Assessing the Potential Extent of Carsharing

A New Method and Its Implications

Thomas D. Schuster, John Byrne, James Corbett, and Yda Schreuder

Members of carsharing organizations reduce both the number of vehicles owned and vehicle miles traveled (VMT). Given these benefits at the individual level, carsharing may interest policy makers as another tool to address the negative environmental, economic, and social consequences of automobile dependence. However, the aggregate effects of carsharing must be estimated before sound policy decisions can be made. This paper describes a Monte Carlo simulation of the economic decision to own or share a vehicle on the basis of major cost components and past vehicle use. The simulation estimates the percentage of vehicles that would be cheaper to share than own. In Baltimore, Maryland, this result ranged from 4.2% under a traditional neighborhood carsharing model to 14.8% in a commuter-based carsharing model. Sensitivity analyses identified travel time and VMT as the most important economic factors, which likely incorporate other factors such as transit access and environmental attitudes. Because travel behavior, not ownership cost, drives the economic carsharing decision, the model hypothesizes that there will be increasing marginal societal benefits from policies that promote carsharing. The model can be applied to any geographic area and can be used to assess carsharing impacts of various policies that change the economics of owning or driving an auto. These results indicate that carsharing can become prevalent enough to be considered an important policy tool.

The U.S. transportation system is becoming increasingly auto centered. From 1950 to 2000, the population grew 81%, while the number of vehicles grew 404% and vehicle miles of travel (VMT) grew 500% (*1*). Since 1980, registered vehicles have outnumbered licensed drivers, and the ratio of autos to drivers is now 1.12:1 (*1*). This increasing automobility is imposing greater environmental, economic, and social external costs, including air pollution (*2*), climate change (*3*), loss of open space (*4*), traffic congestion (*5, 6*), fossil fuel depletion (*7*), and the reduced mobility of those who cannot drive (*8*).

Carsharing mitigates all of these issues. By transforming the fixed cost of ownership into a variable cost based on mileage and travel time, carsharing provides greater incentive for members to be selective about driving. Studies in the United States and Europe have demonstrated that members of carsharing organizations (CSOs) may reduce their VMT by up to 50% after joining (*9–11*). A large percentage of CSO members report giving up or forgoing purchase of an automobile as a direct result of carsharing (*9, 12*), and members often take transit more after joining (*13, 14*). Carsharing can directly reduce emissions, fuel consumption, and congestion. It can also play an important complementary role in encouraging transit use and more compact development of land (by reducing parking demand). Such integrated strategies are seen as essential to successful transportation planning (*6, 15*).

Before policy makers consider ways to promote carsharing, however, it is important to gauge the size of the carsharing market. In Austria, it was estimated that 9% of the drivers of several cities would be candidates for carsharing based on cost savings, the prestige value of auto ownership, and the value of convenience (*10*). However, the estimation methods were unclear, and the results in Austrian cities do not necessarily translate to U.S. cities. Market feasibility studies in the United States tend to rely on focus groups and surveys of individual attitudes (*16*), are expensive, and results may be region specific.

This paper presents a model that describes the economic choice of owning or sharing a vehicle based on its attributes and usage. The model can be used to estimate how prevalent carsharing might become in different metropolitan areas. Exactly how prevalent it must become to play an important role in moving toward transportation sustainability is unknown. However, estimating its potential effect on auto ownership in an area is the first step toward translating the individual member responses cited above into aggregate effects on the system.

CONCEPTUAL MODEL

The conceptual model that forms the basis of this simulation is shown in Figure 1. Previous studies indicate that the individual assesses factors across the four major categories (cost, access convenience, satisfaction with ownership, and environmental attitudes) to decide whether to own or share a vehicle (*16, 17*). This model depicts cost as central to the decision, although it may not be the most important factor. There are interrelationships among the attitudinal factors (e.g., if environment is a high priority, convenience may be less important), and all three attitudinal factors affect the cost switch point. This is the amount one must anticipate saving by sharing before joining a CSO. If the switch point is $0, cost is the only important factor, or the other variables cancel out. A high switch point means that attitudinal variables favor ownership.

All the factors in Figure 1 would have to be addressed to determine the true potential market share of carsharing. However, there are major obstacles to this. Because many of the factors involved are qualitative, determining the exact relationships and quantifying them is dif-

T. D. Schuster, Las Cruces Metropolitan Planning Organization, P.O. Box 20000, Las Cruces, NM 88004. J. Byrne, Center for Energy and Environmental Policy, Graham Hall; J. Corbett, College of Marine Studies, Robinson Hall; and Y. Schreuder, Center for Energy and Environmental Policy and Department of Geography, Pearson Hall, University of Delaware, Newark, DE 19716.

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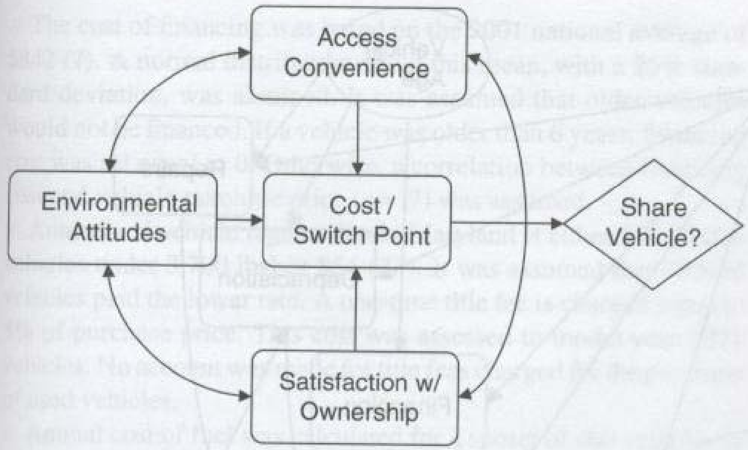

FIGURE 1 Conceptual model of carsharing versus ownership decision. Attitudinal factors affect the cost switch point, which is the monetary value on which the decision is based.

ficult. This might require a pilot project, in which the attitudes of joiners are compared to a larger group (*16, 17*), and would require more resources than are available for this study. For this reason, this analysis focuses on the cost of carsharing compared to auto ownership, that is, it assumes a cost switchover point of $0. This yields the percentage of vehicles for which carsharing makes economic sense. The model does allow for the incorporation of attitudinal factors in the decision, even though they are not addressed in this study. For example, if there is evidence that a certain population values access convenience at an average of $500, this can be set as the switch point (see the section later in this paper describing an economic decision model). In this case, vehicles would be shared only if the savings were greater than $500.

The cost of sharing likely incorporates other factors implicitly, because the cost is based, in part, on revealed travel behavior (VMT and travel time). Revealed behavior may capture important variables such as attitudes and access to nonauto modes. For example, environmentalists may take transit as much as possible and drive less than average (and would therefore have lower sharing costs), while those who value convenience highly may always drive.

One important advantage of this analysis is that it focuses on the vehicle, which may be a more relevant unit of analysis than the individual. From 2001 to 2003, carsharing membership rose 376%, but the size of the carsharing fleet rose 147% (*18*). This may be partly due to more efficient allocation of vehicles by CSOs, but it may also reflect a growing number of people who use CSOs as mobility insurance (i.e., as a backup vehicle if their own is unavailable). These people rarely use shared cars and do not change their everyday travel behavior by joining. By focusing on the vehicle rather than the person, this analysis targets those for whom carsharing could substitute for (rather than supplement) ownership.

By focusing on cost, this approach also provides a more realistic picture of the economics of carsharing than is currently available. It is common to find references in the literature to a "switchover point" in terms of distance driven (*10, 11, 19, 20*). Those below the given mileage level are said to benefit financially from carsharing, and are thus potential candidates. This approach does not account for variation in the cost of vehicle ownership, nor does it account for the potentially large contribution of travel time to carsharing cost (a cost that may be somewhat independent of mileage, due to congestion and time spent at destination). These complicating factors make it impossible to define a single level of travel below which carsharing makes sense for a population. This analysis avoids this problem by assessing each vehicle individually.

ECONOMIC DECISION MODEL DESCRIPTION

A Monte Carlo simulation was used for this analysis. This simulation calculates the expected value of a decision when there is a high degree of uncertainty surrounding the input variables (*21*). A distribution is estimated for each variable, and algorithms are developed to relate the variables to a forecast outcome. The simulation is then run many times, with each iteration representing a possible outcome. In each iteration, a value is chosen at random from the defined distribution for each variable. Correlations between variables are defined if appropriate. Crystal Ball v2000.2, an add-in for Microsoft Excel, was used to run the simulation (*22*).

The decision being modeled is whether to own or share a given vehicle, based on vehicle use and associated costs in one year. Variables influenced by the decision and which contribute to the final cost are shown in Figure 2. The model compares vehicle ownership cost to the projected cost of using a shared vehicle for the same amount of travel:

$$\text{ownership cost} = \text{depreciation} + \text{financing} + \text{insurance} + \text{registration} + \text{repairs} + \text{fuel} \tag{1}$$

$$\text{sharing cost} = \text{membership fee} + \text{time cost} + \text{mileage cost} \tag{2}$$

Each iteration chooses the lowest cost option. Car ownership is represented by "0," and carsharing is represented by "1." The mean of all iterations is therefore the proportion of vehicles for which carsharing is less expensive. It is assumed that ownership of these vehicles would be relinquished if carsharing is available and the cost switch point is equal to $0. Iterations were run until the simulation achieved 95% confidence interval (i.e., the simulated mean did not vary by more than 5% as additional iterations are run).

Data on travel time and VMT, as well as certain vehicle characteristics, were available from the 2001 National Household Travel Survey (NHTS) (*23*). The Baltimore, Maryland, metropolitan statistical area (MSA) was chosen as the subject region because the sample size was large, as Baltimore was an "add-on" area for the NHTS.

Carsharing Inputs and Assumptions

Modeled carsharing rates are those offered by the Flexcar program in the nearby Washington, D.C., metropolitan area in March 2004 (*24*). The annual membership fee is $25, the hourly rate is $9, and the mileage fee is $0.35. On the basis of this rate structure, two variables emerge as important for determining the annual cost of carsharing: VMT and travel time. Both variables are available in the NHTS. VMT was estimated by the respondent for each household vehicle (5,100 total). Because the large data set did not fit a common statistical distribution, the raw data were used. In the Flexcar rate structure, each travel hour comes with 10 free miles. Therefore, charged miles are estimated as follows:

$$\text{charged miles} = \text{total miles} - \text{travel hours} \times 10 \tag{3}$$

The value for charged miles is then multiplied by the mileage fee to determine mileage cost.

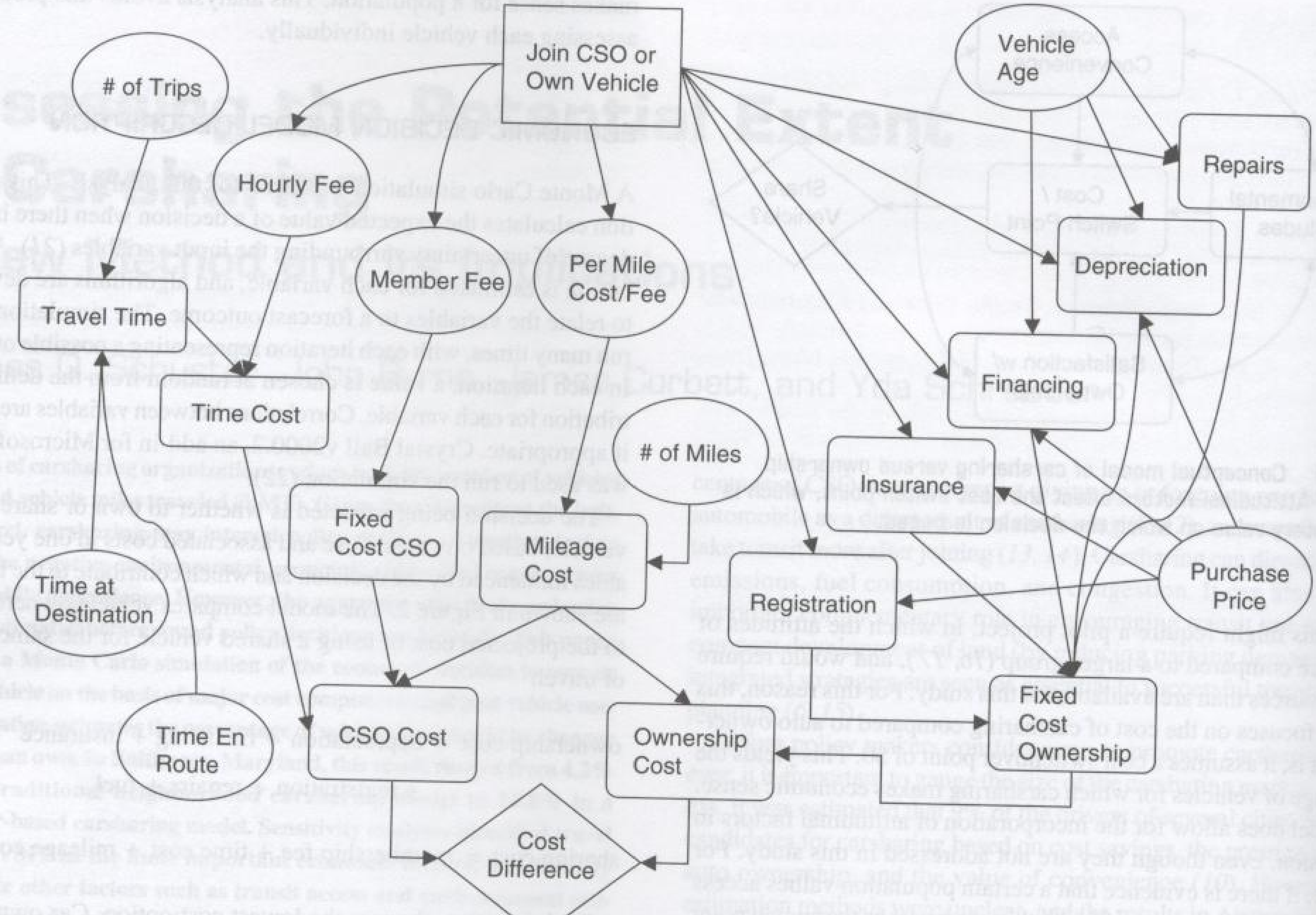

FIGURE 2 Influence diagram of the economic decision to own or share. This is an expansion of the center (cost) component of Figure 1. All nodes are explicitly considered in the simulation, and arrows represent relationships modeled either through equations or correlations.

Travel time is the sum of in-vehicle travel time and destination dwell time (for destinations other than home). The NHTS included a 1-day trip diary, with information on these variables, as well as trip distance, purpose, and vehicle used (24,000 trips taken in 4,515 vehicles). Daily travel time was multiplied by 365 to get annual travel time, assuming a representative travel day. Annual travel time was then multiplied by the hourly rate to estimate annual travel cost. The time spent in travel is weakly but significantly correlated with mileage ($r = .37$). The correlation is weak because many hours may be spent at the destination. Trip data includes day trips only, which are defined as those within a 50-mi radius of residence. Long-distance trips were not considered because use of a shared vehicle for overnight trips would be cost-prohibitive—it would be cheaper to rent a car or use a different transport mode (*9*).

Auto Ownership Inputs and Assumptions

Costs associated with auto ownership (Equation 1) are detailed below. Sample data were not available for the majority of these variables, so assumptions were made about distributions. Later sensitivity analyses tested the effects of these assumptions on model results.

The mean annual auto insurance premium per vehicle in Maryland in 2000 was \$828 (*25*). A lognormal distribution with a standard deviation of 25% was assumed. This results in a 5th and 95th percentile of \$536 and \$1,205, respectively, with a mode of about \$750. This distribution was chosen on the basis of the assumption that there are many relatively safe drivers who pay low premiums, and fewer high-risk drivers who pay much larger premiums.

Depreciation and financing are dependent primarily on vehicle purchase price and age. Model year data from the NHTS were used to generate a custom distribution for age. For purchase price, neither sample data nor a local mean were available, so the 2001 national mean price of new car, \$21,600 was used (*1*). A lognormal distribution, with a standard deviation of 25%, was assumed. As with insurance, it was assumed that vehicle purchase price is skewed to the right. New car prices in the area were found using Edmunds.com, and \$10,500 was found to be a functional minimum price, so values below that price were not allowed. Depreciation in 1 year was then calculated for each case based on the following formula:

$$\text{depreciation} = P/(1+R)^{n-1} - P/(1+R)^{n} \qquad (4)$$

where

P = purchase price,
R = depreciation rate, and
n = vehicle age.

It was assumed that depreciation rate varied uniformly between 15% and 20% (*26*) and was correlated to mileage ($r = .5$). By including depreciation instead of vehicle payments as a fixed cost, the model can account for new and used vehicles of any age.

The cost of financing was based on the 2001 national average of $842 (*1*). A normal distribution about this mean, with a 25% standard deviation, was assumed. It was assumed that older vehicles would not be financed. If a vehicle was older than 6 years, financing cost was set equal to 0. Otherwise, a correlation between financing cost and vehicle purchase price ($r = .7$) was assumed.

Annualized vehicle registration in Maryland is either $40.50 (for vehicles under 3,700 lbs) or $54 (*27*). It was assumed that 75% of vehicles paid the lower rate. A one-time title fee is charged equal to 5% of purchase price. This cost was assessed to model year 2001 vehicles. No account was made for title fees charged for the purchase of used vehicles.

Annual cost of fuel was calculated for a subset of 400 vehicles in the NHTS. The data fit an extreme value distribution reasonably well (Anderson–Darling = 0.66) (*22*), with a mode of $520, a mean of $770, and 5th and 95th percentiles of $84 and $1,694, respectively. Because of the smaller sample size compared to other NHTS variables and the better fit, this distribution was used rather than the raw data. The data indicated a strong, significant ($p < .05$) correlation between fuel cost and VMT ($r = .81$), and a weak but significant negative correlation between fuel cost and vehicle age ($r = -.19$). A weak correlation between travel time and fuel cost ($r = .3$) also was assumed.

To estimate the annual cost of repairs and maintenance, the True Cost of Ownership calculator at Edmunds.com was used. For each of five representative vehicle models, a 5-year estimate was obtained for maintenance and repairs for a new (2004) vehicle and for a used (2000, the oldest model year available) vehicle. Assuming no major engineering changes between model years, this allowed an estimate of the cost of repairs over 9 years for various popular models. The data fit a normal distribution reasonably well (Anderson–Darling = 0.35), with a mean of about $1,200 and a standard deviation of about $500 (41%). Because there were no annual maintenance and repair costs below $300, lower values were not allowed. The data showed a significant ($p < .05$) correlation between cost of maintenance and repairs and vehicle age ($r = .65$). A correlation was assumed between repairs and VMT ($r = .3$) and between repairs and depreciation rate ($r = .5$).

The cost of parking was excluded from this version of the model. Destination parking should not be included, since it will be the same for drivers of shared or owned vehicles (barring policy intervention). Data on residential parking in this study area were not sufficient to allow defensible assumptions about the cost distribution. Furthermore, since the Baltimore MSA includes six counties in addition to the city of Baltimore, the majority of subjects are likely suburban residents who pay no direct residential parking fee. However, the simulation structure allows incorporation of parking costs if data become available.

SIMULATION RESULTS

Base Case Run

In the base case, carsharing was chosen 1,474 out of 35,500 trials, or 4.15 ± 0.10% of the time. Therefore, carsharing is cheaper than ownership for just over 4% of vehicles in the Baltimore MSA. Figure 3 shows the frequency distribution of annual cost for both ownership and carsharing in the base case. Given base case assumptions, there is much less variation in ownership costs than in potential CSO costs. Travel behavior (which is the sole basis for carsharing costs when rates are held constant) is more important to the economic decision to own or share than are the fixed costs of vehicle ownership. Those who drive less are more likely to benefit, regardless of ownership costs.

Sensitivity Analyses

Crystal Ball measures each variable's contribution to the variance of the result. This type of sensitivity analysis is more accurate when there are no correlations among the variables (*22*). The simulation was rerun with correlations turned off; this did not significantly change the result (at the 95% confidence level). The sensitivity analysis indicates that travel time contributes 71.2% of the variance, VMT contributes 16.3%, and vehicle age contributes 10.0%. No other variable contributes more than 2% of the variance. This is encouraging, because these three variables are based on NHTS data rather than assumptions. Because of the large sample size, it can be assumed that these variables are accurately represented.

However, if the variation or magnitude of a particular variable is grossly underestimated, the sensitivity analysis will still understate its importance. Therefore, the simulation was run many more times, while changing one assumption each time. Few of these one-way sensitivity tests had a significant effect on the result. Removal of correlations, removal of title fee, use of March 2004 fuel prices (25% higher than in 2001), use of a normal insurance price distribution

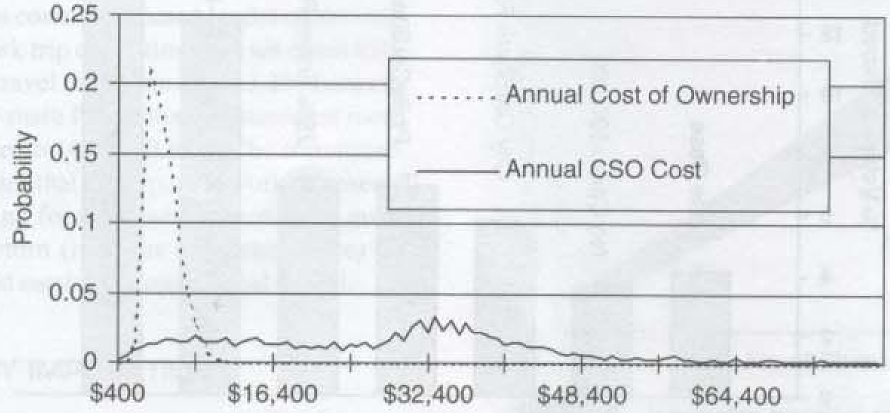

FIGURE 3 Frequency of total costs of ownership and carsharing under the base case assumptions. There is much greater variation in the cost of carsharing than in the cost of ownership.

with greater variation, and adjusting the depreciation rate up or down all yielded results that were within the 95% confidence interval of the base case. Two changes did affect the result. If maintenance costs were 25% lower (reflecting non–dealer- or owner-serviced vehicles) carsharing was less economically viable (mean = 3.73 ± 0.09%). If the distribution of purchase price were normal with a 40% standard deviation (rather than lognormal with a 25% SD), carsharing is more economically viable (mean = 4.39 ± 0.11%).

Despite the fact that model results are somewhat sensitive to several assumptions, there is no compelling evidence that the altered assumptions are more realistic than those used in the base case. The most important assumptions in the model are based on NHTS sample data. Therefore, the base case results seem fairly robust. Nevertheless, it is acknowledged that plausible changes to assumptions could lead to carsharing rates as low as 3.6% or as high as 4.5%.

Scenario Analyses

The base case estimates the percentage of vehicles that would be less expensive to share than own, given current auto travel patterns, a traditional neighborhood carsharing model, and the current Flexcar price structure in the nearby Washington, D.C., metropolitan area. It also assumes that owners of all vehicles are equally likely to prefer sharing. This subsection examines the effects of alternative underlying assumptions.

The results of the base case and several scenarios are compared in Figure 4. The scenarios demonstrate how this model can investigate the dynamics of the economic auto ownership decision. They reveal that economic viability of carsharing can be substantially increased by considering different rate structures, an alternative CSO operational model, or anticipating reduced travel after joining a CSO.

Expensive Vehicles and Prestige Value

Many attitudinal factors interact with economic factors in the carsharing decision. One factor that can be easily incorporated into the model is the prestige value of ownership (*10*). Luxury cars, expensive sports cars, and so forth often contribute to the owner's sense of identity, and the owner may not want to give up the car. Furthermore, those who buy more expensive vehicles are less likely to be receptive to a cost-saving opportunity such as carsharing.

It is possible, however, that the vehicles for which carsharing is cheaper may consist mainly of these more expensive vehicles. To test for this, a scenario was run similar to the base case, but which automatically selected "0" (ownership) if the vehicle purchase price was over \$30,000. The result was a carsharing proportion of 3.69 ± 0.09%, 11% lower than the base case ($p < .05$), but larger than might be expected, given that expensive vehicles represent roughly 8% of the total population according to the base case assumptions. Because travel behavior, not ownership cost, is the most important class of variables, this result is consistent with the base case results.

Different CSO Rate Structures

The base case uses the Flexcar rate structure available in the nearby Washington, D.C., metropolitan area. However, a variety of rate structures are in place in cities across the country. The simulation was run using rates from four different cities to assess their effect on possible carsharing savings. The rates used are as follows:

- Flexcar (Washington, D.C.): \$9/h, \$0.35/mi, 10 free miles per hour, \$25 annual fee;
- I-GO (Chicago, Illinois): \$6/h, \$0.50/mi;
- City CarShare (San Francisco, California): \$4/h, \$0.44/mi, \$10 monthly fee; and
- PhillyCarShare (Philadelphia, Pennsylvania): \$3.90/h, \$0.39/mi, \$10 monthly fee.

The I-GO hourly rate is 33% lower than the Flexcar rate, but the higher mileage rate for I-GO more than negates the hourly savings when applied to the Baltimore population, and it only resulted in a 3.57 ± 0.09% share of vehicles. The PhillyCarShare rate, with its substantially lower hourly fee and only moderately higher mileage fee, captures 67% more (6.93 ± 0.17%) of the Baltimore market than the Flexcar rate.

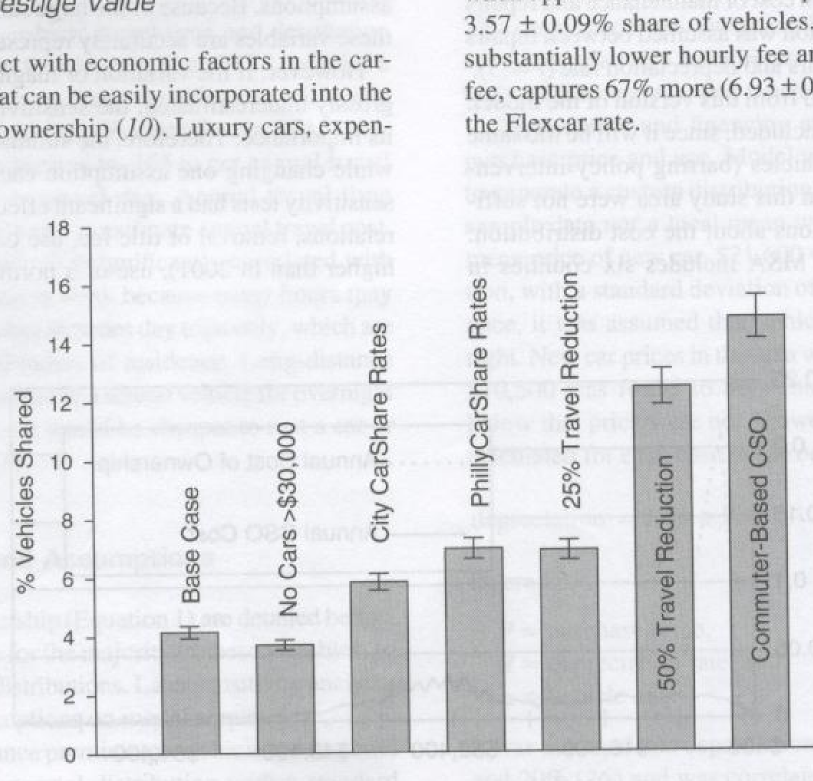

FIGURE 4 Comparison of CSO scenarios to the base case. All scenarios shown are statistically different from all others at the 95% confidence level, except the "PhillyCarShare Rates" and "25% Travel Reduction" scenarios.

This model clearly illustrates that if the hourly fee is reduced substantially, carsharing becomes more affordable than in the base case even though the mileage rate increases. Even small decreases in rates can result in comparatively larger increases in potential membership. The PhillyCarShare hourly and mileage rate are only 2.5% and 11.4% lower, respectively, than the City CarShare rates, but the Philadelphia rate structure captures nearly 20% more of the market (Figure 4).

Anticipated Travel Reduction

A number of studies have indicated that CSO members reduce their VMT after joining (*9, 11, 14*). This may be accomplished by switching to other modes (such as transit, walking, or biking), by carpooling, by trip-chaining, or by forgoing less important trips entirely. If people anticipate that carsharing will change their travel behavior in this way, it may affect the economic decision to own or share. Two scenarios were run to reflect this—a conservative 25% reduction in auto travel, and a 50% reduction in auto travel consistent with U.S. and European experience (*9, 11*). These reductions do not target specific types of trips, and they assume a 1:1 relationship between VMT and travel time reduction. These two variables, as well as fuel cost, were reduced by the chosen percentage.

A 25% reduction in travel resulted in carsharing being economical for $6.87 \pm 0.17\%$ of vehicles, a 65% increase compared to the base case. A 50% reduction in travel resulted in carsharing being cheaper for $12.42 \pm 0.31\%$ of vehicles, 200% more than the base case. Reducing the expected amount of auto travel has a large impact on the proportion of vehicles for which sharing is economical.

Commuter-Based Operational Model

To this point, a traditional neighborhood carsharing model has been considered—one that involves picking up a vehicle near the trip origin, returning the vehicle to the same place, and paying for it the entire time it is gone. Such a carsharing model would be very expensive for people who commute by auto to work. An internodal carsharing model allows a vehicle to be dropped off at a location other than its point of origin (*28*). This could allow a commuter to take a shared vehicle to work, leave it in the employer parking lot during the day (where it would be available for others to use), and take a (possibly different) shared vehicle home at night. Under this system, the commuter would only pay for time spent in the car. Different variations of this type of internodal system have been attempted in Asia and Europe (*28*), and a pilot program in the United States (CarLink) has been studied extensively (*17, 29*).

To simulate the effects of this commuter-based model on the economic decision to carshare, work trip dwell time was set equal to 0. This lowered the mean annual travel time from about 3,200 hours to about 1,700 hours. The market share for carsharing increased more than 3.5-fold from the base case, to $14.77 \pm 0.37\%$. The commuter-based CSO scenario demonstrates that time spent at work represents a significant barrier to carsharing for those who commute by auto. Clearly, there is a potential return (in terms of market share) on investing in a more complicated carsharing operational model.

DISCUSSION AND POLICY IMPLICATIONS

Under base case assumptions, 4.15% of Baltimore MSA vehicles are candidates for carsharing on economic grounds. This is one measure of the potential mode share for carsharing. While 4.15% may seem small, it is comparable to the area transit mode share, which is 5.7% (according to the NHTS). These results indicate that carsharing could be nearly as prevalent as transit currently is in the Baltimore area.

A suite of one-way sensitivity analyses on various costs of ownership showed that the percentage of vehicles for which carsharing is cheaper is consistently between 3.6% and 4.5%. They also demonstrate that the most important factors in the economic decision were both travel behavior variables: travel time (including dwell time) and VMT. These variables are among those included in the NHTS, so the model results are most reliant on empirical data rather than assumptions. Travel time was by far the most important variable, due to the relatively high hourly fee in the base case. The dominance of this variable decreased as the hourly rate decreased, but it remained the most important variable in all scenarios.

Vehicle characteristics such as age, depreciation rate, repair costs, and fuel costs play a less important role. Overall, the variation in the cost of vehicle ownership is quite small compared to the variation in cost of carsharing (Figure 3). Clearly, a large segment of the population will not benefit economically from carsharing unless fundamental changes occur within the transportation system to discourage auto ownership.

This simulation shows that people who would benefit economically from carsharing are predominantly those who use cars relatively infrequently, rather than those who have a high cost of auto ownership. It therefore suggests that there is potential for increasing marginal returns, in terms of reduced externalities, as the percentage of shared vehicles increases (Figure 5). This assumes that all members reduce auto travel by a constant percentage after joining a CSO. Those who drive least join first, and their absolute travel reduction due to membership is correspondingly small. If a policy intervention or economies of scale allow a CSO to offer lower rates, membership should increase. New members will be those who had driven more, who only benefit financially from sharing with lower rates. Thus their travel reduction, in absolute terms, should be greater than those who had previously joined. Each successive increase in membership will translate into greater marginal societal benefits from reduced travel. One implication of this hypothesis is that efforts to support carsharing may be warranted beyond the initial startup phase.

Figure 5 illustrates the potential for increasing marginal returns as each successive vehicle is shared. This effect may be compounded by the scenario results that showed a comparatively high percentage

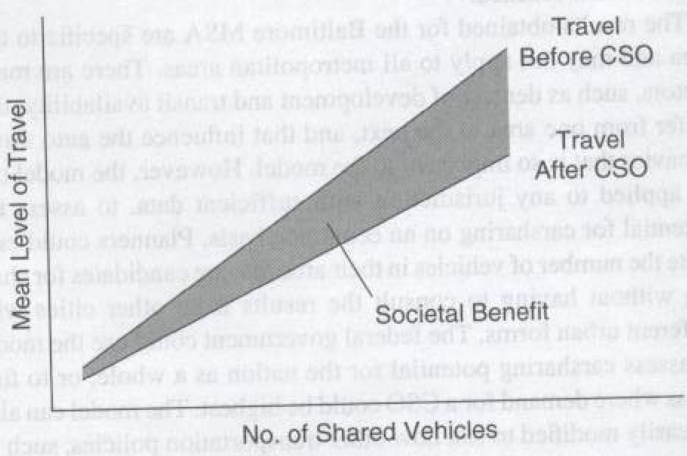

FIGURE 5 Increasing marginal returns hypothesis. Marginal societal benefits of carsharing (in terms of reduced auto travel) should increase as carsharing becomes more prevalent.

increase in economic viability of carsharing for a relatively minor decrease in fees charged. This highlights a potential role of the public sector in encouraging carsharing. If the public sector can modestly reduce certain costs for a CSO, by providing parking or subsidizing insurance, the increase in membership (and therefore in societal benefits) can rise considerably.

However, if policies directly subsidize the cost of carsharing too much, they risk reducing the incentive for CSO members to travel less. The increasing marginal returns hypothesis (Figure 5) is based on the assumption that the average percentage of travel reduction is constant through time for all CSO members. The main travel reduction mechanism of carsharing is the variable cost of auto travel—the lower the variable cost, the less incentive for reduction. There are several ways to avoid this phenomenon. The first is to raise the cost of ownership, rather than lower the cost of carsharing. For example, registration fees could be raised, or free parking could be systematically eliminated for all but shared vehicles. The model suggests that the former would be relatively ineffective because registration fees are such a small factor in the decision. The model could be easily modified to test the latter option if data on current and proposed parking cost were available.

Another option could be to subsidize only the hourly fee, but maintain or increase the mileage fee. The overall cost of sharing would be reduced, but the incentive to limit mileage would remain. VMT is the important variable in terms of environmental and social externalities, which carsharing-related policy seeks to minimize. Rates that are more heavily based on mileage can therefore produce a greater societal benefit than those based on time, and this model has demonstrated that such rates can have the added benefit of increasing the economic viability of carsharing.

The commuter-based CSO is another way of shifting fees more toward mileage, and it greatly increases the potential for sharing. If ownership of 12.4% of vehicles was given up (as in the 50% travel reduction scenario), and it is assumed that one shared vehicle can replace six private vehicles, the total number of vehicles could be reduced by 10.3%. The resulting reduction in the demand for parking spaces would likely be enough to influence parking requirements for new development, and to allow for consolidation or removal of some current parking lots. This may facilitate compact development of a sort that is more pedestrian friendly and allows better functioning transit service. Even those who do not participate in carsharing can benefit from these changes. In short, carsharing may have a synergistic effect with other planning policies if this level of penetration is reached.

The results obtained for the Baltimore MSA are specific to this area and may not apply to all metropolitan areas. There are many factors, such as density of development and transit availability, that differ from one area to the next, and that influence the auto travel behavior that is so important to the model. However, the model can be applied to any jurisdiction with sufficient data, to assess the potential for carsharing on an economic basis. Planners could estimate the number of vehicles in their area that are candidates for sharing without having to consult the results from other cities with different urban forms. The federal government could use the model to assess carsharing potential for the nation as a whole, or to find areas where demand for a CSO could be highest. The model can also be easily modified to test how other transportation policies, such as gas taxes or parking fees might affect the economic attractiveness of carsharing.

There are several other ways to improve the effectiveness of this approach. One would be to incorporate the cost of mode switching into the model. If transit use increases as a result of carsharing, the cost of carsharing and transit should be combined and compared to the cost of ownership. This would surely lower the percentage of vehicles for which carsharing is cheaper, but the magnitude of change is an important question. A second would be to include residential parking cost in the analysis, which would make carsharing more financially attractive. A third would be to devise a way to explicitly account for some of the attitudinal factors that influence the cost switch point, which is central to the conceptual model (Figure 1).

CONCLUSION

Preliminary evidence suggests that carsharing may prove a useful part of an integrated strategy to reduce the negative effects of auto dependence. The promise of carsharing is that auto ownership becomes a choice and not a necessity, which makes other modes more viable. The crucial factor about carsharing and sustainability is the size of the market potential. A model was constructed of the economic decision to own or share a vehicle in an attempt to address this question. While there are surely noneconomic factors that influence the decision, cost is a good starting point because it is based in part on revealed auto travel behavior, which incorporates some of the attitudinal factors, as well as access to nonauto modes. This approach is also vehicle focused, which is likely more relevant than a person-centered model.

The model results indicate that from an economic standpoint, carsharing can be an important mode, with participation rates in the Baltimore MSA that are on a similar level to transit ridership. These rates may increase substantially if auto owners are willing to change their travel behavior, if policy interventions lower the cost of shared-use vehicles, or if carsharing is integrated into the workplace. If this level of vehicle sharing is achieved, there may be a noticeable effect on urban form through reduction in necessary parking spaces. If more compact development is enabled, the potential synergies between carsharing and other transportation strategies, such as transit- and pedestrian-friendly design, may begin to be realized. These benefits are in addition to the direct reduction of fossil fuel consumption and emissions that accompany travel reduction. Of course, the realization of these benefits depends on long-term participation in carsharing, whereas this study focuses on the initial choice to own or share. The choice is the first step, and this model indicates that this choice is of economic relevance to enough people that carsharing should be taken seriously by policy makers and planners as a tool to integrate mobility options.

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