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The cost saving potential of carsharing in a US context

Michael Duncan

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Abstract Carsharing is a vehicle sharing service for those with occasional need of private transportation. Transportation planners are beginning to see great potential for carsharing in helping to create a more diversified and sustainable transport system. While it has grown quickly in the US in recent years, it is still far from the level where it can deliver significant aggregate benefits. A key element to the potential growth of carsharing is its ability to provide cost savings to those who adopt it in favor of vehicle ownership. This research seeks to quantify these potential cost savings. The costs of carsharing and vehicle ownership are compared based on actual vehicle usage patterns from a large survey of San Francisco Bay Area residents. The results of this analysis show that a significant minority of Bay Area households own a vehicle with a usage pattern that carsharing could accommodate at a lower cost. Further research is required to indentify how these cost savings translate to the adoption of carsharing.

Keywords Carsharing · Travel behavior · Vehicle usage patterns · VKT · Sustainability

Introduction

Carsharing is a membership-based service that provides short term access to automobiles (TCRP 2005). Members can reserve one of a fleet of vehicles parked at various locations across a city. Payment for this service usually involves a small membership fee and a usage rate based on time and distance traveled, although the specifics of payment will vary with each carsharing organization. Unlike traditional car rentals or taxi service, carsharing can provide a relatively inexpensive alternative to auto ownership for those with occasional need of an automobile.

Transportation planners have begun to recognize carsharing as a potentially important component of a diversified and sustainable transport system (Enoch and Taylor 2006;

M. Duncan (✉)
Department of Geography and Earth Sciences, University of North Carolina at Charlotte,
9201 University City Blvd., Charlotte, NC 28223, USA
e-mail: m.duncan@uncc.edu

Goldman and Gorham 2006; Parent 2006; Wright and Curtis 2004). It can compliment public transit, biking, and walking by serving certain trips that these non-auto modes cannot effectively cover (Huwer 2004; Barth et al. 2004). Even in the most transit and pedestrian friendly locations, the flexibility, speed, and convenience of a private auto can significantly enhance a household's travel options. Carsharing can provide a measure of automobility without needing to incur the full expense and inconveniences of owning a vehicle (or a second or third vehicle as the case may be).

Carsharing forms a very small part of our current transport system but has grown rapidly in recent years. It has been successful in various European cities since the 1980s, came to Canada in the early 1990s, and then the US in the late 1990s (Shaheen et al. 2006, 1998). In the past decade, it has gained some traction and expanded into several dozen North American cities. Carsharing membership has grown exponentially to nearly 280,000 people in the US and an additional 40,000 members in Canada (Shaheen et al. 2009).

For carsharing to generate significant aggregate benefits and truly improve sustainability, it must obviously continue to expand. A few hundred thousand carsharing members make up only a tiny fraction of North American drivers. One key aspect in the potential growth of carsharing is simply whether it can save people money (Schuster et al. 2005). This paper seeks to address this issue by empirically examining the economic viability of carsharing from the perspective of potential customers in the San Francisco Bay Area. More specifically, this research estimates the share of Bay Area vehicles for which carsharing can provide a cost effective substitute.

Carsharing benefits

Individual benefits

The ability to share the "fixed" costs of auto ownership provides the economic impetus for carsharing (TCRP 2005). Fixed costs are the expenditures a vehicle owner must pay independent of usage. Such costs generally include vehicle depreciation,[1] insurance, and registration fees. When the cost of residential parking is unbundled from housing prices (as is sometimes the case in San Francisco and other urban settings), it also becomes a fixed cost of vehicle ownership.[2] Because of these fixed costs, private vehicles with a low level of vehicle kilometers traveled (VKT) pay a higher cost per VKT. By dividing the fixed costs among many people, carsharing can become a cost effective replacement for owning a lightly used vehicle.

A few groups particularly stand to benefit from carsharing. First, those who do not own a vehicle can enhance their mobility without needing to fully commit to a vehicle purchase (Katsev 2003). This group is generally easy to quantify with census data. According to the 2000 census, nearly 11 million US households (about 10%) did not own a vehicle. In the nine county Bay Area region, roughly a quarter million total households (also about 10%) did not own a vehicle.

[1] Depreciation costs depend on usage and are not entirely fixed. A heavily used vehicle will generally have a lower resale value than a less utilized vehicle of the same age and type. Nonetheless, depreciation will occur to some degree independent of usage.

[2] Even if parking is bundled with housing costs, there still might be a significant opportunity cost associated with residential parking. In other words, if there is a high demand for parking in the surrounding area, one should be able to rent their assigned parking space to the highest bidder. A scan of Craigslist indicates this type of informal market for parking spaces does exist in the more urban sections of the Bay Area.

Those who drive on a limited basis form the next group that stands to benefit from carsharing. Many in this group might trade their vehicles in for a carsharing membership and potentially save money without needing to significantly alter driving patterns. It is this group that this analysis seeks to quantify. There are also those that only occasionally need a private automobile (i.e., they have decent transit or pedestrians options) but, nonetheless, drive more extensively because the fixed costs make this economically prudent. A carsharing option might reorder economic incentives and lead some auto owners to shed a vehicle, use carsharing to replace essential auto travel, and then use other modes to cover any residual travel needs.

For others, the benefits of carsharing go beyond reducing monetary expenditures. For example, vehicle maintenance and parking (especially in urban environments) can be a nuisance that some would like to avoid (Burkhardt and Millard-Ball 2006). For others, the motivation to join carsharing might be ideological (Orski 2001). It provides a good option for those who wish to limit their auto use because of personal concern over environmental and energy issues but lack the discipline to do so when they have easy access to their own private vehicle.

Carsharing and public benefits

Beyond the benefits that accrue to individual users, carsharing can also help to serve broader public goals (Shaheen et al. 2004; Fellows and Pitfield 2000). Carsharing can contribute to a more socially sustainable transport system by offering affordable mobility to the poor. Private transportation can prove financially difficult and sometimes impossible for low-income households (Wachs and Taylor 1998). Carsharing makes access to a vehicle much more reasonable for such households. At the very least, carsharing can accommodate the basic travel needs required to maintain a minimum standard of living (e.g., being able to get to medical appointments or a grocery store).

If carsharing can produce net reductions in auto travel, it can also enhance sustainability with regard to energy and the environment (Murphy and Delucchi 1998). Some may choose carsharing with an intention to reduce driving but even those who don't have such intentions may find themselves driving less. Carsharing forces a more direct consideration of how much each trip costs in a way that a monthly car payment and a weekly gas purchase do not. In effect, carsharing can act as travel demand management tool (Litman 2000). Making the cost of driving more immediate will decrease the likelihood of discretionary auto trips and lead to more efficient travel patterns (e.g., trip-chaining and choosing more proximate destinations). If transit, biking, or walking provides a reasonable option for a given trip, one will more likely choose one of these alternatives. If carsharing contributes to more biking and walking, it can also have public health benefits in addition to reducing emissions and fuel consumption (Warburton et al. 2006).

Some carsharing members that previously did not own a car will actually increase their VKT and temper the aggregate VKT reduction (Cervero 2003). However, the fact that a carsharing membership might deter a future vehicle purchase should be considered in measuring aggregate VKT impacts. Further, if VKT increases come as a result of improved mobility for low-income households, many would consider this a worthy tradeoff.

In addition to reducing vehicle usage, the total number of vehicles in a city can be reduced through carsharing and, thus, the amount of land and infrastructure needed for parking can be reduced. This could decrease the cost of development, open up more space for development and, in the long run, reduce the spatial footprint of a city.

Carsharing may have the additional external benefit of making it more attractive to live in urban environments, which purportedly have a smaller ecological footprint (Glaeser and Kahn 2008; Beatley 2000). Residential parking in urban areas can prove costly and inconvenient and may deter some that would otherwise consider living in such areas. Carsharing can eliminate these parking concerns without requiring a complete abandonment of auto travel.

Carsharing research

As carsharing represents a relatively new transport innovation, academic research about its potential growth and benefits is still in its early stages. Nonetheless, the literature has already focused on a many aspects of carsharing. Much of it has simply focused on tracking the growth and expansion of carsharing (Shaheen et al. 1998, 2006, 2009; Shaheen and Cohen 2007). Other research has focused on administrative or logistical aspects of running a carsharing organization (Kek et al. 2009; Fan et al. 2008; Shaheen et al. 2003; Barth et al. 2003; Barth and Shaheen 2002). Still others have tracked the actual usage of the carsharing vehicles (Morency et al. 2008). Of particular import are studies that empirically examine how the adoption of carsharing impacts VKT and vehicle ownership (Cervero et al. 2007; Lane 2005; Cervero and Tsai 2004; Cervero 2003). Such work plays a critical role in assessing the potential of carsharing to serve sustainability goals. These studies generally indicate that carsharing organizations provide a net reduction in VKT (Shaheen et al. 2006).

Researchers have also put some focus on exploring the market for carsharing. This has involved conducting detailed demographic analyses of those who have chosen to join a carsharing service (Burkhardt and Millard-Ball 2006). Some of the characteristics commonly found among the adopters of carsharing include (TCRP 2005): urban residential locations, concern for environment, propensity to be an “early adopter”, smaller households, high educational attainment, and people in their 30s and 40s. Other studies have focused on surveys of the broader public to understand familiarity with the concept of carsharing and willingness to accept it (Nobis 2006; Loose et al. 2006). Such market analysis can help carsharing agencies provide attractive fare structures, understand effective advertising strategies, and determine the best neighborhoods to locate their carsharing vehicles (Celsor and Millard-Ball 2007). From a broader perspective, market research can help in assessing the potential for carsharing to grow and provide significant public benefits.

Existing usage patterns of private vehicles can serve as an important, if not complete, indicator of the potential market for carsharing. Those that could adopt carsharing and save money without needing to greatly alter their travel patterns would intuitively form a key component of a carsharing firm’s customer base. In fact, the promotional material for many carsharing companies includes a prominent section that illustrates the potential cost savings that one can achieve through carsharing (City Carshare 2010; Zipcar 2010). If a large number of private vehicles have usage patterns conducive to carsharing, this would portend a strong growth potential. The literature has paid very limited analytical attention to this issue. Schuster et al. (2005) have developed a simulation model that uses recorded travel patterns to predict the adoption of carsharing in Baltimore but, to date, this study largely stands alone.

Research questions

This analysis aims to inductively answer two related questions:

(1) What kind of vehicle usage patterns can carsharing accommodate in a cost effective manner given the cost structure of carsharing and auto ownership in the Bay Area? The cost assumptions used to address this question are given a detailed treatment in the subsequent sections.
(2) How many vehicles in the Bay Area have driving patterns that meet the threshold at which carsharing becomes less expensive than auto ownership and how many Bay Area households own such a vehicle? The 2000 Bay Area Travel Survey[3] (BATS) is used to address this question. The BATS includes a sample of more than 15,000 households that were asked to keep a 2-day activity diary for each household member. The diary entries can be used to track the time, place, and mode for each individual's travel movements. In the case of private auto trips, the specific vehicle used for a trip was recorded and this allows for a detailed accounting of the usage pattern for each vehicle owned by a BATS household (roughly 28,000 vehicles in total).

Cost assumptions[4]

Carsharing costs

There are two major companies in the Bay Area that offer carsharing services: City CarShare (a local non-profit firm) and Zipcar (a for-profit firm that has become the dominant provider of carsharing across the US). Each of these companies offers several pricing plans and these are described in Table 1. For the purposes of this analysis, it is assumed that anyone who adopts carsharing will choose the firm and pricing plan that minimizes their costs.

In addition to the direct expenditures associated with carsharing fees, the cost of carsharing also includes the time it takes to get to and from the vehicle location (often referred to as a pod). This access cost will vary based on proximity to the pod and the monetary value assigned to access time. Pod proximity for the each of the BATS households will be calculated based on three different scenarios for pod locations:

- *Scenario 1* assumes existing carshing pod locations. City CarShare currently has approximately 175 locations and Zipcar has 217 locations. Nearly all the existing pods are clustered within the more urbanized sections of the Bay Area (i.e., San Francisco, Oakland, and Berkeley).
- *Scenario 2* represents a hypothetical expansion to high density and transit-friendly locations that could realistically support carsharing. In this scenario, carsharing expands into any Bay Area census tract that has at least 40 driving age (between 18 and 85) residents per hectare.[5] Aside from the tracts that already contain a carsharing pod (as defined in scenario 1), there are 160 additional census tracts that meet this density

[3] This survey was conducted by the Metropolitan Transportation Commission (MTC), which is the Bay Area's metropolitan planning organization (MPO).

[4] Because the purpose of this analysis is to compare the cost of private vehicle ownership to carsharing, costs that would accrue equally to a driver of a private vehicle or a carsharing vehicle are ignored. This includes the value of time spent driving, tolls, and non-residential parking fees.

[5] According to City CarShare (2010), a minimum of 25 members living within 400 m of a pod are needed to justify a pod location. This can be achieved with 40 drivers per hectare if at least 2% of all drivers within 400 m join a carsharing program. As carsharing becomes a more recognizable option, a 2% penetration rate in the area immediately surrounding a pod should be obtainable.

Table 1 Pricing plans offered by Bay Area carsharing companies

	Annual fee	Minimum per month	Distance charges	Time charges		
				Weekday	Weekend	"Night Owl" (12 a.m.–8 a.m.)
City CarShare						
Plan 1	$45	n/a	$0.25/km	$6.50/h	$7.50/h	n/a
Plan 2	$120		$0.22/km	$5.50/h	$6.00/h	$1.50/h
Plan 3	$240		$0.22/km	$5.50/h	$6.00/h	No charge
Zipcar						
Plan 1	$50	n/a	First 290 km/day: no charge	$7.00/h or $73.00/day	$7.00/h or $88.00/day	n/a
Plan 2	n/a	$50	Additional km: $0.28/km	$6.30/h or $65.70/day	$6.30/h or $79.20 day	
Plan 3	n/a	$250		$5.95/h or $62.05/day	$5.95/h or $74.80/day	

The distance charges listed for Zipcar apply to all three zip car plans

threshold and it is assumed that a pod is placed at the center of each of these tracts. Further, it is assumed that 200 additional carsharing pods are placed at each of the region's rail stations and ferry terminals that do not already have a nearby pod. Since it is not clear which of the two carsharing companies will expand into a given area, it is assumed that the pricing plans associated with each company are available at any pod.[6]

- *Scenario 3* assumes ubiquitous access to carsharing where each BATS household lives 100 m from a carsharing pod. While not realistic, this scenario assesses the viability of carsharing purely from the perspective of vehicle usage patterns and without regard to a household's current residential location. This can prove useful because residential locations are not always permanent and, to the degree that a driving pattern makes carsharing economically advantageous, a household might be induced to move near a pod.

In addition to the above described pod location scenarios, the estimation of pod access costs will make the following assumptions:

- Carsharing customers walk to/from the pod at a speed of 5 km per hour.
- The time it takes to walk to/from the pod is assigned a cost of $32 per hour for work tours[7] and $22 per hour for non-work tours. These are adjusted versions[8] of value of time estimates provided by MTC, which is the Bay Area agency that is officially charged with travel demand modeling.

Based on the above assumptions, the access cost of a carsharing session (i.e., the round trip to/from the pod) for someone living 100 m from a pod will approximate $1.30 for a work

[6] This is not unprecedented as there are several pod locations where City CarShare and Zipcar operate side by side.

[7] A tour is a series of trip segments that begin and end at a place of residence. A work tour includes at least one destination that is work-related.

[8] The value of time estimates provided by MTC are for in-vehicle travel time (MTC 1997). It is generally assumed that the value of out-of-vehicle time is double that of in-vehicle time (Small and Verhoef 2007). While there is no good data about the value of time for access trips to and from a carsharing pod, such trips squarely fit into the out-of-vehicle category. As such, the MTC estimates for in-vehicle time have been doubled for this analysis. They have also been adjusted for inflation to 2010 constant dollars.

tour or $0.90 for a non-work tour. These access costs will increase proportionally with distance to a pod (e.g., the access cost for someone living a kilometer from a pod will be ten times higher than for someone living 100 m from a pod).

Carsharing has additional costs and benefits (relative to vehicle ownership) that go beyond the traditional measures of travel cost (time and monetary expenditures). For example, carsharing costs might include the inconvenience associated with always having to reserve a vehicle in advance and the fact that a carsharing membership does not guarantee that a vehicle will be available at the time it is most needed. Carsharing also requires a household to sacrifice its ability to choose a vehicle that most closely matches its needs and preferences. On the other hand, the benefits of carsharing might include having simultaneous access to a variety of vehicle types[9] and not having to worry about keeping a vehicle properly maintained and registered.[10] Because carsharing is both a small and recent phenomenon, good data do not yet exist about the monetary value that people place on the above described aspects of carsharing. Consequently, such aspects cannot be explicitly incorporated into this analysis. Determining how this broader suite of cost and benefits influence the adoption of carsharing presents an important avenue for future research.

Vehicle ownership costs

The existing fleet of private vehicles has a much broader mix of vehicle types than the carsharing fleet, which largely contains late model compact cars. This complicates the process of determining whether carsharing is economically advantageous. Holding vehicle usage patterns constant, those who own a larger or nicer vehicle (e.g., an SUV) may save money by switching to carsharing simply because they will downgrade the vehicle they use. However, a vehicle downgrade does not require a switch to carsharing. A vehicle owner may just as easily trade in their expensive vehicle and buy something more economical. If owning a vehicle that is similar in quality and price to those in the carsharing fleet proves less costly than the adoption of carsharing, one could not rationally adopt carsharing purely as a cost saving measure. This holds true even if the adoption of carsharing would provide cost savings relative to one's current vehicle. As such, the vehicle ownership costs assumed for this analysis are not based on the existing vehicles of BATS households. Instead, the costs of carsharing will be compared to the cost of two different vehicle ownership scenarios: (1) A new compact car equivalent to those in the carsharing fleet (e.g., a Toyota Corolla or a Honda Civic) and (2) a used subcompact car (e.g., a Toyota Echo).

The first scenario of owning a compact car equivalent to those in the carsharing fleet allows for an assessment of the cost effectiveness of carsharing when controlling for the moderating influence of vehicle quality. For this scenario, it is assumed that a compact car is purchased new and, to maintain equivalency with newer vehicles in the carsharing fleet, it is sold after 3 years to make way for the purchase of a newer model. Specific cost assumptions for this vehicle ownership scenario include:

- An initial purchase cost of $19,000 ($16,000 retail price plus and an additional $3,000 in sales taxes and financing charges).

[9] The carsharing fleets of City CarShare and Zipcar mostly include compact cars but they do provide some diversity of vehicle choice, including trucks and vans.

[10] Vehicle maintenance and registration have monetary costs that can be easily quantified and are accounted for in this analysis. However, independent of the monetary costs, these responsibilities can be a burden that some people might want to avoid.

- Depending on usage rates, the resale value for a 3 year old compact car ranges from \$12,000 down to roughly \$4,000.[11] This translates to a net purchase cost between \$7,000 and \$15,000.
- The net purchase cost per VKT for a lightly used vehicle (2,000 average annual kilometers) is \$1.21.
- The net purchase cost per VKT for a heavily used vehicle (50,000 average annual kilometers) is \$0.09.
- Fuel costs are \$0.069 per kilometer (13 km per liter at \$0.90 per liter).
- Maintenance costs are \$0.030 per kilometer (AAA 2010).
- A monthly insurance payment of \$100.[12]
- An annual California registration fee of \$270 (California DMV 2010).

The second scenario of a used subcompact car represents a lower cost option for those less concerned with the size and age of their vehicle. At the time of purchase, this vehicle is assumed to be 5 years old with 150000 km of use. It is further assumed that this vehicle will be driven to retirement, as this usually represents the lowest cost strategy per VKT. The California Air Resources Board (2004) estimates the median retirement age for a vehicle in California is 16 years and the median distance traveled is about 300000 km. Consequently, under this ownership scenario, the vehicle will be driven an additional 150000 km or 11 years (whichever comes first). Specific cost assumptions for this vehicle ownership scenario include:

- An initial purchase cost of \$5,000 (\$4,000 purchase price and an additional \$1,000 in sales tax and financing charges). Since the vehicle is driven to retirement, the net purchase cost is equivalent to the \$5,000 initial purchase cost.
- The purchase cost per kilometer for a lightly used vehicle (2,000 average annual kilometers) is \$0.23.
- The purchase cost per kilometer for a vehicle that accrues at least 13,700 average annual kilometers is \$0.03.
- Fuel costs are \$0.062 per kilometer (14.5 km per liter at \$0.90 per liter).
- Maintenance costs are \$0.060 per kilometer (because this vehicle is older, the maintenance costs are double those of the new vehicle from scenario 1).
- A monthly insurance payment of \$100.
- An annual California registration fee of \$130 (California DMV 2010).

These two vehicle ownership scenarios establish when carsharing can or cannot be economically advantageous. If carsharing proves more expensive than owning a new compact car (as defined in scenario 1) for a given vehicle usage pattern, this clearly indicates that the usage is too extensive for carsharing to provide cost savings. Conversely, if carsharing has a lower cost than owning a used subcompact (as defined in scenario 2), it is highly likely[13] that carsharing will prove the lowest cost option for that usage pattern. If the cost of carsharing lies somewhere between these two thresholds, the cost saving

[11] Based on "blue book" values for a 2007 Toyota Corolla, the resale price starts at \$12,000 and decreases roughly \$400 for every 10000 km of use.

[12] The AAA (2010) estimate for insurance is around \$80 per month but California has higher than average insurance costs.

[13] One could easily find a vehicle priced below the \$4,000 assumed in scenario 2. However, as the price of a vehicle falls below \$4,000, its reliability and longevity can quickly decrease and the maintenance costs can quickly increase. Thus, purchasing something below this cost may be counterproductive from a long term cost perspective.

potential depends on a driver's willingness to tolerate a vehicle of lower quality than those in the carsharing fleet.

As previously described, residential parking can also form part of the cost of vehicle ownership. MTC (2007) tracks the nominal monthly parking rate for traffic analysis zones (TAZs) in the Bay Area and this information is used to assign residential parking costs.[14] Because most areas in the region have ample free parking (both on- and off-street), MTC assumes a parking rate of zero for most TAZs. For the BATS households that live in one of the zones with parking costs, the relevant parking rate is added to the other vehicle ownership costs. While parking costs in these areas can reach more then $200 per month, this has little impact on an aggregate assessment of carsharing because less than 3% of BATS vehicles belong to households living in a zone affected by parking costs.

When is carsharing a financially viable option?

Dimensions of driving behavior

Some literature and promotional material for carsharing focuses on VKT as the key to whether carsharing can save money (Carsharing Network 2009; Litman 2000). While VKT can play a role in determining the cost effectiveness of carsharing, it is not the sole or even the primary determinant. A carsharing session includes an hourly charge that a vehicle owner does not face and this means that dwell times (i.e., the time that one remains at the out-of-home destination) can figure even more prominently than distance in carsharing costs. This holds especially true for Zipcar, which charges only by the hour and not by distance. A pattern of long distance trips with a short dwell times may prove more conducive to carsharing than an equal number of shorter trips with long dwell times. Similarly, slow driving speeds on local roads or in congested conditions will, all other things equal, prove less optimal for carsharing because the increased travel time will result in more hourly charges. The timing of travel can also prove important because carsharing companies often offer a discount for off-peak travel and a surcharge for weekend travel. Finally, because of the cost associated with accessing a carsharing vehicle, tour frequency can also be important. For example, a pattern of one weekly tour of a given distance and duration will prove more favorable to carsharing than dividing the same distance and duration into two or more shorter tours. In sum, the cost competitiveness of carsharing vis-à-vis vehicle ownership relies on all of the following dimensions of travel behavior: tour frequency, average distance per tour, average tour duration (dwell time + in-vehicle time), and the timing of the tour (peak versus off-peak and weekday versus weekend). The relative impact of each dimension will depend on the specifics of the fee structure.

Carsharing for commuting

Because the cost structure of carsharing penalizes long dwell times, it is poorly suited to commuting. Table 2 presents the estimated monthly cost of carsharing and vehicle

[14] The parking rates estimated by MTC are based on commercially operated parking facilities. These rates are used because there is no systematic information about residential parking rates. If residential parking is completely unbundled from housing costs, the residential parking rates should be roughly equivalent to the commercial rates. Even if parking is bundled with housing, MTC's rates still effectively represent the opportunity cost of a residential parking space (as discussed in footnote 2).

Table 2 Monthly cost of driving for various commute scenarios

Tour length	Weekly tours	Vehicle ownership		Carsharing			
		Carsharing-equivalent vehicle (scenario 1)	Low-cost vehicle (scenario 2)	Full-day work schedule (9 h dwell time per tour)		Half-day work schedule (4 h dwell time per tour)	
				City CarShare	Zipcar	City CarShare	Zipcar
90 km 1.9 h in-vehicle	5	$588	$414	$1,767	$1,373	$1,171	$790
	4	$534	$353	$1,416	$1,098	$939	$632
	3	$480	$293	$1,064	$824	$707	*$474*
	2	$425	$244	$713	$549	$475	*$316*
	1	$371	$196	*$361*	*$275*	*$242*	**$167**
45 km 1.1 h in-vehicle	5	$452	$268	$1,458	$1,332	$862	$688
	4	$425	$244	$1,169	$1,066	$692	$550
	3	$398	$220	$879	$799	$521	$413
	2	$371	$196	$589	$533	*$351*	*$275*
	1	$344	$173	*$300*	*$266*	*$180*	**$145**
5 km 0.2 h in-vehicle	5	$332	$162	$1,159	$1,215	$563	$570
	4	$329	$159	$929	$972	$452	$456
	3	$326	$157	$699	$729	$342	$342
	2	$323	$154	$470	$486	*$231*	*$241*
	1	$320	$151	*$240*	*$250*	**$121**	**$120**

Italic cells indicate that carsharing is less expensive than owning a carsharing-equivalent vehicle and **bold** cells indicate that carsharing is less expensive than owning a low-cost vehicle

ownership under a series of hypothetical commute scenarios.[15] The table demonstrates how carsharing can only provide cost savings for those with a limited work schedule.[16] Assuming that a tour includes a traditional 8 h day of work (plus 1 h for lunch), carsharing can only accommodate one tour per week at a cost savings. With a half-day work schedule (4 h per day), carsharing might effectively accommodate two or three tours per week. Either way, carsharing loses it financial viability for any schedule that requires someone to be at their place of work for much more than 10 h per week. This holds true for a long or short commute distance. Employers generally require workers to spend more time at the office than this and, consequently, carsharing will prove viable for very few auto commuters. A few carsharing organizations have tried to implement programs and fee structures that more effectively cater to commuters but this kind of service presents logistical difficulties and has remained very limited (Shaheen and Novick 2005; Shaheen 2001).

Given that carsharing cannot easily serve the needs of regular commuters, the large scale adoption of carsharing will likely depend on workers commuting by non-auto modes and using carsharing for non-work travel. As such, the Bay Area represents a relatively good market for carsharing. It has a large rapid transit system that provides good access to

[15] The cost estimates in Table 2 (and Table 3) assume that residential parking is free. In locations where residential parking can legitimately be added to the cost of vehicle ownership, carsharing will provide cost savings for a broader array of commute scenarios.

[16] The estimates presented in Table 2 assume that the vehicle in question is used only for commuting but, in reality, the vehicle will likely be used for some non-work tours as well. Consequently, the cost advantages of vehicle ownership are likely greater than what is demonstrated in the table.

major job centers (Cervero and Landis 1997). According to the 2000 census, nearly 300,000 or 10% of Bay Area workers commuted by transit. It also has enough density and mixing of jobs and housing that about 100,000 or 3% of workers commute by walking. Finally, about 130,000 or 4% of Bay Area workers avoid commuting altogether by working from home.

Carsharing for non-work travel

Non-work activities such as shopping, dining, and medical appointments rarely require more than a few hours and sometimes take only a few minutes. Because of these short dwell times, carsharing can more realistically accommodate non-work travel. Table 3 compares the cost of carsharing and vehicle ownership for a variety of non-work travel scenarios. Assuming a 1 h average dwell time per tour, carsharing can accommodate multiple tours (up to ten) per week while still providing cost savings. As dwell times increase, the weekly tour threshold quickly drops. If the average dwell time reaches 3 h, more than two tours per week eliminates the potential cost saving of carsharing. However, a large number of tours may not be necessary to accommodate non-work travel needs. Many households could conduct all necessary non-work activities during two weekly tours with an average dwell time of 3 h. Consequently, it seems that carsharing can theoretically provide an economically viable choice for households that do not need a car for commuting.

Table 3 Monthly cost of driving for various non-work travel scenarios

Tour length	Weekly tours	Vehicle ownership		Carsharing					
		Carsharing-equivalent vehicle (scenario 1)	Low-cost vehicle (scenario 2)	Average dwell time per tour 3 h		Average dwell time per tour 2 h		Average dwell time per tour 1 h	
				City CarShare	Zipcar	City CarShare	Zipcar	City CarShare	Zipcar
40 km 1.0 h in-vehicle	10	$558	$380	$1,413	$1,075	$1,169	$818	$924	$560
	8	$510	$326	$1,133	$860	$937	$654	$741	*$448*
	6	$462	$276	$852	$645	$705	$491	$558	*$336*
	4	$413	$233	$571	$430	$473	*$327*	*$376*	*$236*
	2	$365	$191	*$291*	*$227*	*$242*	**$173**	*$193*	**$118**
20 km 0.6 h in-vehicle	10	$437	$254	$1,119	$966	$875	$708	$630	$451
	8	$413	$233	$897	$773	$702	$567	$506	*$360*
	6	$389	$212	$675	$580	$529	$425	*$382*	*$270*
	4	$365	$191	$454	$387	*$356*	*$283*	*$258*	**$190**
	2	$341	$170	*$232*	*$204*	*$183*	**$150**	**$134**	**$95**
2 km 0.1 h in-vehicle	10	$329	$159	$826	$838	$582	$581	$337	*$323*
	8	$327	$157	$663	$671	$467	$464	*$272*	*$258*
	6	$324	$155	$500	$503	$353	$348	*$206*	*$204*
	4	$322	$153	$336	$335	*$239*	*$245*	**$141**	**$136**
	2	$319	$151	*$173*	*$177*	**$124**	**$122**	**$75**	**$68**

Italic cells indicate that carsharing is less expensive than owning a carsharing-equivalent vehicle and **bold** cells indicate that carsharing is less expensive than owning a low-cost vehicle

Observed travel patterns and carsharing cost savings

Monthly cost comparisons for carsharing and vehicles ownership

The previous sections provide an assessment of the types of situations in which carsharing can save people money. This section moves beyond hypothetical situations and seeks to assess the favorability of carsharing based on the way that people actually use their cars. The reported 2-day usage (i.e., tour frequency, distance, duration, and time of day) of each of the 28,000 vehicles owned by a BATS household are extrapolated to an estimate of monthly usage. Using the previously described cost assumptions, the monthly usage patterns are then translated to a monthly cost estimates for vehicle ownership and carsharing. This allows for an estimation of the percentage[17] of Bay Area vehicles with a usage pattern that carsharing can handle in a cost-effective manner.

Making estimates about monthly travel costs from a 2 day travel diary has some problems that should be noted. The travel pattern observed over a limited survey period may not provide a good representation of what is typical for a given vehicle or household. However, to the degree that such inaccuracies are random, they should balance out in a large sample such as the BATS. In other words, those who drive more than usual during the survey period will offset those that drive less than usual.

One potentially biasing aspect of extrapolating from a 2-day survey is that every day of the week cannot be represented. Different days of the week, particularly weekdays versus weekends, have a systematically different set of activities and travel patterns. This presents difficulties because roughly 75% of the BATS households were surveyed over two weekdays.[18] Table 4 presents the usage rates for BATS vehicles by day of week. The table demonstrates that, on average, Bay Area vehicles make fewer and shorter tours on Saturdays and Sundays than on weekdays. To account for this, the extrapolation process was weighted differently based on the days of week on which travel was recorded, with the weighting set to maintain the ratios of weekday to weekend travel demonstrated in Table 4.[19]

How much of the population can financially benefit from carsharing?

For each of the previously described scenarios for pod locations and vehicle ownership, Table 5 presents the estimated percentage of BATS vehicles for which carsharing could act as a cost effective replacement, along with the percentage of BATS households that own at least one of these vehicles. Additionally, the table presents a separate calculation for those vehicles/households that can achieve a savings of at least $100 per month through carsharing. This serves to identify those that might garner the kind of cost savings that can offset some of the previously described inconveniences associated with carsharing. To get

[17] All of the subsequently cited percentages are calculated after applying the household expansion weights developed for the BATS by MTC.

[18] The other 25% were surveyed over a Friday/Saturday or Sunday/Monday. There were no BATS households that were surveyed over a Saturday/Sunday.

[19] For example, the average number of combined weekday tours is 5.40, the average number of combined weekend tours is 1.79 and the average for Monday/Tuesday (combined) is 2.15. Therefore, for a vehicle surveyed over a Monday/Tuesday period, the total weekday tours per week are estimated by multiplying the number of surveyed tours by 2.51 (5.40/2.15). Weekend tours are estimated by multiplying by 0.83 (1.79/2.15). Such calculations were repeated for all unique 2 day survey periods and for all relevant aspects of vehicle usage (i.e., tour frequency, miles traveled, and hours that the vehicle is away from home).

Table 4 Average BATS vehicle usage pattern by day of week

	Tours per vehicle	Kilometers per vehicle	Hours (in-vehicle + dwell) per vehicle
Monday	1.07	28.74	6.23
Tuesday	1.08	28.69	6.39
Wednesday	1.08	28.12	6.37
Thursday	1.08	29.34	6.45
Friday	1.10	29.45	6.28
Saturday	0.94	21.59	4.01
Sunday	0.85	20.52	3.41

Table 5 Percentage of vehicles/households for which carsharing has a lower cost than vehicle ownership

Pod location assumption	Vehicle ownership assumption	% of vehicles where carsharing cost is		% of households owning at least 1 vehicle where carsharing cost is	
		Less than ownership cost (%)	Less than ownership cost by at least \$100 per month (%)	Less than ownership cost (%)	Less than ownership cost by at least \$100 per month (%)
Current locations (scenario 1)	Low cost (used subcompact)	3.7	0.9	5.4	1.1
	Carsharing-equivalent (new compact)	6.5	4.9	9.3	7.1
Expanded locations (scenario 2)	Low cost (used subcompact)	9.0	1.2	13.0	1.5
	Carsharing-equivalent (new compact)	15.6	12.5	21.5	17.6
Ubiquitous (scenario 3)	Low cost (used subcompact)	23.5	3.3	31.2	4.6
	Carsharing-equivalent (new compact)	29.9	26.2	37.5	34.0

a feel for how the presented percentages would translate into raw totals, the reader can refer to the following regional counts for vehicles and households. According to the 2000 US census, the nine county Bay Area region (which is the geographic sample frame for the BATS) had approximately 4.5 million vehicles and 2.5 million households.

Assuming the current pod locations, carsharing would prove financially favorable for up to 7% of vehicles and 9% of households. However, to the degree that households are willing to tolerate owning and driving a used vehicle, these percentages will be cut nearly in half (to 4% of vehicles and 5% of households). While these percentages obviously represent only a small minority, they translate to more than 100,000 Bay Area vehicles and households that could currently benefit from carsharing. If carsharing pods continue to expand into suitable locations throughout the region (as previously defined), these percentages would more than double (up to 16% of vehicles and 22% of households).

If carsharing became ubiquitous, it would provide an economically viable option for roughly a quarter of vehicles and a third of households. While pods will likely never become ubiquitous in this manner, these percentages serve to illustrate that a large number of vehicles (roughly 1 million) have usage patterns suited to carsharing.

In examining the situations where carsharing might provide significant savings (i.e., more than $100 per month), an interesting pattern emerges. When assuming a carsharing equivalent vehicle for ownership costs, the number of vehicles that would receive this higher level of savings is only moderately less than those receiving any level of savings. However, when assuming a lower cost scenario for vehicle ownership, carsharing can rarely provide large cost savings. Even with ubiquitous pod locations, only 3% of vehicles meet the higher threshold.[20] The magnitude of the cost savings obtainable through carsharing depends heavily on whether a household would consider purchasing an older/used vehicle. Owning this type of vehicle can cost as little as $150 per month (see Tables 2 or 3), which makes it very difficult for carsharing to provide more than $100 per month in savings.

Non-monetary considerations

As a previous section has made clear, the decision to adopt carsharing will depend on more than just monetary savings. Attitudes and personal travel preferences will distort raw economic incentives. While the BATS does not provide attitudinal information about respondents, it does include other characteristics[21] about households and vehicles that at least hint at a theoretical disposition toward the adoption of carsharing. Some criteria were developed (apart from usage rates and pod proximity) that indicate a vehicle's predisposition to being replaced by a carsharing membership. The criteria include:

- *The vehicle belongs to a household that owns no more than one vehicle per driver*. A household that keeps more vehicles than it could possibly use at any given time demonstrates a lack of incentive to minimize vehicle costs.[22] If a household does not try to minimize vehicle costs, it may not have an interest in carsharing. Roughly 83% of BATS households have one or less vehicles per driver and these households own 70% of all BATS vehicles.
- *The vehicle belongs to a household with more than one car*. Some may view vehicle ownership as a safety net for emergencies or other needs that occur on short notice. Households with multiple vehicles could trade one in for a carsharing membership while keeping their other car for any immediate needs. About 58% of BATS households have more than one car and these households own 82% of BATS vehicles.

[20] For the most part, the only vehicles that can save more than $100 per month in this scenario are those that belong to households living in zones with high residential parking costs.

[21] In addition to travel diary information, the BATS includes a relatively standard set of demographic information. For each vehicle, the following information is provided: make, model, year of manufacture, year of first possession, and odometer reading at beginning and end of survey period. For households, the following information is provided: residential location, the number of individuals, number of workers, number of drivers, number of vehicles, owners or renters, income, and age, gender, and ethnicity of the householder. For each individual in the household, the following information is provided: age, gender, ethnicity, relation to householder, whether and how frequently he/she works, place of work, industry and occupation of work, whether he/she can drive.

[22] Even if a household does not have more cars than drivers, careful scheduling and carpooling may make some of its vehicles superfluous. However, it seems highly unlikely that a household that would go to such trouble would lack economic incentive to reduce vehicle costs.

- *The vehicle belongs to a household with no children under 6 years old.* California requires children under this age to use a car seat, which might prove difficult to transport to and from the carsharing pod. Further, independent of the car seat issue, it may generally prove difficult to transport children to and from the pod. Roughly 82% of BATS households have no children under six and these households own 78% of BATS vehicles.
- *The vehicle was manufactured after 1970.* Older vehicles generally serve more as collectors' items than a means of transport. Thus, even though these vehicles will frequently have low usage rates, carsharing cannot act as a viable substitute for the utility that these classic cars provide to their owners. Nearly 98% of BATS vehicles were built after 1970.
- *The vehicle is not a light truck (e.g., pickup truck, van, or SUV).* Those who pay the premium associated with a larger vehicle likely gain some utility from them that the smaller carsharing vehicles cannot provide. Some carsharing organizations (including City CarShare and Zipcar) include light trucks in their fleet but in limited number and only at select locations. Consequently, even if they have usage patterns suitable to carsharing, owners of light trucks seem unlikely to switch to carsharing. Roughly 67% of BATS vehicles are not light trucks.

These criteria should not be viewed as comprehensive list of non-monetary factors that influence carsharing adoption. They simply represent some common sense assessments based on the available information. These criteria will vary in how much they actually influence the adoption of carsharing but, without information about actual adoption rates, it is difficult to predict the relative importance of each criterion. For the purposes of this analysis, vehicles that meet all five criteria are designated as demographically "predisposed" to carsharing. Approximately 26% of BATS vehicles fall into this "predisposed" category.

Table 6 presents a series of percentages similar to Table 5 except now the numerator in the percentage calculations excludes any vehicle that is not "predisposed". In other words, Table 6 estimates the percentage of BATS vehicles (and households) that both meet these demographic criteria *and* have usage patterns that make carsharing economically favorable. As one might expect, the percentages in Table 6 are much smaller than those in Table 5. Even under the assumption of ubiquitous pod locations, only 6% of vehicles (and 9% of households) prove both demographically and economical suited to carsharing. This serves to emphasize that many households with economic incentives to adopt carsharing will have other issues that may prevent them from taking advantage of the potential cost savings.

What kind of household has a driving pattern conducive to carsharing?

As previously mentioned, some of the literature about carsharing seeks to identify distinguishing characteristics of households that adopt carsharing. Along these lines, this section will examine the characteristics of BATS households that drive in a way that is conducive to carsharing. Table 7 compares the characteristics of households that do and do not have a vehicle usage pattern that is economically favorable to carsharing.[23]

[23] Since vehicle usage patterns are the key element in this exercise, ubiquitous access to a pod is assumed when making the cost comparison. Otherwise, pod access costs will obscure the influence of usage patterns.

Table 6 Percentage of vehicles/households that are demographically predisposed to carsharing and for which carsharing has a lower cost than vehicle ownership

Pod location assumption	Vehicle ownership assumption	% of vehicles that are "predisposed" and where carsharing cost is		% of households owning at least 1 vehicle that is "predisposed" and where carsharing cost is	
		Less than ownership cost (%)	Less than ownership cost by at least $100 per month (%)	Less than ownership cost (%)	Less than ownership cost by at least $100 per month (%)
Current locations (scenario 1)	Low cost (used subcompact)	1.2	0.3	1.7	0.4
	Carsharing-equivalent (new compact)	1.8	1.4	2.5	2.1
Expanded locations (scenario 2)	Low cost (used subcompact)	2.0	0.3	3.1	0.4
	Carsharing-equivalent (new compact)	3.2	2.6	4.8	4.0
Ubiquitous (scenario 3)	Low cost (used subcompact)	4.7	0.8	7.1	1.2
	Carsharing-equivalent (new compact)	6.4	5.5	9.0	8.0

The table demonstrates that for most characteristics (at least those available from the BATS), households that can monetarily benefit from carsharing do not vastly differ for those that cannot. Nonetheless, there are a few differences that may prove useful in identifying untapped population segments for carsharing expansion. Carsharing cost savings appear to accrue to larger households with more vehicles and more drivers. This likely stems from the fact that larger households present greater opportunities for carpooling with other members of one's household. Therefore, it becomes less likely that every driver in a household needs a vehicle at the same moment and the amount of usage per vehicle generally decreases as the number of vehicles and drivers per household increases. This means that non-traditional households with multiple adults or families with driving age children may provide a key constituency for carsharing firms. This represents a potential growth market for carsharing as the early adopters generally come from small households (TCRP 2005).

Another pattern that emerges from Table 7 is that those households that would benefit from carsharing generally live in higher density locations, which largely coincides with the pattern found among early carsharing adopters. At the same time, they also have a higher rate of home ownership and more frequently live in detached homes. This indicates that streetcar suburbs with relatively dense but detached housing may provide fertile ground for the future expansion of carsharing.

Conclusion

It has been illustrated that carsharing can theoretically provide an economically efficient travel option for those with limited vehicle needs. In particular, carsharing works well for

Table 7 Household characteristics by disposition towards carsharing [table figures assume ubiquitous access to carsharing pods (scenario 3) and low cost vehicle ownership (used subcompact)]

	Households owning a vehicle that is "predisposed" and where carsharing cost is less than vehicle ownership cost	Households owning a vehicle that is not "predisposed" but where carsharing cost is less than vehicle ownership cost	Households not owing a vehicle where carsharing cost is less than vehicle ownership cost
Mean household size	3.0	2.9	2.7
Mean # of workers	1.7	1.5	1.5
Mean # of drivers	2.4	1.9	1.8
Mean # of vehicles	2.3	2.6	1.7
Mean people per hectare	50.6	38.6	37.6
Mean household income	$88,782	$79,958	$76,136
Mean householder age	47.0	45.8	44.3
% owning their residence	65.4%	65.4%	58.0%
% living in detached home	68.4%	72.6%	60.6%
% with White householder	60.7%	60.1%	62.4%
% with Hispanic householder	11.2%	15.6%	12.1%
% with Black householder	5.7%	7.4%	5.8%
% with Asian householder	19.3%	13.7%	16.9%

households that do not need a vehicle for full time commuting. The Bay Area provides fertile ground in this regard with its relatively low shares of auto commuting. It is estimated that a third of Bay Area households (more than 800,000) have at least one vehicle with a usage pattern that is economical conducive to carsharing. This combines with the quarter million Bay Area households that do not own a vehicle (as of the 2000 census) to make an impressive base of potential carsharing adopters. To put this in context, actual number of carsharing members across the entire US as of 2009 was less than 300,000. How well the cost saving potential of carsharing translates to more auto-oriented regions goes beyond the scope of this analysis but this certainly requires more attention.

The ability to provide cost savings based on existing vehicle usage patterns represents an important and probably a necessary condition for carsharing to play a more significant role in the broader transport system and provide some of the public benefits previously discussed. However, many other factors also require consideration. Lifestyle preferences, demographic characteristics, specialized vehicle needs, and neighborhood attributes will also play a significant role in determining whether a household adopts carsharing. This analysis has made a rudimentary effort to define a set of non-economic criteria that would act as a barrier to carsharing. It turns out that many of the households that can economically benefit from carsharing have other characteristics that could deter carsharing. However, it is difficult to determine to what degree these criteria actually prevent the adoption of carsharing. Further, there are many non-economic characteristics that might encourage the adoption of carsharing (i.e., concern for the environment) that cannot be quantified with the data provided by the BATS.

Research that directly models carsharing adoption is clearly needed. Optimally, this would involve a longitudinal analysis that measures travel behavior (including the adoption of carsharing), vehicle ownership, and key attitudinal attributes before and after the introduction of a carsharing service to an area. Such an analysis could take observed vehicle usage patterns and empirically define how these patterns interact with other household characteristics in the choice to adopt carsharing. At present, the data necessary for such an analysis are not available and would be expensive and time consuming to produce. However, as carsharing becomes more popular, regularly conducted travels surveys may begin to include information about carsharing that would better allow for quantifying its adoption.

In sum, many Bay Area households own vehicles with usage patterns that carsharing could accommodate at a lower cost than vehicle ownership. This bodes well for carsharing to play a larger role in the broader transport system. However, it is unclear the degree to which the potential cost savings of carsharing will actually lead to adoption and determining this will require further research.

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Author Biography

Michael Duncan is an Assistant Professor in the Department of Geography and Earth Sciences at the University of North Carolina Charlotte. He holds a doctoral degree in city and regional planning for the University of California, Berkeley. He currently teaches and conducts research in the area of transportation planning and has a broad research interest in sustainable transportation systems.