Functional service economy: a pathway to real energy savings? The case of vehicle rental by French households

Amandine Chevalier*[1] and Charlotte Fourcroy†[2]

[1]BIPE, Mines ParisTech and IFPEN
[2]EDF R&D and Clerse, University Lille 1

Proposal for the ISEE Conference 2012 Rio de Janeiro, Brazil

Abstract

We are now witnessing a proliferation of new car mobility services such as short-term car-rental, car-sharing or car-pooling. These services can be considered as empirical applications of the business model of the functional service economy. Using a system thinking approach that comes from service economics, we seek to address the following question: do new individual mobility services that develop in France permit real energy savings? What conditions must be met and what should be done in order to reach this goal? The results we obtain show that at the scale of the transport sector, new mobility services allow energy savings only on certain conditions, such as the abandonment of private equipment and the minimization of the risk of rebound effect.

Introduction

We are now witnessing a proliferation of new car mobility services such as short-term car-rental, car-sharing or car-pooling. Despite this proliferation, these new services remain marginal compared to the use of private cars. Whereas the shift from private to public transport would allow quite obvious energy savings, the one from private owned vehicles to shared-vehicles has less clear impacts on energy consumption. According to some researchers, the new business model consisting of the substitution of the sale of the product's

*amandine.chevalier@bipe.fr
†charlotte.fourcroy@ed.univ-lille1.fr

function to the sale of its property, which is the concept behind the new individual mobility services we mentioned[1], allows for a decrease in production, lower consumption of natural resources, in addition to encouraging companies to design products that consume fewer resources in their production, use, maintenance, recycling and reuse [Bourg and Buclet, 2005, Du Tertre, 2007]. In addition, some researchers argue that these new individual mobility services also encourage users to modify their behavior [Meijkamp, 1998]. However, it is difficult to estimate the real impact of the adoption of this business model. Many scientific studies investigate these relatively new mobility services but as quoted by Mont [2000] very few of them deeply investigate their energy impacts. Some reports, which are based on surveys about users of these new individual mobility services, reach rather optimistic conclusions.

In this paper we revisit this issue in a new light, using a system thinking approach that comes from service economics. We seek to address the following question: do new individual mobility services that develop in France permit real energy savings? What conditions must be met and what should be done in order to reach this goal?

In a first part, we present a short and critical review of the literature. Then we describe the method we use in this paper. Our results, which we obtain from the analysis of different surveys in France, are then presented in the third part. The last section is devoted to the discussion of this results. We compare them to those from the literature and draw some conclusions about energy savings.

1 Literature review

The question of the energy impact of new services for individual mobility can be approached from different angles. First of all, the theoretical framework of "the functional service model" can be mobilized to address this issue. The "functional service model" is a theoretical economic model developed since the 90s, which origin is generally attributed to Giarini and Stahel [1990]. This model advocates the shift from an economy based on ownership to a service economy based on the use of products to perform functions (meeting needs): the sale of the product's function is substituted for the sale of its property [Stahel, 1998, Bourg and Buclet, 2005, Du Tertre, 2007]. New services for individual mobility, which substitute the purchase of a *shuttle service* (access to a car for a trip) for the purchase of a private car, can be

[1] This new business model is often called the *functional service model* [Bourg and Buclet, 2005] but according to some researchers it does not cover all of the requisite characteristics of the functional service model [Gaglio et al., 2011] and thus corresponds more to a *sustainable service model* or a *Product-Service System* [Mont, 2000].

considered as an application of this model[2]. According to some researchers, this new business model which allows for the shared use of products would induce a decrease in production, lower consumption of natural resources, as well as encouraging companies to design products that consume fewer resources during their entire life-cycle [Bourg and Buclet, 2005, Buclet, 2005, Heurgon and Landrieu, 2007, Gaglio et al., 2011]. Few studies seek to estimate environmental benefits enabled by some practical applications of this model. Among the most famous examples are the cases of Michelin tires or Xerox printers [Folz et al., 2008]. These studies conclude that environmental benefits are a possible outcome of the model. However, to our knowledge, few formal studies exist on the subject to confirm these findings. Some researchers also question the causal link between the economic model of the economy of the functionality and environmental benefits [Bouthillier, 2010].

Other analytical frameworks can be mobilized, such as the concept of *Eco-Efficient Services* [Bartolomeo et al., 2003, Meijkamp, 1998, 2000] or the one of *Product-Service-System* [Mont, 2002, 2004, Tukker and Tischner, 2006]. These concepts are quite similar to that of the "functional service model". Meijkamp [2000] define *Eco-Efficient Services* (EES) as "all kind of commercial market offers aimed at fulfilling customer needs by selling the utilization of a product instead of providing just the hardware for these needs". Bartolomeo et al. [2003] distinguish three main types of EES: product-results services, "where a provider supplies a complete solution to an on-going need for a customer" [Bartolomeo et al., 2003, p. 831] (the examples of Michelin or Xerox fall in this category); product-utility services, "which encourage more intense utilization of products by encouraging customers to abandon individual ownership" [Bartolomeo et al., 2003, p. 831] (among them are the new individual mobility services); and product-extension services, which are services sold with the product that enhance its utility for the customer[3]. The concept of *Product-Service-System* (PSS) is also based on the substitution of services for products, especially by sharing, pooling or renting material goods. Theoretically, eco-efficient services and PSS are supposed to benefit the environment in different ways: changing consumer behavior, improving (optimizing) the utilization of equipment, extending the life span of equipment, encouraging product redesign, etc. [Mont, 2002, 2004].

Beyond these theoretical frameworks for analysis, numerous studies attempt to estimate and quantify the environmental impacts of these new types of service. We are particularly interested in studies on new mobility services. These studies mainly examine car-sharing. The general idea is that these new

[2]At least, the model as defined here. Some researchers redefine the functional service model, adding other features [Gaglio et al., 2011].

[3]The ecological efficiency of the latter category does not seem obvious to us

forms of mobility allow energy savings as they allow to pool equipment. In the traditional model of car ownership neither the number of people per car nor the hours of utilization per day of a car are optimized. The pooling of equipment by car-rental, car-sharing, or car-pooling could reduce the fleet size and reduce energy consumption per passenger and kilometer. Most of these studies are based on surveys. Each survey is conducted among participants of one experiment of car-sharing, in one city or one neighborhood. Participants agreeing to complete the survey are asked about their mobility habits since the beginning of the experiment but also, from memory, before the experiment. They are asked, for example, if they own a car or what is their annual distance traveled by means of transportation.

The methodology used and the questions asked seem really similar between studies and the results are consistent. These studies show that:

- Car-sharing users travel less by car than the average [Baum and Pesch, 1994, Harms and Truffer, 1998, Meijkamp, 1998, Lane, 2005, Ryden and Morin, 2005, Zipcar, 2005, Communauto, 2006, Jemelin and Louvet, 2007]. This is explained by the fact that the use of shared cars requires organization: especially you must book your vehicle in advance [Meijkamp, 1998].

- Car-sharing users use more public transport than the average [Baum and Pesch, 1994, Meijkamp, 1998, Ryden and Morin, 2005, Zipcar, 2005, Communauto, 2006]. This is explained by the fact that, with car-sharing, the real cost for the use of a car is explicit while, when owning a car, journeys are mentally priced at their marginal cost. People can therefore more easily arbitrate between car and other means of transportation [Bartolomeo et al., 2003].

- The car-sharing fleet is made of recent cars, which consume less energy and emit less greenhouse gases than the average [Meijkamp, 1998, Ryden and Morin, 2005]. Some even see in car-sharing a potential market for electric or biogas vehicles [Mont, 2004].

- The equipment has a shorter life span than the average, allowing for greater recycling or reuse [Meijkamp, 1998].

- People participating in car-sharing experiments tend to own less cars than the average. The global need for cars is reduced since the cars are pooled [Baum and Pesch, 1994, Harms and Truffer, 1998, Meijkamp, 1998, Ryden and Morin, 2005, Zipcar, 2005, Communauto, 2006, Jemelin and Louvet, 2007].

- People participating in car-sharing experiments tend to care more about environmental repercussions of mobility [Meijkamp, 1998, Lane, 2005].

These results, although they are consistent, have weaknesses: most of them rely on respondents memories (this weakness has been identified by Steininger et al. [1996] and Katzev [2003] who find conflicting results especially concerning the modal split or total distance traveled by car), some do not see the issue as a whole (shorter life span also means a more important need for new products, cars used for car-sharing might end up on the second-hand market, etc.), and some do not make the difference between the cause and the effect (it is likely that people chose to participate to these experimentation because they are concerned about the environment and/or because they wanted to get ride of their own cars. It does not mean that this would work the other way for everyone).

The first experiments date from the beginning of the 90s. They were proposed by local cooperatives.But it is difficult to challenge the patterns of mobility. Cars have long been an important social marker. Cars also provide independence to their owners. Moreover, the costs and the lack of professionalism of organizations offering car-sharing could be an obstacle to the development of this mobility solution [Shaheen and Sperling, 1999, Mont, 2004]. Therefore, car-sharing is still a marginal phenomenon. It represents less than 1% of traffic in countries where there are experiments.

To accelerate the development of car-sharing, some studies recommend to develop continuity between modes, for example by offering a common access card [Blandin, 2011, Shaheen and Sperling, 1999], to develop partnerships between modes, for example short-term car-rental could provide car-sharing companies vehicles to meet potential peak demands [Mont, 2004], to offer easy access to cars, for example by multiplying the number of access points [Mont, 2004, Shaheen and Sperling, 1999] or to automate the reservation, the management of keys and the payment[4] [Shaheen and Sperling, 1999].

2 Methodology

To address this issue we apply a system thinking approach of mobility. This means that we want to take under consideration the whole system around mobility: the origin of the need and the different ways of satisfying it. Using an analytical framework which has been developed by one of the authors for analysis of the sources of energy consumption related to services and is drawn upon the characteristics-based service innovation model developed by Gallouj and Weinstein [1997], we identify different sources of energy consumption both directly and indirectly related to mobility. Eventually we present how and where new individual mobility services are expected to induce energy

[4]Today the reservation, the management of keys and the payment are automated in much of the car-sharing services.

savings. This gives us a list of data we should try to obtain from surveys to estimate if new individual mobility services really induce energy savings and what should be done in order to reach the promised savings.

2.1 The origin of the need for mobility

The need for mobility is generally a "secondary" need[5], induced by another need such as going to work, going shopping, visiting someone, etc[6]. A number of actions that we perform require some form of contact between individuals (a meeting between colleagues, a purchase, a discussion with a friend, etc.). Traditionally the bringing together of several individuals is achieved by the moving of individuals towards a common place.

The origin of the need for mobility influences the characteristics of the trip: where to go (and thus distance to be traveled), when and how often to travel, the flexibility on the schedule of arrival, possibly the choice of transport mode (the choice may be restricted by where to go, time or flexibility), etc.

2.2 Meeting the need for mobility: mobility services

The need for mobility is satisfied by a mobility service. The customer of this service is the person who needs to move, the provider of this service is the one who realizes the moving. The service provider is sometimes the customer himself. In the following paragraphs we seek to define mobility services.

If one refers to the work of Gallouj and Weinstein [1997] (see also Gallouj [2002], De Vries [2006]), a service may be represented by the mapping of different vectors: a vector of service characteristics, two vectors of technical characteristics (respectively for the user(s) and the provider(s)) and two vectors of competences (for the user(s) and the provider(s)). This representation of services is often called the characteristics-based definition of services. The vector of service characteristics is a set of services or utilities provided to the service user(s)[7]. For example, in the case of mobility services, they are such as distance, comfort, duration of the trip, etc. The vector of technical characteristics is defined as the set of techniques used to provide the service. For mobility services these techniques are mainly means of transportation. Competences are the result of his training, experiences, interactions with others, etc. In this paper, we define the competences in a very broad senses:

[5] "Need" must be considered here in the broadest sense: it refers not only to necessities but also to desires.

[6] Some trips seem to have no other purpose than themselves, such as walks.

[7] It can also include externalities.

they include skills, values, habits that influence the behavior.

Several types of mobility services can be distinguished, depending on whether the service is consumed (get a ride, take a cab, take public transportation) or self-produced (to travel on its own, drive by example), or depending on the main techniques mobilized (the means of transportation: on foot, by bicycle, car, train, bus, etc..). For each of these types of mobility services, the technical characteristics, but also the competences and service characteristics are different. In the case of self-production, for example, individuals who self-produce must have[8] the competences and technical characteristics necessary to the provider (a driver's license and a vehicle for example). Service characteristics of the mobility service also depend on the type of services concerned: the comfort and flexibility of a mobility service by bus are not the same as the ones of a mobility service by car, for example. The choice between different options is therefore based on technical characteristics and competences available, as well as on service characteristics expected. We saw previously that the need for mobility is usually induced by another need, which exercises a strong influence on the characteristics of mobility needed. Thus the choice of the mobility service also depends on the primary need giving rise to the need for mobility (we will see some examples in section 3.1).

In the previous paragraphs we describe a mobility service at the scale of one trip (which can be called elementary mobility service). But there are other analytical level we can consider. We can describe the mobility service at the scale of one individual, that is to say the description of the way this individual travel. This would be an aggregation of elementary mobility services. We can also describe the mobility service at the scale of the country, which would be an aggregation of individual mobility services and would describe the way people travel in the country.

2.3 Energy consumption associated with mobility services

If one refers to the previous description of services, the energy consumption related to mobility depends on technical characteristics of equipment used (ie means of transportation, mainly), on how equipment is used (ie the user's competences and methods or routines implemented[9]) and on service characteristics (the distance traveled, for example).

For now, we have considered only the direct energy consumption, that is to say, the energy consumed during the mobility service for the use of equipment. However, the production, marketing and recycling of such equipment

[8] "Have" can mean own, borrow, rent or even create.
[9] Methods or routines being intangible techniques.

also require energy consumption[10]. These energy consumptions are associated with the mobility service. More broadly, we must include the embodied energy of all of the technical material (equipment, infrastructure) used for the realization of the mobility service[11].

2.4 New types of mobility services

New types of mobility services are emerging since the 90s and are generally considered as "green" or "environmentally friendly". These new types of mobility services are based on the concept of sharing. They are often considered as implementations of the functional service economy. The new services represent an innovation compared to the traditional individual mobility service by car. We can distinguish two main types of innovation:

1. One is based on an increase in the number of passengers per car (which is a service characteristic). This is car-pooling. At first glance, this innovation could lead to reduction in energy consumption per passenger and to reduction in car fleet, which, in turn, could lower embodied-energy associated to the provision of the mobility service.

2. The other is based on an evolution of vehicles ownership (which is also a service characteristic). The main technique, which is the vehicle, is no longer owned but rented for the duration of the trip. This is car-sharing or short-term car-rental. At first glance, this innovation could lead to reduction of the car fleet size which, in turn, could lower embodied-energy associated with the mobility service. Many studies also argue that the evolution of vehicles ownership leads to an evolution of technical characteristics of vehicles: vehicles used for car-sharing might be newer and less polluting on average than the ones owned by individuals.

3 Results

To estimate the real impact on energy consumption of these new mobility services, we begin by studying needs for mobility in France and which of these could be met by new mobility services (section 3.1). Then, in terms of

[10]The total energy consumption during the product life cycle (production, marketing, use and recycling) is called embodied energy.

[11]One could also say that the service requires skills acquisition which in turn, requires experience or training. Energy consumption associated with this experience or training could possibly be taken into account. However, it would be complicated: common life experiences allow us to develop skills, and it is not easy to associate an amount of energy consumption. For training, it is a bit simpler. But then, how much of the acquisition of this knowledge must be attributed to the provision of services? Knowledge are reusable, they may be acquired for themselves, etc.

the provision of services and the characteristics-based definition of services, we seek to identify the evolutions on vectors caused by this innovation that lead to energy consumptions or energy savings (section ??). We distinguish three analytical levels: the mobility service at the scale of the country, the mobility service at the scale of an individual and the mobility service at the scale of one trip. Finally, we attempt to estimate the changes these new mobility services could bring concerning the life span and the end of life of cars, in order to estimate if they could reduce embodied-energy consumption (section 3.3).

To discuss energy consumption and environmental issues of new car mobility services as car-pooling, car-sharing and short-term car renting, we use results from various French surveys: the national transportation and travel survey from 2007 (ENTD by INSEE, SOeS and Inrets), the annual market survey of the short-term car-rental realized by TNS Sofres and GMV Conseil and the 2011 mobility observatory (OMA) from BIPE company.

3.1 The need for mobility in France

It is possible to identify the share of travel purpose (the origin of the need for mobility) in proportion of trips and in proportion of kilometers traveled for local trips (table 1).

Table 1: Pattern of a typical week day trip

	% of trips	**% of km**
Travel for professional reasons (including commuting from home to work)	27%	28%
Shopping	25%	13%
Leisure and visits to family and friends	24%	36%
Go with or pick someone	12%	7%
Other reasons	13%	16%

Sources : OMA 2011 and ENTD 2007

Table 1 shows that French people mainly travel for professional reasons (including commuting from home to work), to make shopping, and for leisure and visits. Most kilometers are covered for leisure and visits, and for professional reasons as shown in Table 1. Shopping and leisure/visits each represents one quarter of the trips, but the proportion of kilometers traveled is less important for shopping than for leisure and visits, which can be explained because we do shopping closest from home than we go for leisure and visits.

In contrast, professional reasons represent the same proportion in terms of number of trips and kilometers traveled.

In addition, it is possible to estimate the distribution of means of transport for each travel purpose in terms of trips and kilometers traveled for local trips. Table 2 shows that car is the main means of transport in proportion of trips as well as in kilometers traveled for all trips patterns. Car is followed by public transport for professional reasons. To go with or pick someone, to make shopping and for leisure and visits, car is followed by walking in proportion of trips and by public transport in proportion of kilometers traveled.

Table 2: Repartition of means of transport for each travel purpose

%trips/ %km	**Car**	**2 or 3 wheelers**	**Walk and bike**	**Public transport**
Travel for professional reasons (including commuting)	67%/83%	2%/2%	15%/1%	16%/14%
Shopping	57%/92%	1%/1%	29%/3%	13%/4%
Leisure and visits to family and friends	56%/83%	2%/2%	27%/4%	15%/11%
Go with or pick someone	71%/95%	0%/1%	19%/2%	11%/2%
Other reasons	50%/71%	1%/1%	31%/3%	18%/26%

OMA 2011 for proportion of trips and ENTD 2007 for proportion of kilometers

Those figures are important to understand the travel purposes (origins of needs for mobility) which require or not the car as the main means of transport, and therefore the needs for mobility for which cars can not easily be substituted by public transport and for which it is especially interesting to try to substitute shared cars to private cars. For many pattern it is possible to substitute car by an other means of transport. For leisure and visits for example it is often possible to substitute car by public transport because it is long and planned trips. For shopping, lots of kilometers are traveled by car, but we found the highest proportion of walk in terms of number of trips. It is explained by the fact that shopping concerns local shops too. The proportion of public transport is the highest for professional trips in terms of number of trips and kilometers traveled.

3.2 The provision of mobility services

3.2.1 At the scale of the country

In this section we seek to describe the mobility service at the scale of France. In order to do so, we describe the aggregation of elementary mobility services within it.

It is possible to identify the distribution of means of transportation used for local trips by two different ways: in proportion of trips through results of OMA or in proportion of kilometers traveled through results of ENTD (table 3). Table 3 shows that most trips traveled during a typical week day are made by car, on foot or by bike. It also shows that the majority of kilometers are traveled by car and public transport. The car is used in two third of the trips and to travel the vast majority of kilometers. Inversely, walking and biking concern more than one trip over three, but enable to travel only 1.3% of kilometers.

Table 3: means of transport used a normal week day

	Car	**2 or 3 wheelers**	**Walk and bike**	**Public transport**
% of trips	74%	4%	42%	23%
% of km	83%	1.3%	2.7%	13%

Source : OMA 2011 and ENTD 2007

Since the 90s, new mobility services such as car-pooling or car-sharing are emerging. The French network of car-sharing services[12], involving a dozen car-sharing services in different cities in France, includes 11,200 members sharing more than 500 cars. With the new Autolib' Parisian service, there will be a significant increase in the number of members and shared cars. Indeed, this service is expected to have 200,000 members in three or four years and 3,000 cars by the end of 2012. After three months of service, there are already 4,500 members with an annual subscription and 1,000 shared cars.

According to the 2011 mobility observatory (OMA) from BIPE, members of car-sharing services represent far less than 1% of the population. However there are also private car-sharing initiatives which are impossible to measure.

On the other hand, 7% of French people carpool: 3% to go to work, 3% for holidays and week-ends and 4% for shopping and leisure. This proportion

[12]www.franceautopartage.com viewed on april 2012

is the same since 2009: car-pooling does not seem to take-off.

According to the short-term car-rental branch of the National Council of Automotive Professionals (CNPA), about 7% of French people have rented a car each year from 2000 to 2010. In 2011, this proportion has increased to reach 12%.

New mobility services are niche market but could develop in the next few years under the effect of the increasing price of fossil energy, as well as the media coverage of sustainable mobility behavior. We are already experiencing a take-off of car-sharing services: on ten services of the France Autopartage Network in 2011, three are new services.

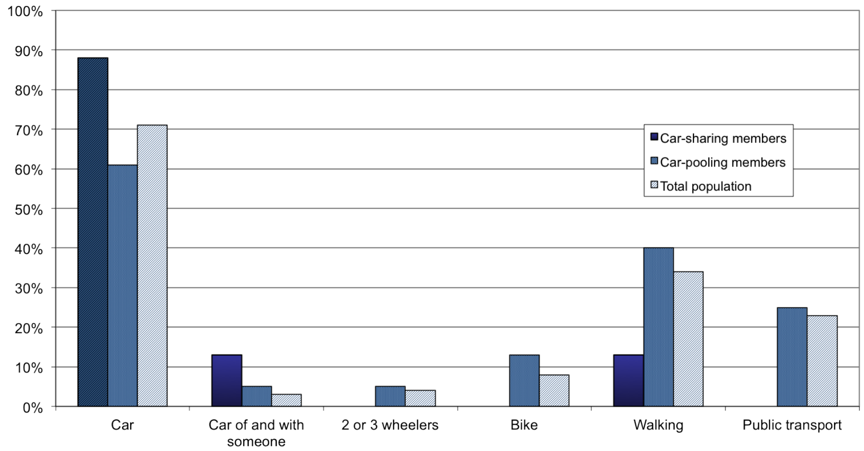
3.2.2 At the scale of individuals

In this section we seek to compare the mobility service of individuals who are members of new mobility services to the one of individuals who are not. In order to do so, we compare the service characteristics, the technical characteristics and the competences involved in each case. The service characteristics considered here are mainly the distances traveled by means of transportation. The technical characteristics are mainly concerned with equipment, owned and used. The term "competences" must be understood in its broadest sense. It includes the knowledge, values and habits that drive individual behavior. For convenience, we will compare simultaneously the service characteristics and equipment used in a paragraph entitled "service characteristics". In the paragraph entitled "technical characteristics" we shall therefore analyze only equipment owned.

Service characteristics. When they have a car, French people travel about 14,000 km per year with their own car. People who carpool travel 14,000 km as well with their own car. People doing car-sharing travel 11,000 km with their own car and on average less than 1,000 km with a shared car (kilometers estimated from France Autopartage services). As we do not know how many kilometers were traveled by new mobility services' members before car-pooling or car-renting, it is impossible to compare and conclude about a decrease in car use by new mobility services' members.
It is possible to compare the distribution of mode of transportation of new mobility services' members to the total population as shown in figure 1.

As shown in figure 1, people who carpool travel less by personal cars than the average and more by two-wheelers, bikes, on foot and by public transport, which means that they are more multimodal than the average. People doing car-sharing travel more by car than the average and less often own no car. But they do not travel by public transport whereas they live in

Figure 1: Distribution patterns of means of transportation used



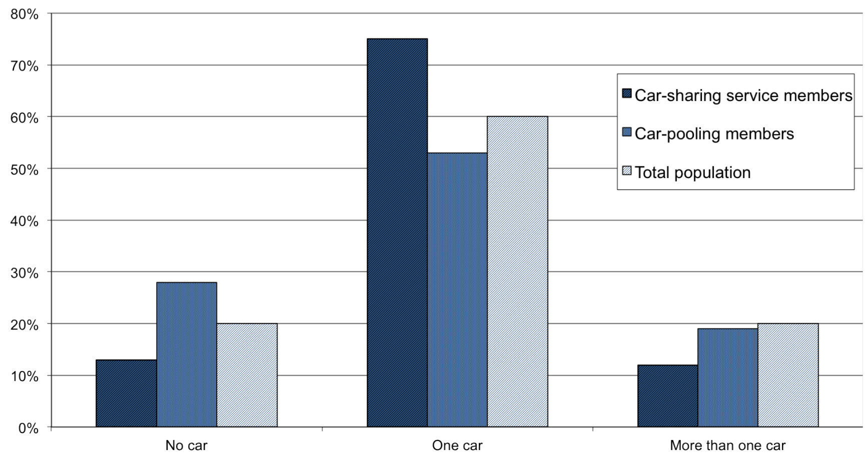
Sources : OMA 2011

urban area which might mean that they attach great importance to travel by car. Those results must be taken with caution given the few car-sharing service members in our sample.

Technical characteristics. The national transportation and travel survey (ENTD) from 2007 shows that the main constraints to buy a new car are the purchasing price of the car and the cost of its use. Among the households with no cars, only 5% report having taken into account the environment to make their decision. For people who renounce to car, the main alternative is public transport. Car-pooling or car-renting are mention by only very few respondents and only as a second alternative. According to the 2011 mobility observatory (OMA) from BIPE, 1% of people report not having bought a car to carpool or borrow relatives' car, 1% to rent a car.

According to the 2011 mobility observatory (OMA) from BIPE, around 85% of people doing car-sharing own at least one car as shown in figure 2, whereas 21% of the total population does not own a car. On average households doing car-sharing more often own a car than the French population, but they less often have more than one car. Among regular users of Autolib' service, 70% have no private car (62% live in Paris). People who carpool less often have a car than the average as shown in figure 2. This might indicates that people who declare to carpool are the passengers and that drivers do not declare to carpool.

Figure 2: Car equipment of households



Sources : OMA 2011

Competences. The 2011 mobility observatory (OMA) from BIPE company shows that people doing car-pooling or car-sharing are not more interested in new power-trains (hybrid, electric, biofuels) than average French people. They do not seem to have significantly different values for car ownership or driving from the average.

3.2.3 At the scale of a journey

In this section we seek to compare the elementary mobility service of new mobility services with the one of traditional car mobility. In order to do so, we mainly compare the technical characteristics and the competences involved in each case. It could also be interesting to compare the service characteristics which would be the comfort, the flexibility of the solution, the social status. But this is not the kind of data we can access from our survey and it has less to do with energy savings or not. However, we take into account these considerations to discuss our results in the following section 4.

Technical characteristics. According to the committee of French Automobile Manufacturers (CCFA), the French personal car fleet accounts 31 millions of units aged of an average 8 years. As shown in table 4, the personal car fleet is mainly composed by lower segments. Moreover, 42% are gasoline cars and 58% are diesel cars. The average consumption of gasoline vehicles being 7.82L/100 km and that of diesel car being 6.56 L/100km, the average consumption of the French personal car fleet is 7.05L/100km.

The energy consumption of personal cars used for car-pooling is impossible to know because it is private personal cars. But we assume that it is the same as that of the total personal car fleet.

Concerning the personal cars shared in French car-sharing services, we have information on 490 cars. As shown in table 4, the share of small cars in the shared-cars fleet is more important than that of the average French fleet.

Table 4: Comparison of the French fleet with the car-sharing fleet

Segment	**French fleet**	**Car-sharing fleet**
Small car	47%	78%
Middle car	43%	9%
Large car	5%	4%
Other (Utilities)	6%	8%

Sources : websites of car-sharing services and telephone interviews

The average energy consumption of shared cars is 4.8L/100 km, very lower than that of the total French passenger cars fleet. Shared vehicles are mainly gasoline and diesel cars but some car-sharing services offer hybrid and electric vehicles. This is the case of the new Parisian service named Autolib' which will permit to reduce the average fleet consumption. In addition, from 2012, shared cars must meet conditions in terms of CO2 emissions to enable the service to obtain the "Autopartage" label.

Cars offered by short-term car-rental are new vehicles which satisfy the standards in terms of CO2 emissions. When we explore 2011 new registrations of short-term car-rental, we notice that the share of each segment is quite similar to that of the 2011 total French personal car market as shown in table 5. As short-term car-rental cars are used an average 18 months, the fleet is similar to new registrations. We therefore consider the energy consumption of the short-term car-rental fleet to be similar to that of the total new passenger cars registration. According to the French agency for environment and energy management (ADEME), 70% of new passenger cars registered are diesel car, the average consumption of diesel car is 4.9L/100 km and that of gasoline car is 5.5 L/100km. The average energy consumption of the short-term car-rental passenger cars is then 5.08 L/100 km, which is lower than that of the total passenger car fleet.

Table 5: Composition of the 2011 short-term car-rental and total personal cars registrations

Segment	**Share of the short-term rental vehicles registrations**	**Share of the total new personal cars registrations**
Small car	38%	39%
Middle car	38%	31%
Large car	19%	26%

Sources : AAA (central file of car registrations in France)

Competences. We identify a potential windfall effect when tariffs include a rental period and a given distance: some users may be encouraged to travel more kilometers than expected to return the rental rate. However, it is likely that the routine use of these services will reduce this bias. In addition, fewer and fewer services offer this type of tariff offer.

3.3 Life span, intensity of use and end of life

The average holding period of a personal car by households is 5 years and the average annual mileage is 14,000 kilometers in 2010[13].

People carpool with private cars and that is the reason why we consider the vehicle life span and intensity of use to be the same as for the average cars. The end of life is the same too: either they are kept until the scrappage or they are sold on the second-hand car market.

Car-sharing services keep their vehicles an average 3 years and they travel an average 20,000 kilometers a year[14]. Short-term car renting services keep their vehicles an average 18 months during which they are leased 240 days per year for 120 kilometers. Vehicles used in car-sharing services and short-term car-rental are sold on the second hand car market making available efficient vehicles for households[15].

[13]Source: CCFA - Committee of French car manufacturers
[14]Source: France Autopartage Network
[15]Source: websites of car-sharing services and telephone interviews

4 Discussion

4.1 Car-pooling

In terms of energy consumption, car-pooling does not seem to have any influence on driver behavior or on cars technical characteristics. Therefore the energy consumption per kilometer is equivalent to that of a traditional travel by car (even slightly higher due to higher load), but energy consumption per passenger is reduced. In addition, individuals who use car-pooling have, on average, fewer cars than others. If car-pooling grow significantly, it is tempting to speculate that the energy consumption required for transportation of all individuals would be lower and that the need for private vehicles (and its associated embodied-energy) would be less.

However, some other results invite us to reconsider our optimistic conclusions.

Our first point concerns the development of car-pooling. Car-pooling is a mobility service that has existed for many years and whose practice is rather stable in France. It may feel as car-pooling grows because it is becoming increasingly publicized. But nothing, statistically, indicates a significant development of this type of automobile transport. One of the main obstacles to the development of car-pooling is that it is an intermediate solution between individual transport and public transport, and as such, it is not as flexible as individual transport. Therefore, car-pooling is an option only for relatively programmed trips (such as to commute, to go for holidays or week ends, etc.). Even for commuting, many professions require some flexibility in schedules and do not allow this type of organization. It also appears in surveys that people who carpool are not more interested in clean (green) transportation modes than others, and that they choose to carpool mainly for economic reasons. Thus, policies to expand car-pooling should primarily seek to facilitate the organization of car-pooling and to reduce the cost of this type of automobile transport, or at least to make pricing more explicit. But there seems to be a significant risk of rebound effect: car-pooling does not seem a comfortable and convenient transport mode and in case of loss of financial constraint, it is very likely that individuals who carpool will return to more individual practices.

Moreover, it seems wrong to think that since individuals who carpool have fewer cars than average, if car-pooling grows, the need for cars would be less. We believe that the causal link between car abandonment and car-pooling works in the opposite direction. As noted earlier, individuals who carpool are usually from a modest background and choose this option for financial reasons. In addition, we see that those who have no car almost never consider car-pooling as the first alternative mode of travel. Thus, we assume that it is because they already have no vehicle that people carpool (car-pooling as an alternative among other modes of transport such as walking or public transport) and not because there is a car-pooling offer that they renounce to car. We assume this is due to the fact that car-pooling is inflexible and cannot be the only alternative to privately-owned cars. The reasons that compel households to dispose of their car are mainly financial constraints (investment and operating cost) and difficulties to circulate and park. As a reason to dispose of their car, protecting the environment has been taken into consideration by less than 5% of households.

If it does allow a reduction in energy consumption per passenger, car-pooling does not seem, in itself, to be the solution for reducing the energy consumption of transport: it is a solution that is inflexible and that today affects only a small segment of the population. The solution is not to expand car-pooling and to wait for energy savings in transport, but to encourage the abandonment of private cars by offering multiple alternatives, including car-pooling. In addition, car-pooling should be facilitated. Currently, some policies already aim to ease traffic and parking for those who carpool, allowing them to travel in bus lanes, or by reserving parking spaces.

4.2 Car-sharing and short-term car-rental

Concerning the performances of car-sharing or short-term car-rental, the results we collected seem to support the ones reported in the literature. Vehicles used by these services are newer, smaller and consume less energy on average than those owned by individuals[16]. Moreover, these types of automobile transport might allow the use of a vehicle more fit for the journey (although in reality the choice of car model is often limited). Therefore, as mentioned in the literature, there is a potential for reducing energy consumption per kilometer.

However, we believe that several features of the car-sharing services and short-term car-rental may slow or hinder the achievement of this theoretical potential.

These types of automobile transport do not always encourage "environmentally-friendly" behavior since, in certain cases, fuel is not paid directly by the user but included in the package price to access the car (this mainly concerns car-sharing). Moreover, since the user does not own the car he is using, he has no incentive to take care of the shared car. These behavioral biases are

[16]In France there is a label "autopartage" that regulates, among other things, energy consumption and GHG emissions from car-sharing cars

related to the so-called principal-agent problem.

Car-sharing and short-term car-rental organizations also highlight the fact that these car mobility services may permit the use of vehicles using alternative energies such as electricity, natural gas, etc. Some studies also mention it and it reinforces the idea that car-sharing is more "sustainable" than traditional transport by privately-owned car. However, it is important to mention that shared cars have a very limited life span, of less than 3 years. After this period, they are generally sold on the second hand market. Depending on the point of view, this can be seen as a barrier to development (if one considers that these alternative energies powered cars are not chosen by car-sharing organizations who fear not being able to resell them easily) or as a catalyst for development (car-sharing organizations' demand for such cars strengthens their development, increasing production and allowing people to try the given type of car before making them available at lower prices on the second hand market). Until recently, in France, car-sharing organizations have mainly offered access to conventional vehicles. But since december 2011, the Parisian organization Autolib' offers access to electric cars. Although this organization is in its early stages of development, it already has over 1,000 electric vehicles.

Moreover, we wish to reconsider the relationship between car-sharing and reducing the distances traveled by car. While many studies seem to highlight this point through surveys, most of them are based on ex post estimates or do not distinguish between people who owned a car before participating in car-sharing and people who did not. In their paper, Steininger et al. [1996] distinguish between these two types of people and carry several lots of measurements before and after the launch of the car-sharing experiment. This study shows that if those who owned a car before the beginning of the experiment tend to reduce the distance that they travel by car, those who do not, in turn, increase it. Thus, the final result depends on the proportion of people who do not have a car before the beginning of the experiment. We believe there is a risk of rebound effect, especially in urban area where some people no longer have a car and are used to public transport: they might start using shared cars which permit more flexibility than public transport.

Measures need to be taken to reduce behavioral biases and encourage users to adopt eco-driving behaviors[17]. Measures must also be taken to minimize the risk of rebound effect, in particular by facilitating the modal shift. We must take the most of the fact that car-sharing makes the price of car use more transparent. Car-sharing should not target individuals who had

[17] Certain actions have already been taken by various organizations, including fixing a price per unit of distance traveled.

renounced the use of the car, but individuals who hardly use their cars and could renounce it (if an alternative type of automobile transport were easily accessible in the rare cases where the use of a car seems necessary).

Another argument is developed in the literature: car-sharing and short-term car-rental permit to dispose of its private vehicle, thereby reducing the fleet size and the need for car production (and its associated energy consumption). Our results do not enable us to verify whether car-sharing leads to the abandonment of the car or not. However, they indicate that people who participate in car-sharing generally have one car, but only one. Car-sharing seems rather a solution to replace a second car or a workaround. This is not contradictory with reducing the need for car. However, it is the relationship between the need for cars and car production that seems more open to criticism. Car-sharing induces a need for new cars, while it replaces the need for a second vehicle, which eventually might have been bought on the second hand market. Households purchase new and second hand cars (about 21% of new cars). Production of new cars is driven by purchases by households as well as professionals (about 60% by households). We know that in case of small variations in households' demand, car manufacturers do not necessarily adapt their production since they can sell their surplus into the professional market, especially to car-rental companies. In support of what we just said, it is rather the young people who participate in car-sharing, while those who buy new cars are mainly over 50.

It is therefore only with a massive development of car-sharing and short-term car-rental that we would see the impact of such development on automobile production.

Conclusions

In this paper we address the question of the energy performance of the functional service model through one practical implementation of this theoretical model: the new mobility services.

New mobility services such as car-pooling, car-sharing or short-term car-rental have the advantage to optimize car use in terms of number of passengers in the car and number of hours of utilization per day. Thus they permit reduction of households' equipment and promote multimodality as shown in the literature review.

The results we obtain show that car-pooling enables a reduction of energy consumption per passenger. However, the reasons that compel households to carpool are mainly financial constraints, as car-pooling does not seem a comfortable and convenient mode of transportation. Therefore there is a significant risk of rebound effect. Policies which aim to expand car-pooling should primarily seek to facilitate the organization of car-pooling. There are some interesting experimentations called *dynamic car-pooling*. It consists in linking, in real time, people wishing to make a particular journey, through a website accessible from a smartphone.

Although car-sharing services and short-term car renting services lead to the production of additional new personal cars (and therefore to an increase in the embodied energy of the transport sector), they make available efficient vehicles for households (both as shared-vehicles during their use by the service and then as private vehicles after their resale on the second-hand car market). Thus there is a potential for reducing energy consumption per kilometer. However, it could encourage users to travel more kilometers than what they would have done normally in order to justify the cost of the rental. Moreover, as it is more comfortable and flexible than public transport, there is a high risk of rebound effect among people who no longer have a car (especially in urban area). Measures need to be taken to minimize the risk of rebound effect, such as making the price of car use more explicit or fixing a price per unit of distance traveled. In France, these conditions must be satisfied to obtain the label "autopartage".

Finally, at the scale of the transport sector, new mobility services would allow energy savings under some conditions. Policies should promote the abandonment of private equipment for the use of mobility services and minimize the risk of rebound effect. The abandonment of private equipment leads to a reduction in the size of the car fleet and prevents a return to private car mobility. Policies should encourage new mobility services to put their stations near the public transport stations to facilitate multimodality, and to develop an extensive coverage network. The handover of the vehicle should be quick and easy, to avoid the need to anticipate. One can also suggest penalties to discourage the purchase of private vehicles and taxes on parking and traffic in cities, which revenues would be used to invest in public transport improvement or in car-sharing services development. In the future, it would be interesting to monitor the service *autolib'* in Paris, and especially to monitor if members have renounced the possession of the car or if those who do not own a personal car are using car again.

Although in this paper we have restricted our methodology to new mobility services, it has a broader scope insofar as that is designed to apply to all of the services which constitute the service sector as a whole. It allows a comprehensive analysis of services beginning with their origin (the need for a given service), continuing through their realization (the provision of the service), and ultimately terminating at the end of their lives. It can not only be used to study a service as performed at a given time, but may also be implemented as a prospective instrument to study the dynamics of innovation in the service sector.

Acknowledgements

We wish to thank Fabrice Decellas and Jared Young for their very helpful comments. Remaining errors or inaccuracies are due to the authors alone. We are also grateful to car-sharing representatives for answering our questions.

References

M. Bartolomeo, D. dal Maso, P. de Jong, P. Eder, P. Groenewegen, P. Hopkinson, P. James, L. Nijhuis, M. Orninge, G. Scholl, A. Slob, and O. Zaring. Eco-efficient producer services-what are they, how do they benefit customers and the environment and how likely are they to develop and be extensively utilised? *Journal of Cleaner Production*, 11(8):829–837, 2003.

H. Baum and S. Pesch. Untersuchung der eignung von carsharing im hinblick auf reduzierung von stadtverkehrsproblemen. Research report n. 70421/93, 1994.

O. Blandin. Du transport collectif à l'écomobilité : m'expérience d'une entreprise de transport urbain d'une ville moyenne du sud de la france. In *L'économie de la fonctionnalité : une voie nouvelle pour un développement durable*. Gaglio, G. and Lauriol, J. and Du Tertre, C., 2011.

D. Bourg and N. Buclet. L'économie de la fonctionnalité. changer la consommation dans le sens du développement durable. *Futuribles*, 313:27–37, Nov 2005.

F. Bouthillier. Performances durables des modèles d'opérateurs intégrés : économie de la fonctionnalité. In *XIXème conférence de l'AIMS*, Luxembourg, 2010.

N. Buclet. Vendre l'usage d'un bien plutôt que le bien lui-même : une piste pour concilier meilleures prises en compte de l'environnement et rentalité des entreprises. In *XV conférence internationale du RESER*, Granada, September 22-24 2005.

Communauto. Le projet auto + bus. evaluation d'initiatives de mobilité combiné dans les villes canadiennes. Technical report, TECSULT Inc., 2006.

E. De Vries. Innovation in services in networks of organisations and in the distribution of services. *Research Policy*, 35(7):1037–1051, Sep 2006.

C. Du Tertre. Des services aux entreprises à l'économie de la fonctionnalité : les enjeux du développement durable. In E. Heurgon and J. Landrieu, editors, *L'économie des services pour un développement durable : nouvelles richesses, nouvelles solidarités*. L'Harmattan, 2007.

J.M. Folz, C. Cros, and D. Nicklaus. L'économie de la fonctionnalité, un plus pour l'environnement. Grenelle chantier n.31, Oct 2008.

G. Gaglio, J. Lauriol, and C. Du Tertre, editors. *L'économie de la fonctionnalité : une voie nouvelle pour un développement durable*. Octares Edition, 2011.

F. Gallouj. *Innovation in the service economy. The new wealth of nations*. Edward Elgar, Cheltenham, 2002.

F. Gallouj and O. Weinstein. Innovation in services. *Research Policy*, 26 (4-5):537 – 556, 1997.

O. Giarini and W. R. Stahel. *Les limites du certain. Affronter les risques dans une nouvelle économie de services*. Presses polytechniques et universitaires romandes, Lausanne, 1990.

S. Harms and B. Truffer. The emergence of a nationwide carsharing cooperative in switzerland, 1998. URL `http://www.communauto.com`. Accessed March 9, 2012.

E. Heurgon and J. Landrieu, editors. *L'économie des services pour un développement durable : nouvelles richesses, nouvelles solidarités*. L'Harmattan, Paris, 2007.

C. Jemelin and N. Louvet. Etude sur l'autopartage à paris. analyse des comportements et des représentations qui lui sont associés. Technical report, Ademe and Mairie de Paris, 2007.

R. Katzev. Car sharing: a new approach to urban transportation problems. *Analyses of Social Issues and Public Policy*, 3(1):65–86, 2003.

C. Lane. Phillycarshare: First-year social and mobility impacts of carsharing in philadelphia, pennsylvania. *Transportation Research Record*, 1927:158–166, 2005.

R. Meijkamp. Changing consumer behaviour through eco-efficient services. an empirical study on car sharing in the netherlands. *Business Strategy and the Environment*, 7:234–244, 1998.

R. Meijkamp. *Changing consumer behaviour through Eco-efficient Services. An empirical study on Car Sharing in the Netherlands.* PhD thesis, Delft University of Technology, 2000.

O. Mont. Product-service systems. Afr-report 288, Swedish EPA, Stockholm, 2000.

O. Mont. Clarifying the concept of product-service system. *Journal of Cleaner Production*, 10(3):237 – 245, 2002.

O. Mont. Institutionalisation of sustainable consumption patterns based on shared use. *Ecological Economics*, 50:135–153, 2004.

C. Ryden and E. Morin. Moses. environmental assessment. Report wp6. version 1.1, Moses, 2005.

S. Shaheen and D. Sperling. Carsharing: Niche market or new pathway? In *Proceedings ECMT/OECD workshop on managing car use for sustainable urban travel*, 1999.

W. R. Stahel. From products to services: Selling performance instead of goods. Report 27, Institute for Prospective Technological Studies (ITPS), 1998.

K. Steininger, C. Vogl, and R. Zettl. Car-sharing organizations: The size of the market segment and revealed change in mobility behavior. *Transport Policy*, 3(4):177 – 185, 1996.

A. Tukker and U. Tischner, editors. *New business for old Europe.* Greenleaf Publishing, 2006.

Zipcar. Zipcar customer survey shows car-sharing leads to car shedding, 2005. URL `http://zipcar.mediaroom.com`. Accessed march 9, 2012.