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# An Analysis of the Costs of Running a Station Car Fleet

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# AN ANALYSIS OF THE COSTS OF RUNNING A STATION CAR FLEET

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## ABSTRACT

Station cars are electric vehicles available at transit stations which may be used for transportation between the transit station and home, work, and/or for errands. This transportation service would be provided by the local transit agency. This report discusses an economic model of the costs of running a station car fleet. While some of these costs are highly uncertain, this analysis is a first look at the required user fees for full cost recovery. The model considers the capital costs of the vehicles and the required infrastructure; the annual fixed vehicle costs for insurance, registration, etc.; the mileage-based costs; and the annual non-vehicle costs for administration, infrastructure maintenance, etc. The model also includes various factors such as the fleet size, the annual mileage, the number of transit stations that would have facilities for station cars, and the number of users. The model specifically examines the cost of using of electric vehicles; however, for comparison, the cost of using a fleet of gasoline-powered vehicles also is calculated. This report examines the sensitivity of the model to the various factors. A principal conclusion from the analysis is that the largest cost contributor is the initial vehicle purchase price. For a given initial purchase price, the factor driving the user fee required for full cost recovery is the number of different daily users of a vehicle. The model also compares the annual cost of transportation using station cars and mass transit to the annual cost of solo commuting. If a station car is used by more than one person a day, and this use replaces the ownership of a conventional vehicle, the annual cost of transportation may be similar. However, for the base case assumptions, the station car user fee required for full cost recovery is higher than the cost of solo commuting.

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# I. Introduction

## The Station Car Concept

A station car is an electric vehicle (EV) which is used primarily for transportation between transit stations and home, work, and/or running errands. This transportation service, if provided by the local transit agency, changes the agency's service from a point-to-point service to a door-to-door service. This feature increases the attractiveness of using mass transit for commuting, especially in the reverse commute direction and for other trips which often lack service from the transit stop to the user's destination. As an incentive to users, this service also would provide assured parking, a definite benefit as many park and ride lots lack sufficient capacity. The use of station cars also increases parking lot efficiency because each additional person using a station car, instead of their own vehicle, opens up another parking space for someone else. Also, the vehicles will be recharged primarily at the stations and maintained by the service providers, thus removing the chore of refueling and maintaining a vehicle for commuting.

Why are electric vehicles the desired station car instead of conventional internal combustion engine (ICE) vehicles? One reason is that electricity already powers many mass transit applications. The transit stations will require little modification to install the necessary recharging infrastructure for EV's, while installing refueling stations for ICE's would be more difficult and expensive. Electric-based transportation door-to-door also has several environmental benefits. First, using an electric vehicle for the short drives to and from the transit station (usually less than 5 miles) produces much less pollution than an equivalent ICE vehicle because the initial 5 minutes of driving, during the cold start period before the catalytic converter warms up, is the time when the ICE vehicle produces the most pollution. Also, when the ICE vehicle is turned off, the engine continues to produce evaporative emissions, a phenomenon known as hot soak, until the engine has cooled. A third source of pollution, oil runoff from the road, is also reduced when EV's are used.

Station cars are an initial market for EV's. The short range requirements of a station car are well within the range of current electric vehicles. They also help companies fulfill their trip reduction requirements.[1] And, with station cars readily available, the use of station cars for commuting and other requirements could replace the ownership of at least one ICE vehicle, thus removing the hassle of owning, maintaining, and fueling this vehicle.

Over the last few years, interest in this concept has grown in many areas of the country. To help develop the concept, the National Station Car Association (NSCA), comprised of pairs of transit agencies and local utilities, has been organized. The goal of this organization is to improve each local team's station car program by the sharing of data and other information and to increase the number of electric vehicles purchased, lowering vehicle purchase prices. The membership is currently comprised of teams located in Chicago, Long Island, Miami, Sacramento, and San Francisco Bay Area. A half dozen other transit agency and utility pairs have also begun planning demonstration programs.

In the San Francisco Bay area the local transit agency, the Bay Area Rapid Transit District (BART), and the local electric utility, Pacific Gas and Electric Company (PG&E), are developing a demonstration program which will be running by 1995. PG&E's interest in the program is to promote the use of electric vehicles. One of BART's program goals is to increase ridership, especially in the reverse commute direction, by providing convenient service to the transit passenger's work site. To give a sense of the market size of reverse commuters, on a daily basis in 1990, there were 26,000 reverse commuters from San Francisco to Contra Costa and Alameda counties. Of these, only 3,500 used BART. There were also 35,500 Alameda to Contra Costa commuters. Of these only 1,200 used BART.[2] BART's current ridership level is 250,000 one way trips, of which, approximately 150,000 are commute trips.[3]

### Implementation Issues of the Station Car Concept

The most basic issues to be discussed in the development of a successful station car program are how much will implementing this concept cost and how much will the transit agency need to charge its station car users for full cost recovery? These two questions will be examined in this report. There are many other issues that will need to be considered. For example, what is the real market potential of this idea and what is the price elasticity of demand for this service? What are the quantifiable environmental benefits? What is the effect on total energy usage? What is the extent of traffic congestion reduction? There are also more specific implementation questions, for example, how does battery life or the logistics of car location affect usage? However, these questions are beyond the scope of this report.

The next two sections of this report discuss a preliminary economic model of the total cost of a station car fleet and examine several ways of calculating the required user fees for full cost recovery. Section II begins with an overview of the cost model including a discussion of the various cost measures, and continues with a description of the required initial data and their respective values which are used in the base case calculations. The results are presented in Section III. First the base case scenarios for station car fleets consisting of electric vehicles and conventional (ICE) vehicles are shown. Next, several parameters in each case are changed in order to show the likely range of values in best and worse case scenarios. Then, the sensitivity of the model to each parameter is determined. Finally the annual cost of transportation is calculated in several examples using different assumptions about the mode of transportation used for commuting purposes.

## II. Economic Model of a Station Car Fleet

### Model Development

The station car economic model was developed using a Microsoft Excel™ spreadsheet. The model first determines the total capital required. Next, the model calculates the total annual fleet cost. The required initial data for these calculations are of two types: cost data and usage data. The model breaks down the annual fleet cost into different unit cost measures: the cost per vehicle and the cost per mile. Based on the usage data, the unit costs are converted into the user fees required to fully recover the costs on a per user or a per trip bases. The numbers quoted below are for the base case calculations. These values are the best estimates for each parameter based on current information on the costs involved in running a corporate fleet[4] of vehicles and information on current electric vehicles. However, some of the data values are highly uncertain. The model's sensitivity to each of these factors will be discussed in the results section.

The model assumes that the station car fleet is running in a mature multi-user form, which means more than one person can use a station car in a day. For example, one person uses the station car to travel from home to the transit station, this same car is then used by someone else to travel from the transit station to work. In the afternoon, the same process is repeated in reverse. A third person could also use the vehicle during the day.

The model also does not include any operating or capital subsidies. The percentage of annual operating expenses covered by the farebox receipts for most transit systems is less than 55%. This return rate measure does not include capital costs, as these costs are usually covered by grants from the Federal or State government or by bond measures.

*Overview of the Cost Model*

The total capital required to implement a station car fleet is the sum of the capital required for the fleet itself and all of the necessary infrastructure. This capital cost is included in the calculation of the annual cost of the fleet through depreciation. The annual cost of the fleet is the sum of the three types of annual costs outlined below: fixed (per-year) vehicle, variable (per-mile) vehicle, and non-vehicle costs. Figure 1 shows a block diagram of the economic model.

Once the total annual cost per vehicle is determined, several different cost measures can be derived, based on the usage per day or month or on mileage. Using the usage category information described below along with the cost measures, the user fees required for full cost recovery are calculated. In the results section below, the user fees are calculated using the following definitions.

$$\textbf{Annual Cost per Vehicle} = \frac{\text{Total Annual Cost}}{\text{Fleet Size}} \ . \qquad (1)$$

$$\textbf{Annual Cost per Mile} = \frac{\text{Annual Cost Per Vehicle}}{\text{Annual Mileage}} \ . \qquad (2)$$

$$\text{Average Daily Mileage} = \frac{\text{Annual Mileage}}{\text{Number of Days in Year}} \ . \qquad (3)$$

$$\text{Average Trip Length} = \frac{\text{Average Daily Mileage}}{\text{Number of Daily Trips}} \ . \qquad (4)$$

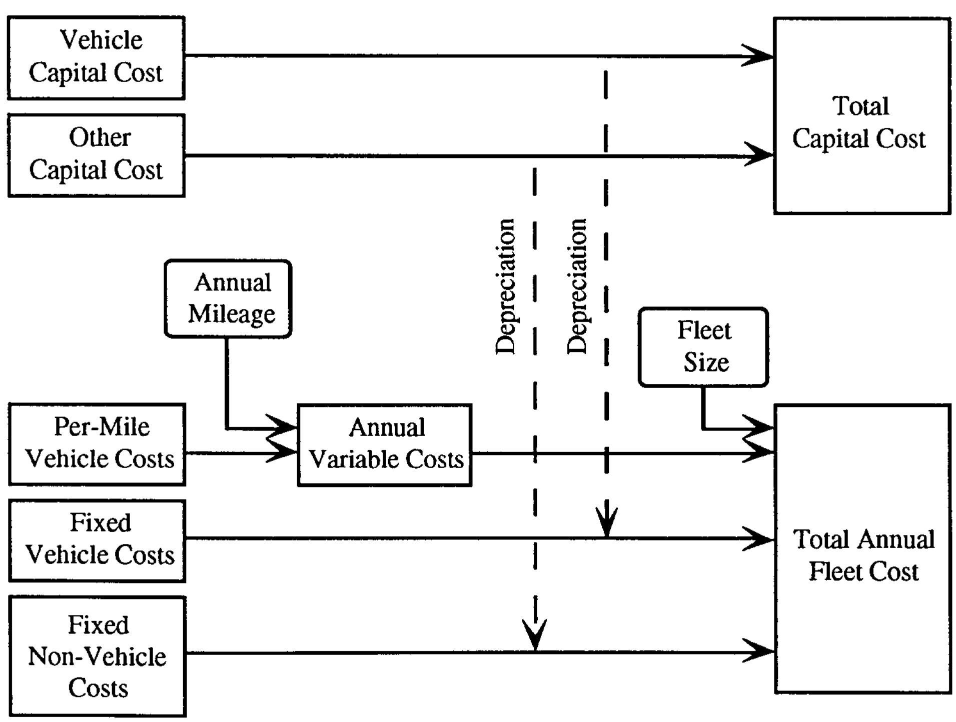


*Figure 1. Block Diagram of Economic Model of a Station Car Fleet*

$$\textbf{Average Trip Cost} = \text{Trip Length} * \text{Cost Per Mile}. \tag{5}$$

$$\text{Monthly Cost per Vehicle} = \frac{\text{Total Annual Cost per Vehicle}}{12} . \tag{6}$$

$$\textbf{Monthly Cost per User} = \frac{\text{Monthly Cost per Vehicle}}{\text{Daily Usage}} . \tag{7}$$

$$\text{Daily Fleet Cost} = \frac{\text{Total Annual Cost}}{\text{Number of Days in Year}} . \tag{8}$$

$$\text{Number of Daily Rentals} = \text{Fleet Size} * \text{Daily Usage} * \text{Availability}. \tag{9}$$

$$\textbf{Daily Rental Cost} = \frac{\text{Daily Fleet Cost}}{\text{Number of Daily Rentals}} . \tag{10}$$

Figure 2 is a block diagram of these user fee definitions showing which usage data are involved in the different cost measures listed in the results section.

*Cost Data*

The two types of cost data are capital costs and annual costs. The capital costs are brought into the annual cost calculations through the annual depreciation. The cost data detailed below is shown in Table I.

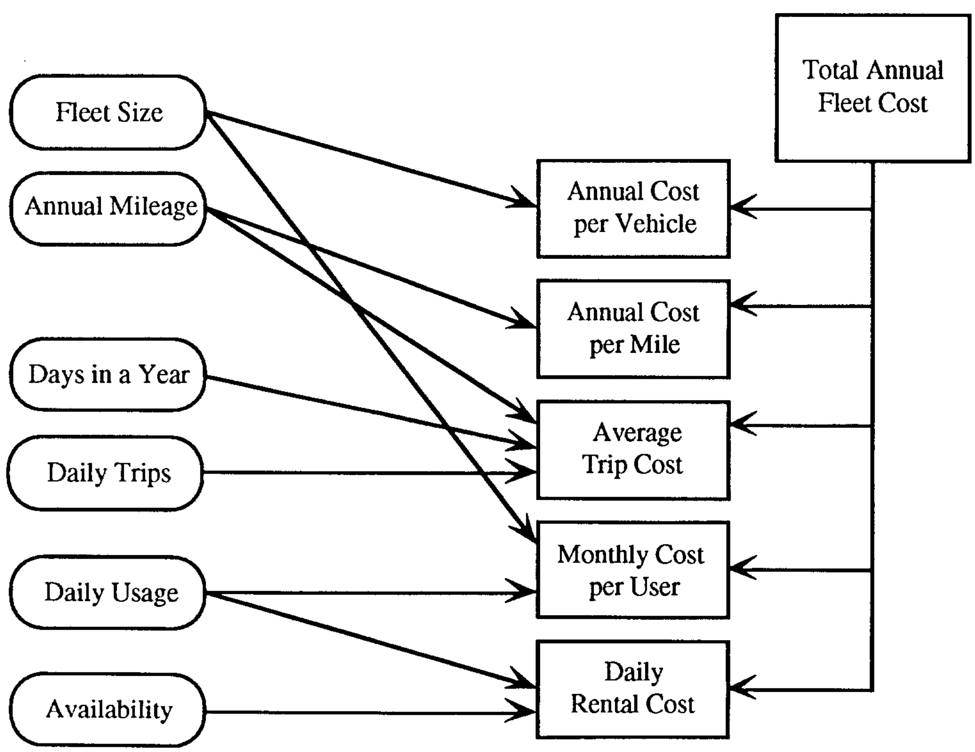


*Figure 2. Block Diagram of the User Fee Definitions*

## Table I. Base Station Car Fleet Scenario Parameter Values

| | Electric Vehicle | ICE Vehicle |
|---|---|---|
| **Cost Categories: Capital** | | |
| vehicle purchase price | $20,000 | $12,000 |
| number of months in service | 36 | 36 |
| monthly vehicle depreciation rate | 1.6% | 1.6% |
| charging station unit cost | $1,500 | $0 |
| parking or garage space unit cost | $2,000 | $2,000 |
| other station infrastructure per station | $1,000 | $1,000 |
| annual property depreciation rate (not land) | 2.6% | 2.6% |
| annual durable goods depreciation rate | 14.3% | 14.3% |
| **Cost Categories: Annual** | | |
| **Annual Fixed Costs per Vehicle** | | |
| insurance | $1,200 | $1,200 |
| title | $10 | $10 |
| registration | $427 | $267 |
| lease service fee | $240 | $240 |
| refueling service fee | $0 | $365 |
| annual depreciation | $3,840 | $2,304 |
| **Variable Vehicle Costs** | | |
| electricity (¢/kWh) | 10 | 0 |
| efficiency (mile/kWh from outlet) | 3.0 | 0 |
| recharging (¢/mile) (electricity/efficiency) | 3.3 | 0 |
| batteries (¢/mile) | 7.5 | 0 |
| tires (¢/mile) | 0.16 | 0.16 |
| maintenance (¢/mile) | 0.91 | 0.91 |
| gasoline (¢/mile) | 0 | 4.99 |
| oil (¢/mile) | 0 | 0.24 |
| **Annual Non-Vehicle System-wide Costs** | | |
| administration, for a 1,000 car fleet | $600,000 | $600,000 |
| maintenance per charging station | $600 | $0 |
| miscellaneous infrastructure maintenance | $40,000 | $40,000 |
| total non-vehicle depreciation | $270,790 | $56,290 |
| **Usage Data** | | |
| **Fleet Numbers** | | |
| fleet size | 1000 | 1000 |
| annual mileage | 10,000 | 10,000 |
| number of charging stations | 1000 | 0 |
| number of garage or parking spaces | 1000 | 1000 |
| number of transit stations with station cars | 30 | 30 |
| **User Numbers** | | |
| daily usage | 1.1 | 1.1 |
| availability | 90% | 90% |
| number of daily trips | 3 | 3 |
| number of days in a year | 365 | 365 |

### Capital Costs

The capitalized vehicle cost is calculated using the initial vehicle price and the depreciation rate. This cost could also be determined using the resale price and the number of months the vehicle is in the fleet. Currently there is not a resale market for electric vehicles, so there is no data for estimating the resale price. The average service life for electric vehicles also has not been determined. The current purchase price for an electric vehicle is $25,000 and up.[5] This price will go down as the number of EV's produced increases. Also, various incentives are in place to encourage EV purchases. For example, California will give a $1,000 tax rebate to EV purchasers; and there is a federal income tax credit of up to $4,000 (10% of purchase price up to $40,000).[6] In this model, $20,000 is used as the average purchase price for an electric vehicle and $12,000 for a conventional vehicle. For the purposes of this initial cost estimate, a monthly depreciation rate of 1.6% is used, for a service life of 36 months and an annual mileage rate of 10,000 miles. This rate is an extrapolation of a chart of average depreciation rates based on total service mileage and service life for intermediate and compact cars from *Automotive Fleet Magazine*.[7] This depreciation rate is slightly lower than the IRS monthly depreciation rate for automobiles of 1.67%.[8]

The capital costs of the infrastructure include the cost of the charging stations, building parking or garage spaces, other station infrastructure, and any other desired facilities, for example, a maintenance facility. The other station infrastructure might be a kiosk, the information and payment center for the charging facilities; or a charging queue, an automatic car wash-type facility which would charge and clean the vehicles as they moved through the queue. The estimated cost for one charging station is $1,500; for one parking and/or garage space, $2,000; and for other station infrastructure, $1,000 per station.[9] Each of these capital costs have their associated depreciation rates based on the IRS annual rates.[10] For the purposes of this model, an annual rate of 2.6% over 39 years is used for depreciation for the buildings, i.e., garages, and an annual rate of 14.3% over 7 years for all of the durable goods; land is not depreciated. The model assumes that no maintenance facility is built in the initial scenario; nor are there any charging queues at this time.

### Fixed Vehicle Costs

The annual fixed vehicle costs include the cost of insurance, parking, title, registration, and lease service fees. The annual depreciation cost also is included in the fixed vehicle costs. The annual insurance cost has a large range of values; for conventional corporate ICE fleets, the insurance per vehicle averages around $600, for the BART/PG&E station car demonstration the insurance fee is $1,200 annually. This latter figure is used as the average cost of insurance in the model base case. The actual insurance cost will depend on the location of the fleet. At this time BART is not charging for parking, so the parking cost is left at $0. Title and registration fees also depend on the location of the fleet. In California, the title cost is $10, and the registration fee is equal to 2% of the market value plus $27. For the purposes of the model, the market price is set to the initial purchase price. The average lease service fee for a conventional fleet vehicle ranges from $48 to $84 annually. A higher service fee of $240 is used in the model because the transit agencies are expecting turn-key services from the vehicle lessors.[11] For the internal combustion engine (ICE) station car, an additional service charge for refueling of $1 a day per vehicle has been added.[12] The electric vehicles will be recharged at the station or at the user's home.

### Variable Vehicle Costs

The variable vehicle costs are calculated on a cost per mile basis. These costs include the cost of electricity, batteries, tires, and maintenance. The cost per mile for electricity is calculated using the cost per kilowatt hour (kWh) and the efficiency of the EV. The efficiency is based on the range of the vehicle per charge, that is, in terms of miles/kWh from the outlet.[13] The cost of electricity varies widely depending on location, utility company, and commercial or residential rates. The model uses an average cost of $.10 per kWh. The efficiency of electric vehicles also varies widely depending on the type of vehicle, propulsion system, and driving cycle. The model uses 3 miles/kWh for the base efficiency; the efficiencies quoted in the literature range from 1 mile/kWh for the GM G-Van to 6 mile/kWh for the GM Impact.[14] The cost of the batteries also varies widely depending on the type. The base model case uses 7.5¢ per mile, which is the projected cost of replacing the Impact batteries ($1,500 after 20,000 miles).[15] For the ICE comparison, the variable costs include the cost of gasoline and oil per mile. The average costs per mile for gasoline, oil, maintenance, and tires used in the model are 4.99, 0.24, 0.91, and 0.16¢ per mile respectively.[16]

Non-Vehicle System Costs

The other type of annual costs are the non-vehicle system costs. These costs include administration, such as site management, record keeping, user recruitment, driver training, and administrative salary costs; infrastructure maintenance; and station personnel costs. The administration costs and infrastructure maintenance values are based on fleet size. As a first approximation, the administrative costs have been set at $600,000 for a fleet size of 1000 vehicles. This cost includes an administrative staff of three and the other expenses listed above. Miscellaneous infrastructure maintenance also is based on fleet size, with an initial approximation of $40,000 annually for a fleet size of 1000 vehicles. The maintenance for each charging station has been set to $50 per month. The current values used in the model are approximations, and better values will be available as experience with station car fleets grow. The full time equivalent (FTE) cost for station personnel is $35,000 per year. This cost is included in the model in case full or part time personnel are required at each station.

*Usage Data*

One usage data type includes numbers required to calculate the annual fleet cost and the other type includes numbers required to calculate the required user fees for full cost recovery. The base case usage data is also listed in Table I.

The first data type includes the fleet size, average annual mileage, the number of transit stations with station car facilities, the number of charging stations, the number of parking spaces, the number of maintenance facilities, and the number of personnel per station (number of FTEs). The base case model uses a fleet size of 1000 vehicles, average annual mileage of 10,000 miles per vehicle, 30 transit stations, one charging station per vehicle, one parking space per vehicle, and no maintenance facilities or station personnel.[17]

The other data type is used to convert the total annual fleet cost into unit costs which provide a basis for pricing schemes. These data consist of the average number of trips per day, the average number of daily users for each car (daily usage), the average availability of the fleet as a percentage, and the number of days in a year. This last variable is included to permit daily cost calculations based on the number of business days in a year. Currently the year is set to 365 days, the average number of trips per day is initially set to 3, and the fleet availability is 90%. The average daily usage is 1.1, which is the average vehicle occupancy rate in the U.S.

## III. Results

### Base Station Car Fleet Scenario

The base station car fleet scenarios for an electric vehicle fleet and a conventional (ICE) vehicle fleet are calculated using the numbers described above in Section II, and shown in Table I, the base case parameter value table. The results are shown in Table II.

The annual cost per vehicle for the EV case is $8420 and the ICE case is $5720. As a comparison to the rental car market in 1992, the average annual revenue per car was $8710 for the at or near airport market and $6300 for the local or replacement market segment,[18] for a daily rental rate of $23.90 and $17.30, respectively.

The largest component of the three cost types in the annual fleet cost is the fixed vehicle cost and within this category the major contributor is the annual depreciation cost, which is a strong function of the initial purchase price. The annual insurance cost is the next largest single cost item.

Figures 3a and 3b show the annual cost breakdown by percentages of the five major components: variable vehicle, non-vehicle, annual insurance, annual depreciation, and the sum of the other fixed vehicle costs. The percentage breakdown for the three cost types for the electric station car fleet are total fixed vehicle costs, 68%; total variable vehicle costs, 14%; and total non-vehicle costs, 18%. The breakdown for the ICE station car fleet are total fixed vehicle costs, 77%; total variable vehicle costs, 11%; and total non-vehicle costs, 12%.

**Table II. Base Station Car Fleet Scenario Results**

| | Electric Vehicle | ICE Vehicle |
|---|---|---|
| Capital Outlay | | |
| Total vehicle cost | $20,000,000 | $12,000,000 |
| Total charging station cost | $1,500,000 | $0 |
| Total parking/garage space cost | $2,000,000 | $2,000,000 |
| Other station infrastructure cost | $30,000 | $30,000 |
| **Total Capital Outlay** | **$23,530,000** | **$14,030,000** |
| Annual Cost | | |
| Variable vehicle cost per mile | $0.119 | $0.063 |
| Total variable vehicle cost | $1,190,000 | $630,000 |
| Total fixed vehicle cost | $5,720,000 | $4,390,000 |
| Total non-vehicle cost | $1,510,000 | $700,000 |
| **Total Annual Cost** | **$8,420,000** | **$5,720,000** |
| **Annual Cost per Vehicle** | **$8,420** | **$5,720** |
| **Annual Cost per Mile** | **$0.84** | **$0.57** |
| Average daily mileage | 27.4 | 27.4 |
| Average trip length | 9.1 | 9.1 |
| **Average Trip Cost** | **$7.70** | **$5.20** |
| Monthly cost per vehicle | $701 | $476 |
| **Monthly Cost per User** | **$638** | **$433** |
| Daily fleet cost | $23,063 | $15,650 |
| Average number of daily rentals | 990 | 990 |
| **Daily Rental Cost** | **$23.30** | **$15.80** |

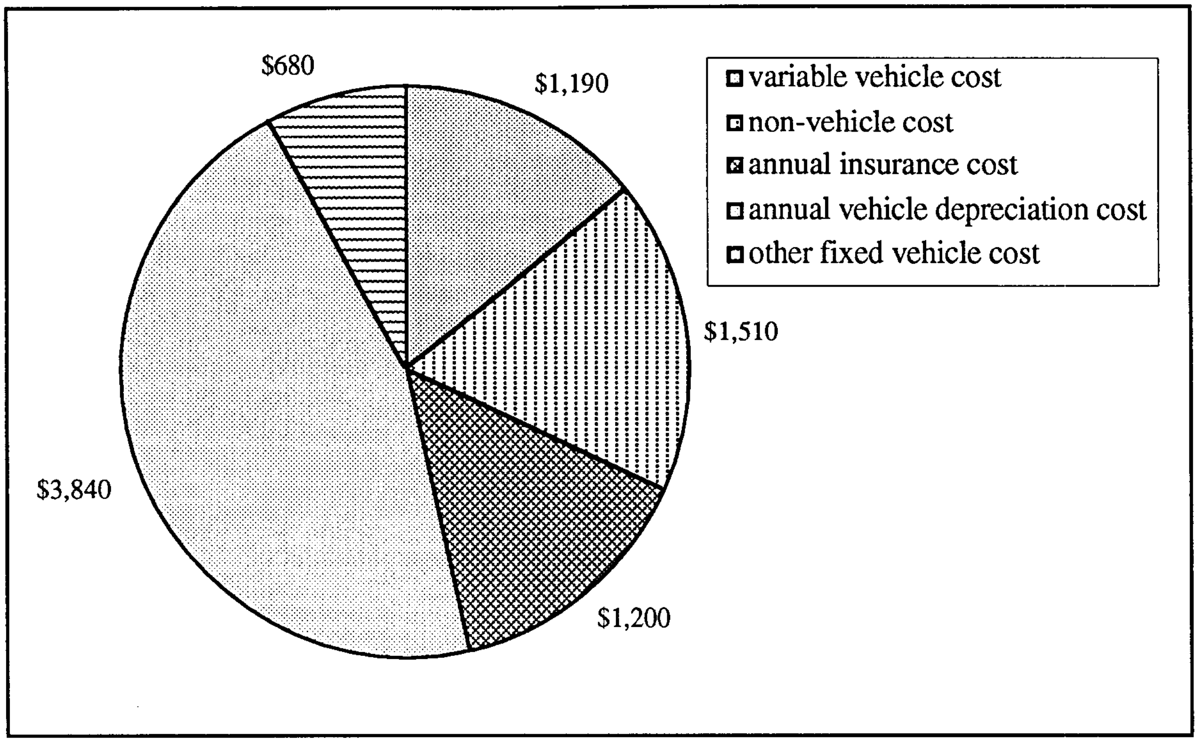


*Figure 3a. Cost Breakdown for Base Electric Vehicle Case*
*Annual Cost per Vehicle = $8,420*

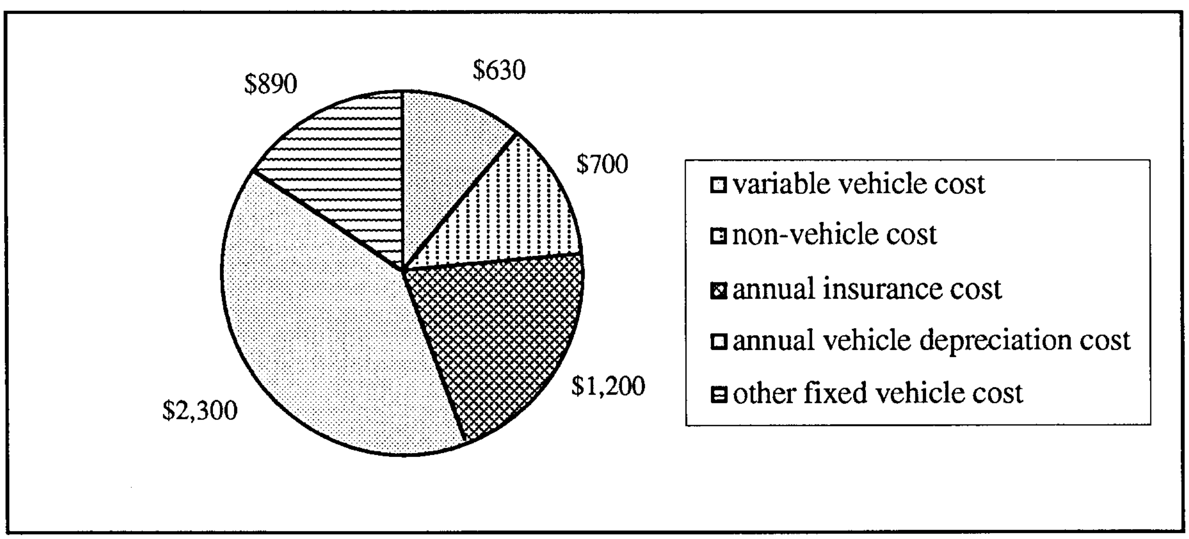


*Figure 3b. Cost Breakdown for Base Internal Combustion Vehicle Case*
*Annual Cost per Vehicle = $5,720*

### Additional Scenarios

In this section, the parameter values of the two base cases are changed to show the effects of a range of costs of a station car fleet. The base cases use the numbers shown above. The worst case scenarios use parameter values that are on the high cost side and the low usage side; the best case scenarios assume low costs and high usage. Any parameter value not explicitly mentioned is the same as the base case. For example, the size of the fleet is 1,000 vehicles and the annual mileage is 10,000 miles per vehicle in all of the scenarios.

The ranges of values for the various parameters are taken from a variety of sources. The number of daily trips ranges from 2 to 4, which would model the use of a station car for one round trip to two round trips each day. The daily usage assumes in the worst case that on average not all station cars would be used every day. The best case scenario assumes that an average of two people would use the vehicle each day. The availability ranges from an assumption that 25% of the vehicles would be unavailable to the better circumstance that only 5% would be unavailable. All of these ranges will be narrowed as better numbers develop from the various demonstration programs. Also all of the usage numbers are the same for both types of fleets.

The electric vehicle price ranges from a typical current EV price of $30,000 to the future price goal of $10,000. The ICE vehicle price range of $10,000 to $15,000 is much smaller since this data is well defined and the market is mature. The difference in this vehicle price parameter is the main source of variation in the cost of the two types of fleets. The insurance ranges from $200 a month to $50 dollars a month. The insurance cost for current corporate fleets is around $55; however, as there will be multiple users of the station cars, the insurance cost will probably be higher than this figure.

The electricity cost varies from a high of 15 ¢/kWh to a low of 7.5 ¢/kWh. As indicated above, the cost of electricity varies widely depending on location and whether the vehicles will be charged at commercial or residential rates. The efficiency range is based on the ranges of current electric vehicles, as mentioned earlier. The battery replacement cost is bracketed around the expected cost of the batteries for the Impact.[19] The maintenance cost is another parameter that does not have much data to base the cost of maintaining an electric vehicle. The range used for the electric vehicle goes from a cost of twice the maintenance cost for ICE's to 80% of this cost. The ICE maintenance cost ranges from the average to twice the cost. The nominal gasoline cost is equivalent to a fuel cost of $1.25/gal. with an efficiency of 25 miles/gal. The worst case assumes the price of gas has risen to $1.90 with the same efficiency. The worst case for oil assumes that the price of oil has increased by 25%. The gasoline refill cost goes from a high of $2/day to a low of $.50/day.

Figure 2 shows the cost breakdown of the annual fleet cost per vehicle for each of the six scenarios into their major components. In all six scenarios the annual depreciation cost, largely determined by the initial vehicle purchase price, is the largest contributor to the cost.

### Table III. Electric Vehicle vs. Internal Combustion Vehicle in Several Different Scenarios

| | EV Station Car | | | ICE Station Car | | |
|---|---|---|---|---|---|---|
| | base case | worst case | best case | base case | worst case | best case |
| **Changing Initial Values:** | | | | | | |
| number of daily trips | 3 | 2 | 4 | 3 | 2 | 4 |
| daily usage (# of users/vehicle) | 1.10 | 0.80 | 2.00 | 1.10 | 0.80 | 2.00 |
| availability | 0.90 | 0.75 | 0.95 | 0.90 | 0.75 | 0.95 |
| vehicle purchase price | $20,000.00 | $30,000.00 | $10,000.00 | $12,000.00 | $15,000.00 | $10,000.00 |
| insurance (annual cost) | $1,200.00 | $2,400.00 | $600.00 | $1,200.00 | $2,400.00 | $600.00 |
| electricity cost (¢/kWh) | 10.00 | 15.00 | 7.50 | 0.0 | 0.0 | 0.0 |
| efficiency (mile/kWh) (outlet) | 3.00 | 2.00 | 5.00 | 0.0 | 0.0 | 0.0 |
| battery replacement cost (¢/mile) | 7.50 | 15.00 | 5.00 | 0.0 | 0.0 | 0.0 |
| vehicle maintenance (¢/mile) | 0.91 | 2.00 | 0.75 | 0.91 | 2.00 | 0.91 |
| gasoline (¢/mile) | 0.0 | 0.0 | 0.0 | 4.99 | 7.50 | 4.99 |
| oil (¢/mile) | 0.0 | 0.0 | 0.0 | 0.24 | 0.30 | 0.24 |
| gasoline refill charge | 0.0 | 0.0 | 0.0 | $365.00 | $730.00 | $190.00 |
| **Calculation Results:** | | | | | | |
| **Total Capital Outlay** | $23,530,000 | $33,530,000 | $13,530,000 | $14,030,000 | $17,030,000 | $12,030,000 |
| total fixed vehicle operating cost | $5,720,000 | $9,040,000 | $3,000,000 | $4,390,000 | $6,590,000 | $3,190,000 |
| total vehicle mileage cost | $1,190,000 | $2,470,000 | $740,000 | $630,000 | $1,000,000 | $630,000 |
| total non-vehicle cost | $1,510,000 | $1,510,000 | $1,510,000 | $700,000 | $700,000 | $700,000 |
| **Total Annual Cost** | $8,420,000 | $13,020,000 | $5,250,000 | $5,720,000 | $8,290,000 | $4,520,000 |
| **User fees for full cost recovery:** | | | | | | |
| Annual Cost per Vehicle | $8,420 | $13,020 | $5,250 | $5,720 | $8,290 | $4,520 |
| Annual Cost per Mile | $0.84 | $1.30 | $0.52 | $0.57 | $0.83 | $0.45 |
| Average Trip Length (miles) | 9.1 | 13.7 | 6.8 | 9.1 | 13.7 | 6.8 |
| Average Trip Cost | $7.69 | $17.83 | $3.60 | $5.22 | $11.34 | $3.09 |
| Monthly Cost per User | $638 | $1,356 | $219 | $433 | $863 | $188 |
| Cost per Daily Rental | $23.30 | $59.40 | $7.60 | $15.80 | $37.80 | $6.50 |

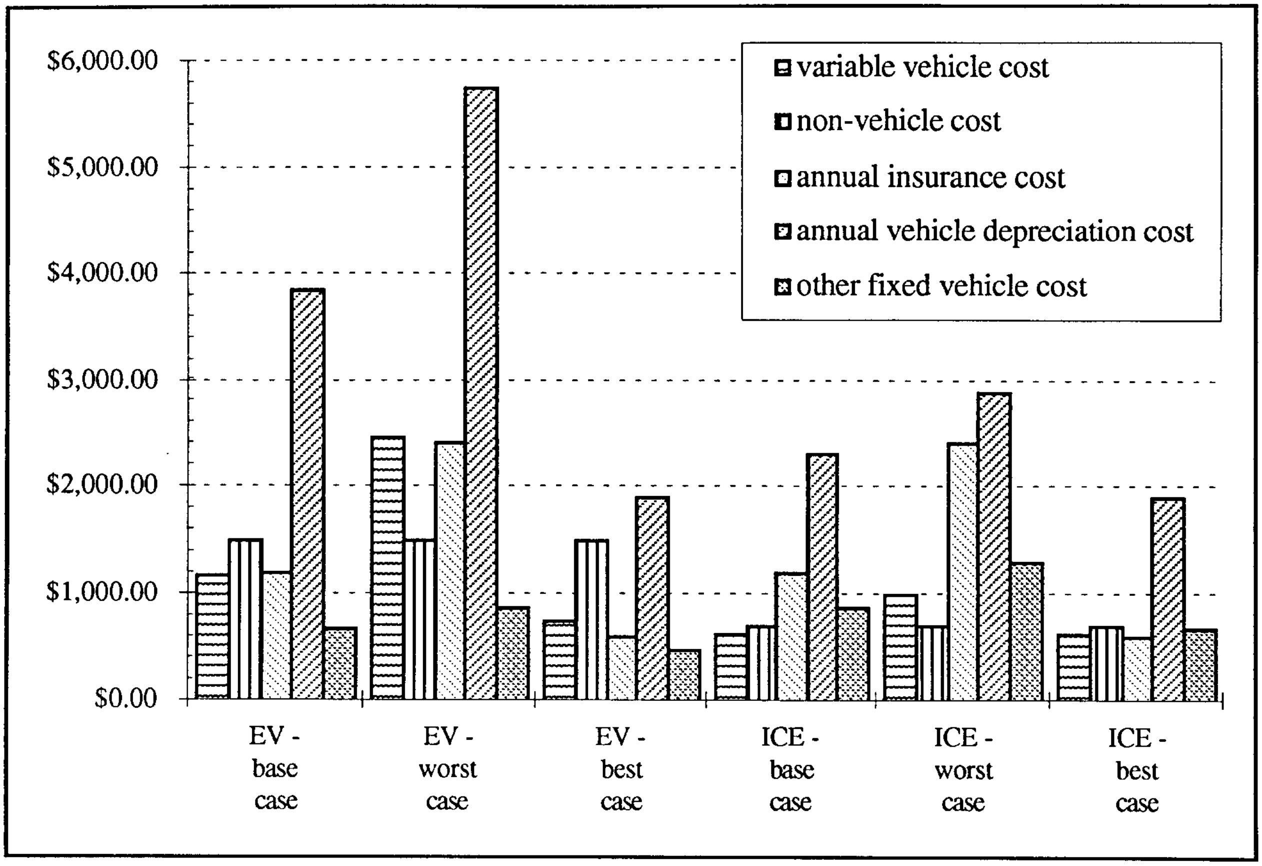


*Figure 4. Cost Breakdown for the Different Scenarios*

## Cost Sensitivity: Effects of Other Parameters

This section shows the sensitivity of the model to individual parameters. The high and low values for the factors are based on reasonable ranges for each parameter. The sensitivity of each cost measure to variation in a factor is determined by calculating the value of that cost measure using the maximum, minimum, and nominal (base) values of the factor.

$$\text{Cost Sensitivity} = \frac{\text{Cost at Maximum} - \text{Cost at Minimum}}{\text{Cost Measure at Nominal Factor Value}} \tag{11}$$

Tables IV and V show the change in the annual cost per vehicle due to changes in the various cost parameters and usage factors. Table VI shows the sensitivity of the annual cost per vehicle as well as some of the required user fees to changing the daily usage, the annual mileage, and the availability factors. These three factors affect the various cost measures differently. The sensitivity percentages listed for the other parameters in Tables IV and V are the same for all of the cost measures, so only the change in the annual cost per vehicle is shown. Tables IV and V list the three factor values, the resulting annual cost per vehicle using each factor value, the difference between the cost using the maximum factor and the cost using the minimum factor, and the % change which is the difference divided by the cost using the nominal factor value. Table VI shows the same information for additional cost measures in a format where the usage factor values are listed in a row with their resulting cost measures in the column below. For each of the calculations the other input parameters are held at the nominal values, the base case, shown in Table I above.

The largest percentage change, 76%, is due to the four-fold, or 66%, increase in the initial purchase price of the vehicle. As the monthly depreciation rate is the other major factor in calculating the depreciation cost, it follows that the next largest percentage change in the annual fleet cost per vehicle is due to the change in the monthly vehicle depreciation rate. The range in the monthly depreciation rates corresponds to the range of monthly depreciation rates in the *Automotive Fleet* chart cited in section II above.[20] The maximum monthly depreciation rate of 2.75% corresponds to a vehicle usage rate of 70,000 miles in two years, an annual mileage rate that is much higher than expected for station cars. The change in the cost per mile price of batteries has the next highest effect on the fleet cost. This cost is uncertain at this time. The annual cost per vehicle is also sensitive to the cost of insurance since this cost is one of the larger contributors to the annual cost. The total administration cost is another of the more uncertain parameters in this model. A five-fold increase in this cost from $300,000 to $1,500,00 for 1000 cars changes the total annual vehicle cost by 14%. However, changes in the cost of electricity, efficiency, maintenance, and tires only have a small effect on the annual cost of the fleet. Changes in the capital cost of the charging stations, parking spaces, and other infrastructure also do not have a large effect the annual cost per vehicle. The sensitivity of the annual cost of an ICE vehicle to the price of gasoline is listed as a comparison.

Table V shows the sensitivity of the annual cost per vehicle to various usage factors. Only adding station attendants has an appreciable affect on the annual cost per vehicle.

The three usage factors listed in Table VI affect cost measures other than the annual cost per vehicle. The daily usage factor affects only the annual cost per user because this cost measure is dependent on the number of users per day. Increasing the average daily usage by a factor of five causes the largest percentage change in this analysis, decreasing the monthly cost per user by 110%. The number of daily users is the driving factor in how much users need to be charged for this service. The annual cost per vehicle is sensitive to the annual mileage due to the mileage dependency of both the annual variable vehicle costs and the depreciation rate. Also, as the annual mileage increases, the cost per mile decreases, since the fixed vehicle cost and the non-vehicle cost are spread out over more miles. The availability parameter includes the change in the cost per daily rental because it is the only cost measure which includes the availability as a parameter.

**Table IV. Sensitivity of Annual Cost per Vehicle to the Cost Parameters**

| | | factor | annual cost per vehicle | difference | % change |
|---|---|---|---|---|---|
| **Vehicle Purchase Price** | min | $10,000 | $6,300 | | |
| | base | $20,000 | $8,420 | $6,360 | 76% |
| | max | $40,000 | $12,660 | | |
| **Monthly Vehicle Depreciation Rate** | min | 1.60% | $8,420 | | |
| | base | 1.60% | $8,420 | $2,760 | 33% |
| | max | 2.75% | $11,180 | | |
| **Batteries (¢/mile)** | min | 5.0 | $8,170 | | |
| | base | 7.5 | $8,420 | $2,000 | 24% |
| | max | 25.0 | $10,170 | | |

## Table IV. Sensitivity of Annual Cost per Vehicle to the Cost Parameters (con't)

| | | factor | annual cost per vehicle | difference | % change |
|---|---|---|---|---|---|
| **Insurance ($/year)** | min | $400 | $7,620 | | |
| | base | $1,200 | $8,420 | $1,600 | 19% |
| | max | $2,000 | $9,220 | | |
| **Administration ($/year for 1,000 cars)** | min | $300,000 | $8,120 | | |
| | base | $600,000 | $8,420 | $1,200 | 14% |
| | max | $1,500,000 | $9,320 | | |
| **Electricity (¢/kWh)** | min | 4.00 | $8,220 | | |
| | base | 10.00 | $8,420 | $530 | 6.3% |
| | max | 20.00 | $8,750 | | |
| **Charging Station Cost (per charging station)** | min | $0 | $8,200 | | |
| | base | $1,500 | $8,420 | $430 | 5.1% |
| | max | $3,000 | $8,630 | | |
| **Efficiency (mile/kWh)** | min | 2.00 | $8,585 | | |
| | base | 3.00 | $8,420 | ($400) | -4.8% |
| | max | 10.00 | $8,185 | | |
| **Maintenance (¢/mile)** | min | 0.50 | $8,380 | | |
| | base | 0.91 | $8,420 | $200 | 2.4% |
| | max | 2.50 | $8,580 | | |
| **Parking Space Cost (per space)** | min | $0 | $8,370 | | |
| | base | $2,000 | $8,420 | $100 | 1.2% |
| | max | $4,000 | $8,470 | | |
| **Tires (¢/mile)** | min | 0.08 | $8,410 | | |
| | base | 0.16 | $8,420 | $320 | 0.4% |
| | max | 0.40 | $8,440 | | |
| **Other Station Infrastructure Cost (per station)** | min | $0 | $8,410 | | |
| | base | $2,000 | $8,420 | $20 | 0.2% |
| | max | $4,000 | $8,430 | | |
| **Gasoline (¢/mile) (ICE Station Car)** | min | 4.00 | $5,610 | | |
| | base | 4.99 | $5,710 | $600 | 11% |
| | max | 10.00 | $6,210 | | |

## Table V. Sensitivity of Annual Cost per Vehicle to the Usage Parameters

| | | factor | annual cost per vehicle | difference | % change |
|---|---|---|---|---|---|
| **Number of Station Attendants (per station)** | min | 0 | $8,420 | | |
| | base | 0 | $8,420 | $1,050 | 12% |
| | max | 1 | $9,470 | | |
| **Fleet Size** | min | 400 | $8,690 | | |
| | base | 1,000 | $8,420 | ($370) | –4.4% |
| | max | 2,000 | $8,320 | | |
| **Ratio of Number of Charging Stations to Fleet Size** | min | 0.75 | $8,210 | | |
| | base | 1.0 | $8,420 | $200 | 2.4% |
| | max | 1.0 | $8,420 | | |
| **Number of Maintenance Facilities** | min | 0 | $8,420 | | |
| | base | 0 | $8,420 | $20 | 0.3% |
| | max | 1 | $8,440 | | |
| **Ratio of Number of Parking Spaces to Fleet Size** | min | 0.75 | $8,405 | | |
| | base | 1.0 | $8,420 | $15 | 0.15% |
| | max | 1.0 | $8,420 | | |
| **Number of Stations with Vehicles** | min | 10 | $8,415 | | |
| | base | 30 | $8,420 | $5 | 0.05% |
| | max | 40 | $8,420 | | |

## Table VI. Sensitivity of Various Cost Recovery Variables to Several Usage Parameters

| Usage Factors | Cost Type | Minimum | Maximum | Difference | Nominal Value | % Change |
|---|---|---|---|---|---|---|
| **Daily Usage** | | 0.80 | 4.00 | 3.20 | 1.10 | 291% |
| | annual cost per vehicle | $8,420 | $8,420 | $0.00 | $8,420 | 0.00% |
| | monthly cost per user | $877 | $175 | ($702) | $638 | –110% |
| | annual cost per mile | $0.84 | $0.84 | $0.00 | $0.84 | 0.00% |
| **Annual Mileage** | | 7,000 | 20,000 | 13,000 | 10,000 | 130% |
| | annual cost per vehicle | $8,060 | $10,570 | $2,510 | $8,420 | 30% |
| | monthly cost per user | $611 | $801 | $190 | $638 | 30% |
| | annual cost per mile | $1.15 | $0.53 | ($0.62) | $0.84 | –74% |
| **Availability** | | 0.50 | 1.00 | 0.50 | 0.90 | 56% |
| | annual cost per vehicle | $8,420 | $8,420 | $0.00 | $8,420 | 0.00% |
| | monthly cost per user | $638 | $638 | $0.00 | $638 | 0.00% |
| | annual cost per mile | $0.84 | $0.84 | $0.00 | $0.84 | 0.00% |
| | daily rental cost | $41.90 | $21.00 | ($20.90) | $23.30 | –90% |

## Annual Transportation Cost Comparison

In this section the annual cost of transportation is calculated using the base case results calculated above. The calculations are based on 250 annual round trips for commuting to and from San Francisco and Lafayette.

*Example i: Commute from Lafayette to San Francisco and back*

In this example, the commute trip is in the normal direction, and four different scenarios are studied. The results are shown in Table VII.

The first scenario is based on owning an ICE vehicle and driving alone to and from San Francisco. This round trip is 45 miles; requires paying for parking in the city, $200/month; and has a daily toll of $1. This example also assumes that the vehicle is driven for 5,000 non-commute miles for an annual rate of 16,250 miles. The annual fixed cost is the fixed cost of $4,386, calculated in the ICE base case, Table II. The cost per mile of 6.3¢ is the sum of the ICE variable vehicle costs shown in Table I.

The second scenario also assumes that an ICE is owned and used, however it is now only used to drive to the Lafayette BART station, BART is used for the major portion of the commute trip, and the trip is completed on foot. This scenario includes a 10 mile round trip to the BART station and a round trip BART ticket of $4.50. In this scenario the cost of insurance is lowered by a third to $800, reducing the fixed cost to $3,986, because the vehicle is not driven as many miles.

The third scenario assumes the use of an electric station car for the round trip to the BART station. It also assumes that the station car has not replaced an ICE vehicle. The station car has a monthly rental fee of $640, the monthly cost per user in the base case scenario. In this scenario the cost of insurance is lowered by a half to $600, reducing the fixed cost to $3,786, because the vehicle is not driven as many miles and is not used for regular commuting.

The last scenario is the same as the third scenario except that the use of the station car has replaced owning an ICE vehicle. In this scenario, the non-commute miles are driven using the station car, which does not change the monthly rental fee. However, two additional expenses may need to be included in this scenario if the family only owned one vehicle before replacing it with the use of a station car. The first is personal liability insurance. It is not clear at this time how drivers of station cars who do not have a separate automobile insurance policy would be covered. The other expense would be the occasional rental of a conventional vehicle for travel or trips that are inappropriate for a station car.

## Table VII. Commute to San Francisco from Lafayette Using an Electric Station Car

| | Drive<br>use own car<br>own a car | BART<br>use own car<br>own a car | BART<br>use station car<br>own a car | BART<br>use station car<br>no car |
|---|---|---|---|---|
| annual mileage | 16,250 | 7,500 | 5,000 | 0 |
| cost per mile (gas, oil, etc.) | $0.063 | $0.063 | $0.063 | $0.00 |
| total mileage cost | $1,024 | $473 | $315 | $0 |
| annual parking and toll cost | $2,650 | $0 | $0 | $0 |
| total annual fixed cost | $4,386 | $3,986 | $3,786 | $0 |
| **Total car cost** | $8,060 | $4,459 | $4,101 | $0 |
| annual BART cost | $0 | $1,125 | $1,125 | $1,125 |
| annual station car cost | $0 | $0 | $7,680 | $7,680 |
| **Total BART cost** | $0 | $1,125 | $8,805 | $8,805 |
| Total car cost | $8,060 | $4,459 | $4,101 | $0 |
| Total BART cost | $0 | $1,125 | $8,805 | $8,805 |
| **Annual Cost of Transportation** | $8,060 | $5,584 | $12,906 | $8,805 |

For comparison purposes, if the first scenario is calculated using the IRS mileage allowance of $0.29/mile instead of using the variable and fixed costs from the model, the total variable and fixed annual cost is $4,712.50; adding the parking fees and toll charges to calculate the total car cost, the annual cost of transportation is $7,362.50.

*Example ii: Commute from San Francisco to Lafayette and back (electric vehicle case)*

In this example, the commute trip is in the reverse direction, and three different scenarios are studied. These are essentially the same as those in Example I, except the park and ride BART with the user's own ICE vehicle scenario is not included because there are no parking facilities at the downtown San Francisco BART stations. The other changes include the use of the station car in Lafayette to get to and from work and using a MUNI (the San Francisco municipal transit system) Fast Pass ($35/month) to get to and from BART in San Francisco. The insurance rate is increased to $1,800 annually to reflect the higher rates in San Francisco for the first scenario, increasing the annual fixed cost to $4986. For the second scenario, the insurance cost is set to $900, for a fixed vehicle cost of $4,086. The parking fee is reduced to $100/month for the first two scenarios, as parking in San Francisco is less expensive in residential areas. These results are shown in Table VIII.

**Table VIII. Reverse Commute to Lafayette from San Francisco Using an Electric Station Car**

| | Drive<br>use own car<br>own a car | BART<br>use station car<br>own a car | BART<br>use station car<br>no car |
|---|---|---|---|
| annual mileage | 16,250 | 5,000 | 0 |
| cost per mile (gas, oil, etc.) | $0.063 | $0.063 | $0.00 |
| total mileage cost | $1,024 | $315 | $0 |
| annual parking and toll cost | $1,450 | $1,200 | $0 |
| total annual fixed cost | $4,986 | $4,086 | $0 |
| **Total car cost** | $7,460 | $5,601 | $0 |
| annual BART cost | $0 | $1,125 | $1,125 |
| annual station car cost | $0 | $7,680 | $7,680 |
| annual MUNI Fast Pass | $0 | $420 | $420 |
| **Total BART/MUNI cost** | $0 | $9,225 | $9,225 |
| Total car cost | $7,460 | $5,601 | $0 |
| Total BART cost | $0 | $9,225 | $9,225 |
| **Annual Cost of Transportation** | $7,460 | $14,826 | $9,225 |

For comparison purposes, if the first scenario is calculated using the IRS mileage allowance of $0.29/mile instead of using the variable and fixed costs from the model, the total variable and fixed annual cost is $4,712.50; adding the parking fees and toll charges to calculate the total car cost, the annual cost of transportation is $6,162.50.

*Example iii: Commute from San Francisco to Lafayette and back (internal combustion engine vehicle case)*

The third example is the same as Example ii, except the station car is now part of an ICE fleet and the monthly station car rental has been reduced to $435/month from $640/month, the monthly cost per user from Table II for the ICE scenario. These results are shown in Table IX.

**Table IX. Reverse Commute to Lafayette from San Francisco Using an ICE Station Car**

| | Drive<br>use own car<br>own a car | BART<br>use station car<br>own a car | BART<br>use station car<br>no car |
|---|---|---|---|
| annual mileage | 16,250 | 5,000 | 0 |
| cost per mile (gas, oil, etc.) | $0.063 | $0.063 | $0.00 |
| total mileage cost | $1,024 | $315 | $0 |
| annual parking and toll cost | $1,450 | $1,200 | $0 |
| total annual fixed cost | $4,986 | $4,086 | $0 |
| **Total car cost** | $7,460 | $5,601 | $0 |
| annual BART cost | $0 | $1,125 | $1,125 |
| annual station car cost | $0 | $5,220 | $5,220 |
| annual MUNI Fast Pass | $0 | $420 | $420 |
| **Total BART/MUNI cost** | $0 | $6,765 | $6,765 |
| Total car cost | $7,460 | $5,601 | $0 |
| Total BART cost | $0 | $6,765 | $6,765 |
| **Annual Cost of Transportation** | $7,460 | $12,366 | $6,765 |

For comparison purposes, if the first scenario is calculated using the IRS mileage allowance of $0.29/mile instead of using the variable and fixed costs from the model, the total variable and fixed annual cost is $4,712.50; adding the parking fees and toll charges to calculate the total car cost, the annual cost of transportation is $6,162.50.

## IV. Conclusion

This station car cost model shows that the purchase price of the electric vehicles is the major cost driver. Also, making the use of station cars convenient for multiple users is critical for reducing the required cost per user fee for full cost recovery. The cost of battery replacement and the annual cost of insurance are the next largest factors in the annual cost of the vehicles. However, from a cost standpoint, the efficiency of the vehicles and the cost of electricity are negligible cost components. Using the base case assumptions, the cost of using a station car is similar to the cost of using a conventional rental car.

The model also is used to compare the annual cost of transportation using station cars and mass transit to solo commuting. Under the base case conditions, the normal commute from Lafayette to San Francisco, replacing the ownership of a car with the use of a station car increased the annual cost of transportation by $800. This calculation used the monthly fee required for full cost recovery of $640 per month for the unlimited use of a station car. The least expensive commuting choice is to use BART without using a station car. For the reverse commute in an electric station car, replacing the ownership of a car with the use of a station car increased the annual cost of transportation by $1800. However, there are a few non-monetary benefits for replacing the ownership of a car with the use of a station car: the maintenance and "refueling" is done by someone else, assured parking, and reduced pollution. In an ICE station car, the annual cost of transportation was reduced by $700. This $200 per month difference in the annual cost of transportation between the electric and ICE station cars is largely due to the difference in the initial vehicle purchase price. If multiple users use each station car, thus increasing the daily usage, the required monthly user fee would be reduced, reducing the annual cost of transportation for any of the scenarios using a station car.

The major uncertainties in the total cost calculation are the electric vehicle purchase price and the non-vehicle costs, for example, what will the administration of the fleet cost. In the required user fee calculations for full cost recovery, the major uncertainties are the average annual mileage, daily usage, and availability. The certainty of these numbers will be improved as more data is collected in the station car demonstrations and early implementation of the concept.

## V. References


1 Trip Reduction Requirements are regulations for large employers to put plans into place for reducing the number of employees commuting to work in single occupancy internal combustion vehicles with the goal of improving air quality and reducing the number of Clean Air Act non-compliance days. In the Bay Area, the Bay Area Air Quality Management District has adopted *Regulation 13, Rule 1 – Trip Reduction Requirements for Large Employees*, December 16, 1992, which explains the Bay Area trip reduction requirements. For the purpose of calculating the average vehicle employee ratio, EV's count as zero and single occupancy internal combustion vehicles count as one.

2 Planning Section, Metropolitan Transportation Commission, *The Journey-to-Work in the San Francisco Bay Area: 1990 Census, Census Transportation Planning Package, Working Paper #5* (April, 1993).

3 BART Planning Department, *1992 Passenger Profile Survey Summary Report* (May, 1993). Note, a round trip is counted as two one-way trips.

4 A corporate fleet is used in this report to refer to a fleet of vehicles owned by a corporation that is not in the business of selling, renting, or leasing vehicles.

5 The base price of a Solectria Force is $26,000 on Solectria's 12/93 price list. Current conversions of internal combustion vehicles to electric vehicles are priced from about $5,000 over the initial vehicle price.

6 Energy Policy Act of 1992 and California Tax Code.

7 "Analysis of Lessor 1995 Fleet Recommendations", *Automotive Fleet* **33**, no. 10, p. 26 (1994). A monthly depreciation rate of 2% is generally used for fleet calculations, assuming a service life of 30 months and 20,000 annual miles. P. Bradley, "What's Your Full Fleet Cost? Here's One Way to Find Out.", *Purchasing* **114**, no. 8, p. 45 (1993).

8 The annual IRS depreciation rate for automobiles is 20%, a monthly depreciation rate of 1.67%. IRS Publication 534 for 1993.

9 Based on information from BART.

10 IRS Publication 534 for 1993.

11 A turn-key service indicates that the service providers will take care of everything, driver training, all service calls, all maintenance, etc.

12 Rental car agencies charge a $4 refueling service fee.

13 The efficiencies stated in the literature are usually in terms of kWh/mile or kWh/km and often are stated in terms of the energy use from the battery, not the outlet.

14 Q. Wang and M. DeLuchi, "Impacts of Electric Vehicles on Primary Energy Consumption and Petroleum Displacement", *Energy*, 1992, **17**, n. 4, pp. 351-366.

15 D. McCosh, "We Drive the World's Best Electric Car", *Popular Science* **244**, no. 1, p. 52 (1994). D. Woodruff, "Electric Cars: Will They Work? And Who Will Buy Them?", *Business Week* no. 3374, p. 104 (1994).

16 *Automotive Fleet*, Bobit Publishing, vol. **32** supplement, p. 42 (1993).

17 BART currently has 22 stations out of 34 total stations with parking facilities. In the next fifteen years, 18 additional stations are planned, most of which will include parking facilities.

18 *Automotive Fleet, op. cit.* footnote 7, p. 38.

19 *Popular Science, op cit.* footnote 15.

20 *Automotive Fleet, op. cit.* footnote 7.

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