary, the co-evolutionary model emphasizes that the emergence of new technology depends (i) **technologically**, on increasing returns leading to a dominant design, (ii) **industrially**, on oligopolistic market structures leading to Schumpeterian competition, and (iii) **institutionally**, on the buildup of supporting institutions solving collective needs of users and producers. As a prospective framework, Nelson’s model can be used to analyze an emerging technology or service along these three dimensions as well as their interplay. In short: a new industry that exhibits strong increasing returns to adoption, a Schumpeterian
competition dynamics, and conditions favoring institutional change, is likely to develop into a mass market.\(^4\)

3. Car sharing

Car sharing is an emerging phenomenon. It is a local phenomenon in that it currently takes place in a selected number of places (mainly large cities), but it is also a global phenomenon in that, by now, car sharing takes place in many countries. While Switzerland was long the only country with a sizeable market for car sharing services (Truffer 2003), diffusion rates are now accelerating in many other countries as well (Shaheen and Cohen 2013). In The Netherlands, growth in shared cars has been estimated as high as 26 per cent in 2011 and 86 percent in 2012 (KpVV 2012a; KpVV 2013). The market potential of car sharing is also evidenced by the market entry by mainstream car rental companies and, more recently, even by car manufacturing companies (Crossland 2012; Brook 2013). What is more, the national railways (NS) integrate car sharing services as a way to make their railways stations better accessible by car.\(^5\)

Probably the best definition of car sharing is as a system that allows people to rent locally available cars at any time and for any duration. Following this definition, car sharing differs

\[^4\] Our analysis is similar to a recent model on “regime destabilization” by Turnheim and Geels (2013) who distinguish three core dimensions: “(1) flow of financial resources from an external economic environment (markets, supply), (2) legitimacy and support from wider public and policymakers in an external socio-political environment), (3) endogenous commitment of firms-in-industries to the existing regime (trust, confidence)” (Turnheim and Geels 2013, p. 2). Our co-evolutionary framework, however, highlights the technological dynamics related to increasing returns and switching costs vis-à-vis substitute technologies as a separate dimension, while dimensions (2) and (3) by Turnheim and Geels are mostly covered by the Nelson’s third institutional dimension. Our model also links to the functions approach in Technological Innovation Systems literature (Hekkert et al. 2007), where particular functions of a technological innovation systems may support technological standardization, mass production and institutional change.

\[^5\] http://www.ns.nl/reizigers/reisinformatie/stationsvoorzieningen/voorzieningen/vervoerauto/greenwheels
from the traditional car rental business model, where the client has to pick up the car at the rental station and typically has to rent the car per day. And, car sharing also differs from the model of vehicle leasing; as in the car sharing model, lease cars are not privately owned, but different from car sharing, a lease car is not being shared in daily use. Finally, car sharing differs from taxi services in that the user of a car sharing service has to drive the car herself/himself (self-service). Importantly, car sharing is not restricted to services offered by business firms; car sharing also includes individual car owners who rent out their car supported by an Internet service. For example, the website of Snappcar offers 4000 cars all over The Netherlands. Indeed, the share of such informal peer-to-peer car sharing services is estimated to be account for about half of all cars used for car sharing (KvPP 2013). Figure 1 provides examples of the main players in The Netherlands offering car sharing services, based on difference business models.

Figure 1. Greenwheels (upper left) and Connectcar (upper right) adopt a business model where the company owns the cars and allocates each of these to a fixed parking space. They charge users for the time the car is not at its designated parking space. Car2go (lower left) adopts a one-way business model without a fixed parking space, and charges the user only when the car is in actual use. This company uses only electric cars. Lastly, Snappcar Snappcar (lower right) is a platform for informal peer-to-peer car sharing for cars privately owned by users themselves. See more at Kvpp (2013).

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6 Also note that similar business models of sharing is exists for renting out your apartment (e.g., airbnb.com) or equipment (e.g. spullendelen.nl).
Car sharing has multiple advantages over the current system of private car ownership (Carsharing.US 2013; Shaheen and Cohen 2013):

- First of all, car sharing is cheaper than private car ownership for infrequent car users. The same applies for households such as families, who previously owned two cars, and now only need one car as they can rent a second car when needed. For frequent car users (such as daily commuters), private ownership is clearly more affordable.
- Second, those who do not own a car but occasionally rented a car from a traditional car rental company, now have access to a car rental service in their own neighborhood, at any time during the day and for any period of time.
- Third, car sharing has the further advantage that people are more flexible. With widespread use of car sharing, people have readily access to a car, not just in their own local neighborhood, but almost anywhere and at any time. In addition, people are no longer tied to the use of one particular car, but can choose between different types of cars depending on their specific purpose.
- Fourth, car sharing makes more efficient use of scarce parking space. As a result, more parking space will become available lowering prices and congestion. Alternatively, parking space can be converted for alternative uses by local governments. This explains why local governments are generally supportive of car sharing initiatives, for examples, by assigning dedicated parking places for cars that are part of a car sharing program.
- A final advantage of car sharing holds that it is expected to yield environmental benefits. On average, car sharing reduces mileage as well as environmental pollution related to car production. Possibly more important, car sharing promotes the use of
electric cars since car sharing is generally used for shorter trips and recharging can take place at night at the dedicated parking space. Again, support by local governments, such as in the city of Amsterdam, has been important to promote the use of electric cars in combination with car sharing.7

Clearly, car sharing holds a promise given the many advantages over private car ownership. However, it is hard to assess its future potential given that it is still small compared to private ownership. At present, car sharing actually a niche product that is particularly appealing only to specific groups. For example, in The Netherlands, car sharing is especially popular in cities like Amsterdam and Utrecht where little parking space is available (KpVV 2012a).

Furthermore, car sharing is often used only as a complement to public transport or as a second car. In that sense, car sharing is simply ‘reinforcing’ the two dominant mobility regimes of public transport on the one hand and private ownership on the other hand. The question arises whether car sharing continues to be just a niche product, or whether it has the potential of becoming the third dominant mode of mobility in society.

4. Assessing the future potential of car sharing

4.1 Technology

The prime self-reinforcing dynamic in technological diffusion processes are increasing returns to adoption, meaning that the adoption of a technology becomes more attractive as

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7 For example, Car2go offers car sharing services using only electric cars (see, car2go.com).
more fellow actors (producers, users) are already using it (Arthur 1989; Frenken et al. 2012). This principle certainly applies to car sharing. On the supply side, the cost per trip will go down because providers will have a higher utilization of their car fleet as the number of users increases. Also, a company with more customers can negotiate lower prices for gasoline, cars, maintenance and insurance clauses from its own suppliers. On the demand side, there are also increasing returns. For new users, car sharing becomes increasingly attractive as there are more users, since the more users, the greater the range and variety of cars one can choose from in the neighborhood. All these forces render the returns to adoption for users to increase as more users start to adopt car sharing. Hence, the diffusion dynamics becomes a self-reinforcing process.

Obviously, the current dominant system of private ownership also benefits from increasing returns to adoption. The current road infrastructure is primarily built with reference to car use. Hence, the current system makes car ownership attractive. However, the sources of increasing returns for private car ownership also apply to car sharing, as car sharing makes use of the existing car infrastructure that was built before. Hence, from an infrastructural point of view, car ownership is not necessarily preferable over car sharing. If anything, current development favor car sharing over private car ownership as municipalities dedicate parking space for car sharing use only.

For users, the costs of switching from the old system of private ownership to the new system of car sharing are rather small. One can simply sell their privately owned car and subscribe to a car sharing program. Some use car sharing in combination with public transport, as the national railways facilitates car sharing services as a means to improve the car accessibility their railways stations. This means that while car sharing typically substitutes for private car
ownership, it complements the public transport regime. In all, the current mobility regimes pose few constraints on the further diffusion of car sharing.

4.2 Industry

The current industrial structure of car sharing market can be safely described as an oligopoly with only few service suppliers. In The Netherlands, Greenwheels, ConnectCar and Car2go dominate the current market. Though these companies are still rather small given the small size of the car sharing market, all three firms are part of a larger company. Greenwheels, which started as a startup in the 1990s, has been taken over in May 2012 by a large Volkswagen distributor. ConnectCar was founded by KAV, a leading traditional car rental company. And, Car2go is a globally operating company founded by Daimler. It can be argued that this industrial structure of the car sharing market is particularly supportive of further innovation and diffusion, for at least four reasons.

First, the strong market power of individual firms provides strong incentives to do R&D. Larger firms can spread the fixed costs of R&D over a larger number of items or service handlings compared to smaller firms (Cohen and Klepper 1996). Furthermore, larger firms can more easily appropriate the returns on investments, in this case, not by property rights but by being the first to introduce an innovation at a large scale and accumulating experience and brand value.

Second, the three market leaders are all backed by a larger company with access to capital and experience in related industries. Indeed, for many radical innovations, firms that can
leverage experience in related industries outperform other firms in the same industry (Klepper 2002; Boschma and Frenken 2011). And, since the three firms come from three different, but related industries, a variety of business models is in place that spurs further innovation through recombinant innovation (Geels 2002; Frenken et al. 2012).

Third, even if the market for car sharing is highly concentrated, competition seems warranted by the relatively low barriers for entry. In this sense, the market is a contestable market (Baumol 1982). Since markets for car sharing are geographically delineated (typically, through municipality boundaries), firms can enter the market just by starting to serve a single geographic market. Furthermore, sunk investment is rather low. The knowledge required to operate a car sharing company is not extremely advanced, and experience with similar services is already available with traditional car rental and lease companies. And, even if the initial investment in a car park is substantial, the cars can be sold as second-hand cars in case of bankruptcy. Hence, given the low barriers of entry, there is ample room for experimentation with new service concepts and business models.

Finally, car sharing is a service industry emerging in many countries at the same time. As business models are difficult to protect, innovations can be readily imitated. In particular, those companies operating multi-nationally, such as Car2go, can learn across geographical and institutional contexts, and possibly leverage this experience in the case of entering new geographic markets.

4.3 Institutions
The creation of a niche for car sharing was greatly supported by local governments who adapted their parking policy with the introduction of dedicated and free parking spaces for car shares. This was primarily motivated by environmental concerns and more efficient land use. In some cases, local governments even give subsidies to citizens who decide to give up their private parking permit, and switch to car sharing. As such, the creation of car sharing as a small niche can be understood from an alignment between interests of environmentally aware users, service providers and local governments (Truffer 2003).

The question we pose here, however, concerns the likelihood of the widespread adoption of car sharing in the future. For this to happen, more fundamental institutions need to be adapted, in particular, that of private (car) ownership. This institution is strongly embedded in the capitalist cultures. In particular, sociologists emphasize that private car ownership for people is not just a simple consumption act, but is also a cultural phenomenon as people use cars to express their identity, class and status (Bourdieu 1984). Indeed, people’s wish to express themselves in consumption is unlikely to disappear. The question here, however, is whether the car will remain the typical product that people use to express themselves. A younger generation may care more about other products (e.g., clothing or smart phones) to express identity and status than about owning a car. First signs of a change in attitudes is apparent from the decrease in car use among younger people, which has been partially attributed to the rise of car sharing (David and Dutzik 2012). Furthermore, it must be reminded that the adoption of car sharing as a service in itself does not imply that a user can no longer express themselves in public. Identity, class and status can still be part of the decision what car sharing organization to join and what type of car to use. And, peer-to-peer

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8 The various local policy options, meanwhile, have been codified in a manual (KpVV 2012b).
car sharing is still based on private car ownership by users. Hence, car sharing may even spread without people having to give up private car ownership.

Following institutional sociology (Lawrence et al. 2009; Battilana et al. 2009), a fundamental institutional change, such as the demise of private car ownership, is only likely when car sharing is seen as a socially legitimate activity to begin with. At a very general level, car sharing appeals to generally accepted sustainability values of urban livability (“people”), efficient use of capital goods (“profit”) and environmental sustainability (“planet”). That is, car sharing seems to fit a general, albeit slow, trend towards more sustainable awareness among the urban population.

Whether car sharing has become more legitimate over the recent period can be traced by counting the number of articles about car sharing and marking whether these articles value car sharing generally as a positive or negative development, or take a stance in between (using the query “autodelen” in krantenbank.nl). The resulting trends in Figure 2 clearly point towards increased legitimacy with the number of positive articles rising from 1 in 2004 to 12 in 2012, with very few articles reporting a negative assessment of car sharing in the same period. Hence, the strong increase in legitimacy in the recent past suggests that the conditions for institutional change in support of car sharing are in place.

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9 Legitimacy is often spurred by positive evidence from foreign countries as well (Hannan et al. 1995). In this respect, car sharing benefits from positive media exposure in international mainstream media. Most prominently, The Economist (March 9, 2013) had a cover and a special section about the “sharing economy” highlighting car sharing in particular.
Politically, the fit of car sharing with the existing regime also seems warranted, as interests of key players are aligned, not just at the local level as remarked before, but also on the national and European level. The current dominant players, car companies and ministries of transportation, actively participate in car sharing, through provision of car sharing services themselves (in the case of car companies like Daimler and BMW) and the promotion of car sharing services and policies supporting them (in the case of the ministry). Nevertheless, vested interests of competing service providers such as taxi drivers are threatened and argue that, at least for what concerns informal car sharing practices, regulation is required to have them operate under the same regulatory (tax) regime as taxi drivers (e.g., Hamilton 2013). It remains to be seen to what extent such actors can truly organize a political lobby to reverse the current diffusion of car sharing practices and services.
5. Conclusion

We developed a new, prospective transition framework based on Nelson’s co-evolutionary model of technical change, and further refined this model using more specific insights on the dynamics of increasing returns, Schumpeterian competition and institutional work. This model is a general model than can be applied both retrospectively, as already been done in historical case studies (e.g., Murmann 2003) as well as prospectively. Notwithstanding the inherent uncertainty regarding the future course of technical change, the prospective transition framework is meant as a heuristic device to assess the future potential of a radical innovation that potentially may grow out into a new socio-technical regime.

As an illustrative case study, we assessed the future potential of car sharing as an alternative to the current regime of private car ownership. Taking The Netherlands as a case study, it was argued that car sharing may well become a new car regime. Car sharing, however, is unlikely to replace private ownership altogether, since daily car users may still prefer to own or lease a car. Rather, one can envisage future mobility to consist of three complementary mobility regimes: private car ownership, car sharing, and public transportation. We hope to see more empirical applications in future research, be it retrospectively or prospectively, as to further investigate the validity and usefulness of the framework proposed.
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