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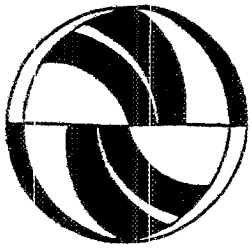

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Reprint
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The University of California
Transportation Center
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Disclaimer

The authors are solely responsible for the opinions and conclusions presented here. Nothing contained in this report is a statement of policy or intent by any funding agency or sponsor. The mention of commercial products, their source, or their use in connection with the research reported herein does not constitute an actual or implied endorsement.

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EXECUTIVE SUMMARY

Defining Neighborhood Electric Vehicles

The general defining characteristic of NEVs is their specialization for local travel. As such, they will have limited range and low top speeds and thus, low energy storage and low power needs. Consistent with keeping energy and power requirements low, NEVs will be small. They will likely accommodate two or three persons plus storage space, but some may be larger so as to accommodate families with children. We envision that NEVs will range from top-end vehicles that are intended to travel on arterial streets at speeds of up to 45mph, to bottom-end NEVs, with top speeds of about 25mph.[1] Bottom-end NEVs might have separate right-of-ways, only mixing with other motor vehicles in specialized circumstances, such as streets with stringent vehicle speed and size restrictions. We see little reason for the driving range of NEVs to exceed 40 miles or so, since they will only be driven on sequences of short trips and can be readily recharged each night.

The Research Tasks and Goals

Under the auspices of the CALSTART Neighborhood Electric Vehicle Program, the Institute of Transportation Studies at the University of California, Davis conducted neighborhood electric vehicle (NEV) market assessments and vehicle demonstrations. This report describes that research and provides descriptions of the potential personal, private transportation market niches for NEVs in California. The CALSTART-sponsored NEV market research and demonstration projects performed by ITS-Davis encompassed the following sub-projects:

- case studies of the "golf cart-communities" Sun City, Arizona and Palm Desert, California;
- ride-and-drive clinics in which people drove and reviewed a wide variety of electric vehicles, including NEVs;
- vehicle trials in which households were given use of a NEV for a one-week period; and
- a statewide mail survey of household electric vehicle purchase intentions.

The overall goal of this research agenda was to determine whether households can imagine using a NEV, and based on that assessment, whether they would buy one. We wish to

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[1] Electric-assist bicycles are considered by some to be NEVs. We do not include them in this discussion since there are few policy, infrastructure or marketing issues that differentiate electric-assisted from non-assisted bicycles In fact, electric-assist bicycles enjoy the advantage, relative to other NEVs, of already being explicitly recognized in vehicle codes

understand the possible dynamics of market development Most of the research we report here was conducted on small samples of households, in highly interactive settings. Our use of in-person interviews, ride-and-drive clinics, focus groups, travel diaries and detailed surveys was intended to provide detailed images of households' responses to NEVs. Based on these, this report provides the basis for developing quantitative estimates for NEV market niches. We summarize the main results of these four research activities before providing a brief description of the theoretical basis for our work and a market overview based on a synthesis of our results.

Summary of Results

Case Studies of "Golf Cart Communities"

- Palm Desert, CA and Sun City, AZ represent two alternative pathways to implementing NEVs. Palm Desert represents an effort to retrofit existing roadway infrastructure to serve very low speed vehicles. Sun City shows that in communities intended for low speed vehicles, specialized roadway infrastructure may not required.
- The demonstration project in Palm Desert shows it will be possible to retrofit some communities to very low speed vehicles. The few complaints by cart drivers about the golf cart roadway infrastructure deployed in Palm Desert centered on a few intersections where prior roadway conditions made it impossible to implement the new infrastructure in a consistent manner.
- Half the participants in the Sun City focus groups had displaced a gasoline vehicle from their household vehicle holdings with an electric or gasoline golf cart. The most common vehicle ownership pattern among our participants was one cart and one automobile.
- In Sun City, there has been a shift away from electric golf carts toward gasoline carts. Our informants indicate this is largely due to the higher top speed of gasoline carts (reported to be as high as 25 miles per hour as opposed to 15 to 18 miles per hour for electric carts).
- As this shift to gas carts indicates, top speed was more likely to be a constraint on cart use than was driving range. In communities designed, or otherwise intended, for NEVs, 25 miles per hour may be an acceptable top speed capability.
- While carts might be used for any given local trip, trips made by cart tended to be single purpose trips. Linking together of several activities was generally not possible because the carts had no locking storage. However, most households did not appear to link activities, even in their automobiles.

Ride-and-Drive Clinics

- Though intended to determine the response of two hypothetical early market segments—EV hobbyists and environmentalists—to NEVs, the ride-and-

drive clinics indicate that activity analysis concepts better identify possible NEV buyers than does membership in either of the hypothetical segments.

- The speed limitation of NEVs created a clear demarcation of vehicle classes. Those willing to buy a NEV lived in locations that allowed access to a substantial set of their activities by a low speed vehicle.
- Across the wider variety of households contained in these sub-samples (than contained in the sub-samples from "golf cart communities"), vehicle size (that is, passenger and payload capabilities) was an important determinant of whether households judged NEVs to be practical vehicles.

Vehicle Trials

- The interaction between household activity choices, available travel tools, and the physical environment determine whether households judged NEVs to be practical travel tools. The ability of a household to construct a meaningful set of activities to which the NEV could provide access was a prerequisite to a favorable NEV purchase intention.
- We hypothesized that households had, or would be willing to form, distinct sets of activities they accessed by different travel modes. We found this to be true in those households in Davis that made extensive use of bicycles. Bikes are not used casually or haphazardly. These households had regular and well-defined, if occasionally overlapping, sets of activities they accessed by bike and by automobile
- Households had to distinguish NEVs from some other travel mode (usually automobiles) in order to form a positive purchase intention. If they saw the NEV simply as a limited car, they were less likely to consider buying one.
- Travel by all households was controlled to a very large degree by routines formed in response to schedules and activity links imposed by authority and coupling constraints.
- NEVs replaced a higher proportion of households' trips than of miles in all but one of our participant households. Across all households, NEVs traveled only 19% of the total distance households traveled during their diary weeks, yet they were driven for 41% of all trips.
- An important tradeoff between whether to drive the NEV or a car centered around adaptations to driving range. Adaptations included planning to decide which driver (if any) would take the NEV, switching vehicles between drivers during the day, planned changes in trip linkages, unplanned interruptions of trip linkages and daytime recharging of the vehicle.
- The experience of almost all the households argues for NEVs with minimum ranges of 40 miles, minimum top speeds of 40 miles per hour, and the option of vehicles capable of seating 2, 3, or 4 persons for NEVs intended to be used on the existing infrastructure of cities and towns not originally designed for NEVs.

Statewide Survey

- The 4.3 percent our sample who chose a NEV translates into an annual share of the new car market in California of just under 1 percent. In practice, the 19 households that chose a NEV (of 454 households) represent too small a sample to form a suitable basis for market share estimates, so we present the estimate simply as point of reference from which to make observations about markets for NEVs and marketing of NEVs.
- These households demonstrate that some households living in suburban communities around the state can visualize that NEVs allow them access to an important part of their activity space.
- They demonstrate that households are willing to construct entirely different household fleets of vehicles around a NEV, lending credence to our premise that household vehicle purchase decisions are based on the vehicles the household already owns as well as the vehicles they are considering for purchase.
- Thesw households reinforce the conclusion that people who chose EVs and NEVs regard them as practical transportation tools first, and as expressions of environmentalism second, if at all.

Household Travel Behavior and the Research Questions

We use the concept of a *household activity space* to provide a unifying thread throughout our NEV research. Briefly we describe a household's activity space as.

- the household members' activities;
- the time schedule of those activities;
- the geographic location of those activities;
- linkages between activities; and.
- the modes and routes used to access those activities.

Linkages include both linkages between one person's series of activities (e.g., whether the female household head makes a trip to her dentist on the way home from work) and linkages between household members (e.g., whether she then stops at daycare on her way home from the dentist to pick up one of the family's children).

The constraints on a household's activity space include:

- the household structure of relations and responsibilities;
- vehicle ownership and availability of other travel modes;
- time schedules imposed from outside the household;
- an income budget; and in the case of electric vehicles,
- a distance budget.

The distance budget is new to households. Gasoline (and diesel) vehicles and their ubiquitous fuel stations provide long daily range. But battery EVs and NEVs will have short

driving ranges and may require a few hours to recharge. Providing the information context for households to competently imagine how they would incorporate a limited range vehicle into their stocks of vehicles is the core of the designs for all of our studies.

From previous studies of the impact of limited range on households (Kurani, Turrentine and Sperling, 1994; Turrentine, Sperling, and Kurani, 1991), we identified two elements within the households' overall activity spaces that affected their demand for driving range:

- The *routine activity space* is defined by that set of activities that the household accesses on a daily and weekly basis (including all the other associated dimensions—location, mode and route to access, etc.);
- A *critical destination* is a destination that a household member feels they must be able to reach even if the "unlimited range" gasoline vehicle is not available.

As an additional premise for the NEV research we include:

- Households have, or can create, sub-spaces of their activity space that are defined by the choice of travel mode to access those activities.

Given these, our research questions are:

- "Will households create *NEV activity sub-spaces*?"
- "Is the existence of these *NEV activity sub-spaces* a sufficient condition for households to include NEVs in their choice sets for their next vehicle purchase decisions?"

Hypothetical Market Niches for NEVs: How we chose our samples

Each of the research tasks was intended to examine the response of real or hypothetical market niches to NEVs. The case studies of Sun City, Arizona and Palm Desert, California provide insights into the vehicle purchase and use behavior of households that already own small, low-speed vehicles. The physical infrastructure of these towns is similar to suburban developments everywhere; What makes these towns special is the characteristics of the households. First, most households that own and drive golf carts are made up of retired persons. They tend to have a great deal more discretion as to the schedules they keep than do households with children and workers. We conducted focus groups with 35 households in Sun City and 11 in Palm Desert that own and drive golf carts, but do not necessarily play golf. We also conducted interviews with city and county officials charged with overseeing traffic safety, and in Palm Desert, with overseeing the golf cart demonstration program that implemented golf cart infrastructure and cart permit plans.

The ride-and-drive clinics tested the response of small samples of two groups who are often cited as likely early buyers of electric vehicles—EV vehicle hobbyists and environmentalists. EV hobbyists are assumed to be knowledgeable regarding EV technology and the performance characteristics of the vehicles, and to be habituated to, or accepting of the shorter range and long recharge time of EVs. This interest and familiarity are hypothesized to translate into a greater willingness to buy original equipment manufacturer's (OEM's) electric vehicles. Environmentalists are hypothesized to be among the early buyers of EVs because of their interest in the potential for clean air. A total of 26 people took part in the ride-and-drive clinics and the subsequent focus groups.

The week-long NEV trials allowed households to explore they would use a vehicle that is not intended for highway travel, but intended to fill the specific niche of local travel on surface streets. By providing a NEV to a household for a week, we allow them to begin to explore how they would incorporate such a vehicle into their vehicle holdings. Fifteen households participated in the NEV vehicle trials, seven from Davis and eight from Sacramento. In this way, we explored differences in household response based on spatial scale, traffic levels and speeds, and the prior existence of mode-defined activity sub-spaces within the households' activity spaces. Household size ranged from one to four persons. A wide variety of household types were included in the study: households containing a single adult, two adults without children at home, two parents with a child or children, and single parents of a child or children. Ages of participants ranged from mid-twenties to mid-fifties.

To test whether households in California are willing and able to incorporate a vehicle that is clearly not a *car* into their household stock of vehicles, we included NEVs in a study of the statewide market potential for electric and natural gas vehicles. In that survey, we formalized and tested the concept of a *hybrid household*. Households who buy electric vehicles will be hybrid households, owning two very different types of vehicles that they use to access distinct sets of activities. Hybrid households will create activity sub-spaces defined by the types of vehicles they own. We believe that households who can construct *NEV activity sub-spaces* will perceive NEVs as valuable travel tools. Certain household characteristics facilitate the formation of this *NEV space*. These include the presence of additional travel tools (in suburban cities this primarily means ownership of more than one car) to overcome potentially binding constraints and a *NEV spaces* that contains important routine activities located near home or work.

For the statewide survey, we sampled from households whom we believe make up the single largest group of *potential hybrid households*. Household selection criteria included: own two

or more vehicles; buy new vehicles; own one 1989 or newer vehicle *and* one 1986 or newer vehicle; and at least one vehicles is not a full-sized vehicle. A total of 454 households from the San Francisco Bay Area, Sacramento, Fresno, Los Angeles, Santa Barbara and San Diego returned completed surveys. The response rate of useful surveys was 69 percent.

Because of the sampling scheme, we did not expect many households to choose a NEV. We did not sample from communities especially designed for NEVs (such as Palm Desert) nor from places that are otherwise very suitable for NEVs (such as Davis), but focused on variety of urban and suburban towns and cities in which the vast majority of Californians live. Thus, the image that the households created of their own activity space during the survey is not only useful to them in their decision making, but is crucial to our interpretations of these households' vehicle choices.

Activity Space and NEV Market Potential

We found that NEV purchase and use is most likely when:

- a high density of the household's activities are located within a compact geographic area around a location at which the NEV would regularly be charged, usually home but possibly also work;
- these household activities are accessible by low speed, or otherwise appropriate, streets;
- the household has few binding authority constraints or binding coupling constraints associated with its routine activities; and
- the household has a high degree of flexibility in assigning travel tools to household members (because of high automobile ownership, use of multiple travel modes, or a compatible structure of links between household members' activities).

Households that reject buying a NEV do so for one (or more) of three reasons:

- the small size of NEVs (expressed as a response to passenger occupancy, cargo capacity or safety perceptions of small vehicles) ruled out NEVs;
- the speed limitation of the NEVs created a binding capability constraint that precluded travel on some crucial roadway network links; or
- the *NEV- space* was not clearly differentiated from the activity sub-space of some superior (cleaner, cheaper, safer, bigger, etc.) mode or modes.

Markets for Neighborhood Electric Vehicles

Of the different market segmentation strategies we employed, the most powerful and consistent concept for identifying households amenable to NEV purchases was the *household*

activity space. Because it is multi-dimensional (including not only space and time but also types of activities, household relationships, and available travel tools) it is difficult to generalize which elements of *activity space* determine who will buy NEVs. One useful way to employ the concept is to describe buyers and users not in terms of their personal characteristics, but in terms of the characteristics of the environments in which the vehicles would be used.

Described this way, important market niches for NEVs include resort towns and facilities, new developments of virtually any land use type designed to accommodate low speed vehicles, smaller cities and towns receptive to NEVs, and persons unable to operate standard motor vehicles but who could operate a NEV with appropriate assisting technologies. We also recognize that many households who live in larger cities can construct *NEV spaces*. These represent a viable NEV market, but are difficult to identify by conventional market survey techniques.

As a market development strategy, if the large OEM manufacturers do not step forward to offer NEVs, then smaller companies may do so. These smaller companies will presumably be better able to serve smaller, concentrated market areas than larger, dispersed ones. NEV-friendly resort areas and new developments represent such concentrated markets for NEVs. In non-resort cities and towns, greater effort will have to be expended to market NEVs. This will require providing images of NEVs as practical transportation tools and developing adequate sales and service networks. Persons who are now unable to drive cars, but could operate a NEV, are dispersed throughout our cities and towns. To provide them with access to activities through the adaptation of NEVs to their travel needs will require that substantial resources be committed by either a few large manufacturers or by numerous small, entrepreneurial firms.

Different types of NEVs are also required for these different markets. Throughout our studies, households have demonstrated a need for different levels of passenger, payload, speed and range capabilities. We see "enhanced golf carts" as a viable NEV for many settings; we see a much higher level of performance NEV as a necessity in others. In the towns of Palm Desert, California and Sun City, Arizona, we find that vehicles of minimal performance capabilities can provide valuable transportation services. We see this in Sun City, even with no specialized infrastructure to accommodate low-speed vehicles. Most households living in the neighborhoods of Davis and Sacramento, California, found that a minimum 45 mph top speed was essential to their use of a NEV. Families with children

often required more than the two seats available to them in either of the vehicles in our demonstrations.

We contrast the importance of household activity space concepts in defining markets for NEVs with other, less useful, concepts. In developing market segments for gasoline vehicles, household travel patterns have played a much less important role than other household characteristics. We find, at best, mixed evidence that NEV markets can be identified by socio-economic, demographic, and attitudinal information about households so often used to identify and create markets for conventional vehicles.

From the case studies of Sun City and Palm Desert, we learn that it is not the retirement status of the households that determines golf cart ownership and use, but the specialized nature of the communities in which these households live.

We find little evidence in the ride-and-drive clinics that EV hobbyists or environmentalists per se will be among the first buyers of NEVs if they, as any other household, do not first perceive the NEV as a practical transportation tool. Whether they perceive a NEV to be a useful transportation tool is not a function of technical prowess or environmentalism, but is a function of their activity space. For example, as our environmentalist sub-sample lives in Davis, their "neighborhood vehicle" is a bicycle. Within this small city, with its flat terrain and abundance of bicycle infrastructure, the bicycle is seen as a better environmental vehicle. Within our small sub-samples of EV hobbyists, those who lived in downtown Sacramento, closely surrounded by many of their routine activity locations, stated a positive purchase intention toward NEVs.

Households that chose a NEV in the statewide survey did so because their travel and vehicle ownership patterns were amenable to NEV use or because they were willing to add the NEV as an additional vehicle. We cannot ignore that NEVs cost less than other vehicle type within our experimental design. Never the less, a household would not choose a vehicle they could not use. Households that chose NEVs appear to be no more motivated by environmental concerns than are the households that chose any other EV, and they are on average no more likely to believe that large, immediate lifestyle changes are required to address environmental problems. Thus, to some households in suburban California, NEVs will be seen as entirely suitable means to maintain the mobility that comes with multiple vehicle ownership, but at a greatly reduced cost.

The descriptions of the households that do, and do not, choose NEVs in the statewide survey must be interpreted with care. While we expect households of middle age parents with

children to be more responsive to EVs (see Turrentine, Sperling and Kurani, 1991), the low cost of NEVs confounds any expectations we may have had based on household income. The apparent disinterest toward NEVs shown by households made up of retired persons should not dissuade us from believing that households of retired people will be an important market for NEVs. These households in particular highlight the importance of the physical environment in which the NEV might be used. While it is possible that retired households in our statewide survey sample did not choose NEVs because they do not foresee enlarging their stock of vehicles and may be conservative regarding new technology, we need only recall the case studies of Palm Desert and Sun City to know that within appropriate environments, retired households will be important NEV market segments.

Recommendations

Demonstration projects

To develop these markets, there is no more important task than continued demonstrations of a variety of NEVs. As a distinct class of vehicles that embodies performance characteristics well outside the bounds consumers usually experience, markets for NEVs will depend on education, reflection and increased familiarity. We have demonstrated that the ability of a household to conceptualize a distinct and valued set of activities to which a NEV provides access is central to purchase consideration. Households will have to examine, and possibly reconsider, mode choices, route choices, activity choices and a variety of other travel and life style choices that simply are not as relevant to the vehicle purchase decisions they now make. In some communities, such as golf resorts, this process is already underway. If many households are driving about in golf carts, it is much easier for others to imagine they can too. In other communities, greater effort will be required to provide examples and images for households to use in constructing their own *NEV spaces.*

Demonstration projects must be designed with clear goals and objectives. Whether households buy NEVs will depend on NEVs provide access to some substantial subset of activities. This *NEV space* is constrained, in part, by the interaction between the capability constraints imposed by the NEV and the objective spatial structures (primarily transportation infrastructure) of the city or town in which the household lives. Matching vehicle capabilities to intended use environments will increase the effectiveness of NEV demonstrations. Vehicles with capability constraints (performance attributes) that are too limiting may lead to peremptory rejection of NEVs by consumers. Vehicles that are of greater performance capabilities than required will unnecessarily drive up the cost of NEVs.

Either error will lead to misguided investments in supporting infrastructures, including roadway, recharging, and vehicle sales and service.

Coalition building

NEV proponents will need to form coalitons to overcome several key problems. These include the currently limited variety and limited production of NEVs and barriers to the acceptance of NEVs by safety regulators. These issues are important to consumer acceptance because they represent barriers to consumers ever having the opportunity to evaluate NEVs. While legislative approval of specific demonstration projects (such as that in Palm Desert) can be time-consuming, such approval for large-scale demonstrations might generate sufficient demand for production of NEVs. Though they have chosen to initially invest in freeway capable EVs, the National Station Car Consortium is one model for a coalition that is trying to call forth EV production In order to address safety problems within the existing institutional structures for transportation safety, coalitions of NEV manufacturers, NEV users, and communities and policy makers interested in promoting NEVs should lobby for changes in existing vehicle definitions to legitimize NEVs in the codes and regulations governing the design, sale, and registration of vehicles and the design of roadway infrastructure.

Quantitative market estimates

While the intent of the market research reported here was to understand the dynamics of markets for NEVs, it will be beneficial to develop quantitative estimates of the NEV market niches. Such estimates could also build momentum and legitimacy for continued development of NEVs. We would caution against analyses based on such simplistic measures as counts of golf carts, even within golf resort communities. We observe that the introduction of a variety of NEVs creates fundamentally new dynamics into the market for household vehicles. A more appropriate starting point is to examine the activity spaces of households living within the types of vehicle use environments identified as NEV market niches in this report.

I. INTRODUCTION

Tom Wolfe. Kandy*Kolored Tangerine*Flake Streamline Baby. Cited in Dettelbach.

"To conjure up California—that vast sun and smog-blinded country swaddled in bands of highways and cloverleaves—is to see why cars are America's newest gods."

As cars proliferated during this century, people came to rely on them more, creating a spiraling dependency. As dependence on cars increased, cars began to dominate land use patterns and transportation infrastructure. Streets were made wider and sidewalks narrower or non-existent. Now, most people in suburban neighborhoods often do not consider walking, bicycling, or even riding transit. Automobility has spiraled upward, creating, in an iterative fashion, increasingly auto-centric infrastructure and social behavior.

Some excesses of automobile dependence can be avoided, but, at least for the U.S. and other affluent countries, private transportation is here to stay into the foreseeable future (Sperling, 1995). The growing tensions between demand for greater automobility and demand for more environmental quality can be eased, however, with more environmentally benign vehicles. One strategy is to use very small electric vehicles, for now referred to as neighborhood electric vehicles (NEVs). Not only will they reduce environmental degradation, but they also could be a catalyst in creating more environmentally benign, human-scale communities.

The Challenge

Motor vehicles of today are capable of carrying 4 or more people, accelerating quickly to 60 mph, and cruising comfortably at 75 mph. These attributes are desirable for some trips. As long as all vehicles are expected to serve all trips, large powerful vehicles will be preferred. But this all-around capability comes at a cost, not only in terms of the direct costs of vehicles, fuels, and road space, but also external environmental costs and the indirect costs of maintaining an auto-centric transportation system. Multiple vehicle ownership allows an increasing number of households the flexibility to specialize their vehicles. Almost 40% of households own 2 vehicles and an additional 20% own 3 or more, comprising a total of 54 million households with 2 or more vehicles (U.S. Federal Highway Administration, 1990). Moreover, for most trips and households, large, full-powered vehicles are not necessary.

Approximately half of all trips are less than 5 miles in length. Further, they are made by a person traveling alone at a relatively low average speed (EPA, 1992).

The problem is a uniformity of expectations by consumers, government regulators and highway suppliers. All vehicles are expected to satisfy all purposes; all roads are built to serve all these multi-purpose vehicles; and all rules are designed to facilitate their movement. The result is a strong inertia that discourages innovation and change.

The time is ripe for change. Continued attachment to such cars holds back policy demands. Continued attachment to familiar vehicles frustrates efforts to reduce energy consumption, adopt battery-powered zero emission vehicles, and create more human-scale neighborhoods.

Small cars are one outlet for relieving these pressures. They provide an opportunity not only to reduce energy and environmental impacts, but also to catalyze the creation of more human-scale neighborhoods. Neighborhood vehicles are a compelling idea that deserves to be tested and nurtured. The potential drawbacks—primary among them, the safety of vehicle occupants—are few and can be mitigated. The potential social, economic, environmental and private benefits are hugely positive. But realizing those benefits requires overcoming the hegemony of large vehicles.

The variety of vehicles to which the name "neighborhood electric vehicle" (NEV) has been given ranges from electric-assist bicycles to small, lightweight, freeway capable electric vehicles. The purpose of all these vehicles is to substitute a clean, efficient vehicle for the most polluting, least efficient trips made by full-size, internal combustion engine vehicles (ICEVs). These trips are characterized by short distances, low average speeds and frequent speed changes and stops. Further, these trips may often link several stops and activities together—increasing ICEV emissions through multiple cold start/warm soak cycles.

Under the auspices of the CALSTART Neighborhood Electric Vehicle Program, the Institute of Transportation Studies at the University of California, Davis has conducted a variety of NEV market assessments and vehicle demonstrations. This report describes that research and the potential personal, private transportation market for NEVs in California.

Overview of the NEV Market Research and Vehicle Demonstrations

The market studies and demonstrations described in this report include the entire spectrum of NEV types, with the exception of electric-assist cycles. The vehicles that were part of the NEV market research and demonstrations are summarized in Table 1.1. Each NEV type is

suited to different applications, and thus different market segments. The demonstration projects and marketing studies conducted by the Institute of Transportation Studies at UC Davis focused on household market niches for NEVs, rather than fleet market niches. While we developed infrastructure and policy studies that include new, NEV-friendly land use development, we focused our demonstration projects and market assessments primarily on whether NEVs (and which of them) would fit into the existing urban structure of California. Our primary intent was to explore household adaptations to NEVs, to illuminate likely market dynamics for these novel transportation options, and to examine the responses of market segments that be hypothesized to be early buyers of NEVs.

Table 1.1: NEVs Evaluated in Market Research and Demonstration Projects

Research Element	NEV Types	Vehicle Descriptions		
		Seating	Top Speed[1]	Driving Range[1,2]
Case studies of Sun City, AZ and Palm Desert, CA.	Golf carts	All carts: 2	Electric: 15 mph Gasoline: 25 mph	Electric: 15 to 25 miles Gasoline: > 200 miles
Ride-and-Drive Clinics	City Com City-El	1	35 mph	20 to 30 miles
	Kewet El-Jet	2	40 mph	25 to 30 miles
	Horlacher City	2	60 mph	45 to 60 miles
	Horlacher Sport	2	75 mph	55 to 90 miles
	Esoro	2+2	75 mph	55 to 90 miles
	Solectria	2	60 mph	80 miles
Household NEV Trials	City-El	1	35 mph	20 to 30 miles
	Kewet	2	40 mph	25 to 30 miles
Survey of multi-car households who buy new vehicles.	Shown images of Kewet El-Jet as an example NEV.	2, 3 or 4	40 mph	40 miles

1 Top speed and driving range for the City-El and Kewet are based on our actual experience. Data for the Horlachers, the Esoro and the Solectria are based on published specifications. Speed and ranges for golf carts were reported by cart owners in our case studies in Sun City and Palm Desert

2 All ranges are based on lead-acid batteries. Longer ranges are offered by Nickel-Cadmium batteries available on all these vehicles except the City-El and the golf carts

The CALSTART-sponsored NEV market research and demonstration projects performed by ITS-Davis included:

- case studies of the "golf cart communities" Sun City, Arizona and Palm Desert, California;
- ride-and-drive clinics in which people drove and reviewed a wide variety of electric vehicles, including NEVs;
- vehicle trials in which households were given use of a NEV for a one-week period; and
- a statewide survey of household vehicle purchase intentions based on existing household vehicle holdings, vehicle purchase intentions, household travel diaries and maps of household activity locations.

In our market research we examined both existing communities where NEV-like vehicles are in use today and used a variety of techniques to create information contexts in which people unfamiliar with NEVs could competently imagine how such a vehicle might fit into their household's stock of vehicles. We examined the response of market segments defined both by dominant urban development patterns and by characteristics of the respondents themselves. Davis, a small university town in California's Sacramento Valley and already widely known for its extensive bicycle infrastructure, served as one research setting. The nearby city of Sacramento provided a setting that contrasts with Davis in urban scale and transportation networks. Two groups of hypothetical "innovators"—EV hobbyists and environmentalists—assessed NEVs. A wide variety of household types participated in the different studies—single person, single parent, unrelated adults, nuclear families, retired couples and more

Market Study and Demonstration Project Goals

The overall goal of this research agenda was too determine whether households can imagine using a NEV, and based on that assessment, whether they would buy one. We wish to understand the possible dynamics of market development. Most of the research we report here was conducted on small samples of households in highly interactive settings. Our use of in-person interviews, ride-and-drive clinics, focus groups, extensive travel diaries and detailed surveys was intended provide detailed images of households' responses to NEVs. It was not our intent to develop quantitative estimates of the market. Rather, this report provides a sound basis for subsequent estimates of the size of identified market niches.

We do not suggest that the level of reflection and testing that our survey participants put into their evaluation of NEVs is similar to that which they apply to their purchase of gasoline

vehicles, but neither are we trying to sell them just another car. Electric vehicles and neighborhood electric vehicles will change more than just the mix of cars, they will change the basis upon which cars are bought and sold. One trend that these vehicles will reinforce is specialization. Increased vehicle ownership by households allows for the specialization of vehicles to specific tasks.

Vehicle and urban infrastructure attributes likely to affect the marketability of NEVs were examined. Reduced driving range, possible restrictions on access to public roads, smaller load-carrying capacity, new maintenance regimes, uncertain consumer safety perceptions, elimination of vehicle emissions, and home recharging were evaluated for near-term markets Longer term issues examined included the effects of family structure, vehicle ownership arrangements, neighborhood morphology, and land use patterns on NEV market potential.

Each of the four specific market assessment elements listed above emphasizes one or more of these goals. The Sun City and Palm Desert case studies focus on safety, accessibility to activities, and vehicle, road, and neighborhood attributes that cannot be evaluated within the context of a single household's vehicle and travel choices. Additionally the case studies include interviews with planners, designers, developers and engineers responsible for the physical construction of neighborhoods, policy actions to accommodate NEVs and support infrastructure. They also suggest a potential historical dynamic for the development of land use forms and density that will affect the marketability of NEVs.

Initial perceptions of NEVs, their attributes and their usefulness are ascertained in the vehicle trials and drive clinics. Street infrastructure, accessibility to activities, transportation control measures (TCMs) and transportation demand management (TDM) were treated in greater detail in the household vehicle trials. Lastly, a sense of the relative attractiveness of NEVs to the larger population of new vehicle buyers was assessed in the statewide survey.

Each of these main research elements is described independently in subsequent chapters of this report. A synthesis of results and overall conclusions and recommendations are presented in the final chapter. First though, this introduction provides an overview of the theoretical approach to travel analysis that provided the unifying structure to the variety of market assessments and demonstrations.

Unifying Theoretical Concepts

The variety of NEV types and the differences between implementing NEVs in existing urban development and in urban structures specifically designed for them presents a potentially

confusing array of research possibilities. We use the concept of a *household activity space* to provide a unifying thread throughout our NEV research This concept and its application to each of the market study and demonstration elements will be described in detail later, but briefly we describe a household's activity space as:

- the household members' activities;
- the time schedule of those activities;
- the geographic location of those activities;
- linkages between activities; and
- the modes and routes used to access those activities.

Linkages include both those between one person's series of activities (e.g., whether the female household head makes a trip to her dentist on the way home from work) and those between household members (e.g., whether she then stops at daycare on her way home from the dentist to pick up one of the family's children).

The constraints on a household's activity space include:

- the household structure of relations and responsibilities;
- vehicle ownership and availability of other travel modes;
- time schedules imposed from outside the household;
- an income budget; and in the case of electric vehicles,
- a distance budget.

The distance budget is new to households. Gasoline (and diesel) vehicles and their ubiquitous fuel stations provide very long daily range—the distance one can travel in a day is limited by time constraints (and speed limits), not the total amount of energy that can be stored onboard the vehicle or the rate at which that energy can be replenished. But battery EVs, and NEVs in particular, will have short driving ranges and may require a few hours to recharge. Providing the information context for households to competently imagine how they would incorporate a vehicle of limited range into their stocks of vehicles is the core of the designs for all of our studies. In the case of golf cart case studies, we examine households that have already incorporated limited range (and low speed) vehicles into their fleet.

In previous studies of the impact of limited range on households (Kurani, Turrentine and Sperling, 1994), we identified two elements within the households' overall activity spaces that affected their demand for driving range:

- the *routine activity space* is defined by that set of activities that the household accesses on a daily and weekly basis (including all the other associated dimensions—location, mode and route to access, etc.); and

- a *critical destination* that a household member feels they must be able to reach even if the "unlimited range" gasoline vehicle is not available.

As an additional premise for the NEV research we include:

- households have, or can create, sub-spaces of their activity space that are defined by the choice of travel mode used to access those activities.

Given these, our initial research questions are:

- "Will households create *NEV activity sub-spaces*?"

- "Is the existence of these *NEV activity sub-spaces* a sufficient condition for households to include NEVs in their choice sets for their next vehicle purchase decisions?"

The remainder of this report is devoted to answering these questions. In the following section we develop the concepts from the activity analysis paradigm that we use throughout our NEV research. In particular, we present our rationale for focusing on the new daily distance constraint posed by NEVs and for discussing neighborhood electric vehicles in terms of the access they provide to a *local activity space* that we define as the *NEV activity sub-space.*

What is Activity Analysis?

Activity analysis is distinguished from other transportation research paradigms by its emphasis on travel as a derived demand that exhibits daily and multi-day patterns, related to and derived from differences in life style and activity participation across the population (Jones, et al, 1990). Individual households and their members are the behavioral units that are the source of activity participation. Individual household members' choice of activity and location are mediated by systems of constraints that include the structure of family relationships within the household. Travel is derived from changes of activity type by household members that result in a change of activity location. Practitioners of activity analysis map activities in time and space and trace the interdependencies and constraints that define activity choice Further, transportation researchers are concerned about choices of travel mode and timing, duration, and distance of the trips that link activities.

The intellectual roots of activity analysis are studies in geography that delineated systems of constraints on activity participation in time-space (Hägerstrand, 1970) and identified patterns

of behavior across time and space (Chapin, 1974), and psychological studies of why people participate in activities and how those motivations are mediated by social structure (Fried, et al, 1977). While later writers (e.g., Koppelman and Townsend, 1987; Salomon and Koppelman, 1988) have incorporated elements of sociological and economic theory, the research reported here hearkens back to the early geographical roots of activity analysis to define the new travel constraints and tools that NEVs might represent. Once we have defined the new constraints and tools, their effects on household travel behavior are explored in the market research and vehicle demonstrations described in the following chapters.

The Early Geographical Roots of Activity Analysis

In his presidential address to the members of the Regional Science Association in 1970, Hägerstrand made what is often cited as the seminal statement both of the need to examine spatial relationships as expressions of human behavior and of a set of organizing principals around which to begin such an examination (Hägerstrand, 1970). He called for models of spatial behavior based on an examination of individuals rather than statistical aggregates of people. To do so, he introduced the concept of *time-space prisms* —bounded areas of time and space in which it is possible for a person to exist. Discontinuities of existence in time are not allowed and a person's possible locations in space at one point in time are determined in part by their locations in space at preceding points in time and anticipated locations in the future. Within these prisms of allowable time-space, individuals follow *paths* of actual time-space locations.

Central to defining the shapes and sizes of these prisms and the paths through them, Hägerstrand proposed a typology of constraints: capability constraints, coupling constraints, and authority constraints. Capability constraints arise from biological requirements and the tools available to an individual. Some capability constraints, notably biological constraints such as sleep and sustenance, follow the individual throughout their time-space path, but are typically satisfied at a single, home location and require a certain minimum amount of time.

How Capability Constraints Subdivide the Time-Space Prism

We stated above the premise that households have, or will construct, portions of their time-space prism that they access by different travel modes. The origin of this premise lies in the fact that different travel modes impose different capability constraints on our ability to move through space and time. Distances between activity locations can be mediated by movement (of people or goods) or communication by either inherent physical abilities or the use of tools. Thus we travel by a combination of certain physical functions and tools—walking,

bicycles, buses, autos, etc. We communicate either directly through our senses or by communications technology. Thus the time-space prism through which an individual moves can be divided into regions of varying accessibility, depending on her physical capabilities and the availability to her of different travel and communication tools.

The NEV is a new tool to mediate distance—but it is a limited tool compared to the capabilities of a full-size ICEV. Because a NEV can only be driven a relatively short distance before requiring a lengthy recharge time, it accesses only a limited part of the time-space prism in which the household members can exist. Whether a household will consider buying a NEV will depend in part on whether that household can access desired paths through its time-space prism using a NEV in conjunction with other travel tools available to the household.

While capability constraints define the extent of our time-space prism, our path inside that prism is determined in large part by coupling and authority constraints. Coupling constraints "define where, when, and for how long, the individual has to join other individuals, tools, and materials in order to produce, consume and transact " (ibid.) To get a haircut, we must arrive at the barber shop during the hours it is open, and if we are particular, on a day our favorite barber is working. Employment usually requires that we interact with other people and tools on a particular schedule at one or more locations. Authority constraints define *domains* within the time-space prism to which an individual either controls the access of other individuals or to which his access is controlled by others.

Empirical research has shown that household travel can be explained by this framework of constraints. For example, Kitamura, Nishi and Goulias (1990) show that choices of timing and location for non-work activities by commuters are consistent with a set of hypotheses based on the constraints Hagerstrand proposes. Those authors found that coupling constraints (shop opening times) and authority constraints (work start times) severely limit the number of non-work trips made before work. Because of authority constraints and capability constraints, non-work activities made during work-time are tightly clustered in space around the work location and tend to be either work-related trips or trips to eat. Non-work trips made after work access a wider variety of activities, and though clustered around home, are not as tightly clustered as either before- or during-work trips.

Time-Space Prisms and Household Activity Space

Our use of the phrase *activity space* to describe the sets of activities that households access is based on definitions used by Horton and Reynolds (1971) in their initial development of an

analytical framework to examine the effects of urban spatial structure on individual behavior. If Hägerstrand defined the limits of the time-space prism, then Horton and Reynolds provide additional insight into how households choose paths within the prism. They define *objective spatial structures* as the location of a household relative to the objective locations of potential activities and their associated objective levels of attractiveness. By "objective" they mean that relative locations are measured by some standard meter, such as miles of separation or changes in degrees of latitude and longitude, that is applied to all locations. This objective spatial structure contains linear features (e.g., transportation networks, commercial "strips"), nodes (e.g. shopping centers, individual residences or manufacturing plants) and surfaces (e.g., residential population densities). Further, the household's *action space* is defined as that group of all locations or nodes within the objective spatial structure about which the household has information and the subjective utility the household associates with those known locations. This subjective utility may be a function of linear features connected to the node (e.g., how accessible is the location by various transportation networks) and surfaces in which the node is embedded (e.g., whether the location is perceived to be located in a safe area). Finally, the *household activity space* is defined as the subset of all locations in the action space with which the household has direct contact as the result of day-to-day activities. Thus a household's *activity space* is a set of realized *paths* through Hägerstrand's *time-space prism*. The home location, as the point from which all else in the activity space is perceived, is itself part of the activity space.

Horton and Reynolds go on to postulate a theory of learning that directs activity space formation and change. The salient point here is that changes do occur in objective spatial structures, action spaces and activity spaces. While a household may reach a point where its activity space remains relatively stable, all that is required to produce a change in the activity space is for the household to add one location to its activity space from its current action space or delete one location from its existing activity space. A change in the action space itself requires learning of a new location and forming an initial assessment of its subjective utility. Changes in the objective spatial structure typically take place outside the control of a single household. Such changes are typically long-lived additions or removal of nodes (e.g., newly installed EV recharging at a mall already in the household's action space), linear features (e.g., a new NEV-only lane), and surfaces (e.g., agricultural land newly incorporated into a city for urban development).

Upon this largely geographical foundation, some transportation researchers are building models of personal travel and goods transport. Transportation research is fundamentally concerned with changes of activity location that require the consumption of resources outside

the individual or the household. Much of this work has dealt with identifying patterns of travel in an effort to plan transportation infrastructure and services. Daniels and Warnes (1980) observe that

> "...it remains true that for most of the time, most of the population exhibit spatial behavior which in its main elements is both repeated and conventional The point is illustrated by drawing the distinction between our relatively high ability to predict the daily volume of demand or flow on a particular road, bus or train service ... and our much weaker ability to predict which individuals would constitute that flow."

It is our intention to take on this more difficult problem; to identify who will buy NEVs before concerning ourselves with how many people will buy NEVs. To achieve this aim we explore how individual households respond to constraints—a distance budget, a speed limit and a vehicle size limit—on their activity space. Adaptations may take the form of rejection of a vehicle that embodies the constraint (refusal to consider buying a limited range vehicle), changes in their activity space (including those that require changes in their action space) or other adjustments. Only with this background, built up through ride-and-drive clinics, vehicle trials and case studies, do we attempt draw conclusions about vehicle ownership choices that will determine the market for NEVs.

NEVs: New Travel Constraints, New Travel Tools

NEVs, because of their short daily range, low top speeds and small payload and passenger capacities, represent a new travel tool with many potential capability constraints. These constraints may act to restrict the choice of activities that could be accessed in a NEV. We hypothesize NEV purchase decisions will be predicated on households' assessment of how tightly a NEV restricts activity choice. Whether a household is willing to include a NEV in the set of vehicles it will potentially buy will depend in large part on whether the NEV is seen to provide access to some meaningful set of activities. This set of activities we call the *NEV activity sub-space* or more simply, the *NEV space.*

There has been an overwhelming pre-occupation with the effect that limited range will have on the market for electric vehicles. We have explored this pre-occupation elsewhere and greatly discounted the impact of a daily range limit on households that own more than one vehicle. Driving range limits on one vehicle appear to cause insurmountable problems in only a few of the increasing proportion of multi-vehicle households (Kurani, Turrentine and Sperling, 1994; Turrentine and Kurani, 1995). Yet, driving range limits may be relevant to analyses of the market for NEVs because these vehicles will have even shorter ranges than their larger, freeway-capable electric brethren. NEVs also represent a possible new time

constraint because of their limited top speed. The choice of activities accessed in a NEV may be circumscribed by how long it takes to get places as well as how far those places are from home or each other. These two constraints act to reduce the size of the time-space prism in which it is possible for an individual to exist. They limit the activity locations that can be accessed in a NEV.

If the payload and passenger capability constraints do not allow a driver to provide needed or expected transportation services to another household member (or carpool member or some other person dependent on that driver), this creates conflicts through the coupling constraints to those dependent travelers. Further, these capability constraints—range, speed and size limits—may produce conflicts with authority constraints. For example, perhaps the only way an adult in the household could drive a NEV to work would be to leave earlier to be sure of arriving on time (workplace authority constraint and speed capability constraint causes earlier departure from home). Now suppose this person is also responsible for delivering children to daycare (a coupling constraint) However, the daycare center may not open in time (an authority constraint) for the adult household member to both leave early enough to arrive at work on time and yet leave late enough to deliver the children to daycare as it opens. In this hypothetical case, the new capability constraint on vehicle speed, the existence of a coupling constraint to another household member, and the conflict between authority constraints imposed by work place schedules renders a time-space path via a NEV unfeasible.

Despite such possible limits, we should not lose sight of the fact that, especially in multi-vehicle households, a NEV may represent a highly valued travel tool. If the household can construct a *NEV space*, then the vehicle may be seen as a way to maintain the high accessibility and mobility of multi-vehicle ownership at a much reduced cost over owning and operating yet another ICEV. Thus in multi-vehicle households we expect NEVs might be accepted as either additional vehicles or replacements for existing vehicles. Further, because of their low initial cost and operating expenses, NEVs may draw one-vehicle households into the market for EVs.

The activity analysis framework demonstrates that trips cannot be treated as single, divisible units. Each single trip is dependent on choices made about previous trips and on trips still to come. This point is central to the choice of the activity analysis framework for our NEV market research. Activity analysis provides a structure in which to explore the meaning of travel constraints within a household's entire set of activities and travel tools. With this background, we proceed to a discussion of the specific market assessment and vehicle demonstration tasks.

II. CASE STUDIES OF "NEV" COMMUNITIES: Palm Desert, California and Sun City, Arizona

Excerpt from California State Assembly Bill 1229.

> *"It is the further intent of the Legislature that this [golf cart] transportation system be designed and developed to best serve the functional commuting needs of the employee, student, businessperson, shopper, and sportsperson,..."*

Electric golf carts are a challenge to those who seek to develop and sell electric vehicles and neighborhood electric vehicles. To many people, electric golf carts symbolize electric vehicles—slow, small, toy-like novelties. Electric vehicles will never be regarded as serious transportation tools unless this perception is overcome. Yet in some communities, an electric golf cart is a nearly ideal neighborhood electric vehicle—simple, inexpensive, clean, quiet, and functional. Golf resort towns and other adult retirement communities are examples of such places. We visited two such locations—Palm Desert, California and Sun City, Arizona.

Our purpose in visiting these communities in May 1993 was to compare and contrast two very different approaches to using golf carts as general purpose transportation vehicles. Palm Desert had recently instituted a Golf Cart Transportation Demonstration Program. The program continues to involve a directed effort by the City of Palm Desert to facilitate and legitimize the use of electric golf carts as a general purpose travel mode. The laissez-faire approach of government to the widespread use of golf carts in Sun City is in stark contrast to that in Palm Desert. Many of these differences can be attributed to forms of governance (both state and local) and differences in timing and patterns of urban development within the historical process of vehicle technology development and air quality legislation. However, these sources of differences are not the primary focus of this analysis.

Our primary focus is to observe vehicle ownership and use patterns within these locations and to observe whether households in these communities had constructed an activity sub-space that they access by golf cart. In each town, we conducted focus groups with people who use their golf carts for varying amounts of their daily travel. Some people use their cart as they might use a second car—making local trips to any of a variety of activities. Others primarily use them to travel to and from important recreational activity locations, i.e., golf courses. Many of the differences in these *NEV spaces* were explored in focus groups with golf cart drivers. These focus groups and interviews with local and regional officials were used to discover differences in the contexts in which residents of each town were making decisions about *NEV spaces*. The

context includes the types of carts, availability of specialized infrastructure, history of cart use for general travel purposes, and insurance and registration requirements

The basic land use patterns and roadway infrastructure designs of the two towns are similar. Both have networks of wide residential streets that can provide generally good access for golf carts to a variety of activities. In both towns though, certain locations can only be accessed by crossing a few major, high-speed roads. However, Sun City was built by private developers as a retirement, golf resort. From the day the first homes were sold, golf carts were allowed on the streets. Automobile and cart drivers have always shared the roads. In contrast, Palm Desert is attempting to produce a cart-friendly network in the midst of existing roadway infrastructure that is perceived as hostile to carts.

While golf carts may operate in an atmosphere of laissez faire in Sun City, the types of households that may live there are tightly controlled. Sun City is exclusively an adult, retirement community. Palm Desert features a wider variety of households living within the city limits. Thus it has many activity locations absent from Sun City—notably facilities for children such as daycare centers, schools and parks. Still, Palm Desert's economy is dependent on the recreation opportunities afforded by its golf courses and while its population is not entirely dominated by retired households as is Sun City, Palm Desert does have a large population of households made up of retired persons. Palm Desert and Sun City represent two different paths to building communities around NEVs. We do not examine them because electric golf carts are our model NEVs, but because the experience of people who use these small, low speed vehicles on a daily basis to access a wide variety of activities informs us of the possibilities for such vehicles elsewhere.

Palm Desert, California

This section examines the efforts of Palm Desert, CA to implement its golf cart demonstration program. Researchers from ITS-Davis traveled to Palm Desert in May 1993 to interview city personnel and golf cart drivers and to observe the infrastructure developments. Electric golf cart owners have been able to obtain permits to use their carts throughout the approved golf cart street and path network since January 14, 1993. By May 1993, some 80 cart owners had obtained permits for their carts. The installation of the cart-specific physical infrastructure—routes, lanes, paths and signs—had begun in April 1993. The Palm Desert experience is examined as a relevant example of the types of roadway infrastructure changes localities may have to make to assist the market entry of small, light-weight, non-freeway capable vehicles.

Physical barriers to the likely entry by neighborhood electric vehicles (NEVs) into urban communities are suggested by this recent urban experience with golf carts.

The Golf Cart Demonstration Program

In January 1993, the City of Palm Desert, California implemented a golf cart demonstration project. Previous to that time, a survey of city residents had indicated that many people in this community would use their golf carts for local travel if they were allowed to do so. Until recently in California, golf carts were only allowed on public streets that had speed limits of 25 mph or less and that were within 1.5 miles of a golf course. The California Attorney General issued an opinion in 1992 stating golf carts could drive on any street with a speed limit of 25 mph or lower regardless of proximity to a golf course, but could neither drive on, nor cross, any streets with a posted speed limit higher than 25 mph.

Because of the Attorney General's opinion and opposition from the California Highway Patrol (CHP) and the California State Department of Transportation (Caltrans), an act of the California State Legislature (Assembly Bill 1229, circa 1992) was required to authorize the Palm Desert demonstration project and to define the limits under which golf carts would be allowed to travel on public streets in Palm Desert. The bill was introduced by Assemblyperson Tricia Hunter and was supported by the South Coast Air Quality Management District (SCAQMD). As stated in the quote at the top of this chapter, the bill is clear in its intent to expand the use of golf carts to general purpose, local travel. To achieve this end, the bill creates Chapter 5 of Division 2.5, Sections 1930-1941 of the Streets and Highway Code, California Vehicle Code Section 21115.5 and amends California Vehicle Code Section 21716. In addition to these changes to these Codes, AB1229 stipulates the city's responsibilities to plan and develop golf cart specific infrastructure, golf cart safety standards and operating limits. The bill includes this specific definition of a golf cart:

> "'Golf cart' means an electric motor vehicle having not less than three wheels in contact with the ground and an unladen weight less than 1,300 pounds which is designed to be and is operated at not more than 15 miles per hour and is designed to carry golf equipment and not more than two persons, including the driver."

An oversight committee—the Golf Cart Transportation Committee—monitors the progress of the demonstration project. The agencies represented on the Committee are: City of Palm Desert, California Energy Commission, California State Assembly, Caltrans, South Coast Air Quality Management District, California Highway Patrol, Riverside County Sheriff, Southern California Edison, Automobile Club of Southern California, Palm Desert Town Center, the Program engineering consultants and local electric golf cart retailers

Specific golf cart and driver criteria for participation in the demonstration project were developed, as specified by AB1229. Because the project is intended to explore the potential of small, low speed vehicles to improve air quality, only electric golf carts can be approved for use, not gasoline-powered carts. The carts must be equipped with basic safety equipment—horn, head lights, brake lights, front and rear turn signals, rear view mirrors, reflectors, parking brake, windshield, seat belts, and a cart locking device Each cart must pass a City inspection of these features. The cart owner must take part in an orientation at the time the permit is issued. Drivers of the cart must hold a valid driver's license or be certified as physically disabled, yet capable of operating an electric golf cart. The cart operator must provide proof they and their cart are insured for use on streets. The permit expressly limits the time that carts may be on the streets to the period between one hour before sunrise to one hour after sunset. Further, the permit expressly provides for operation of the cart on designated golf cart routes, paths, and lanes

A hierarchy of right-of-ways for golf carts with city permits is described in AB1229. First, Class I golf cart paths are separated from the motor vehicle right-of-way and are intended for the sole use of golf carts. Class II lanes define legal right-of-ways for golf carts on some streets with speed limits higher than 25 mph. In some places, these lanes are shared use lanes for golf carts and bicycles As per the Attorney General's opinion, Class III cart paths are those streets with a speed limit of 25 mph or less, on which carts may travel in mixed traffic. Special traffic signs and signals continue to be developed to inform and educate golf cart and motor vehicle drivers alike of the new infrastructure. All these improvements—paths, lanes, signs, parking spaces, etc.—were developed according to the existing guidelines by which all other roadway infrastructure is designed. These guidelines are contained in the Manual of Uniform Traffic Control Devices (MUTCD) and the American Association of State Highway Traffic Organizations (AASHTO) Design Manual. Detailed descriptions of the golf cart lanes and paths are provided in Appendix A. The guidelines and procedures are described in greater detail in a companion report on NEV infrastructure completed as part of our overall evaluation of the NEV concept for CALSTART (Stein, et al, 1994).

Results of Focus Group with Golf Cart Drivers

At the time of our case study, approximately eighty golf cart drivers had gone through the golf cart permit process in Palm Desert. Eleven of these people participated in our focus group. The outline for this group is in Appendix B. Briefly, participants were asked to describe their carts, to talk about how they used them other than to play golf, how the Demonstration Project

had affected their use of their carts and to suggest any changes in their carts, the developing infrastructure or institutions that would assist them in making greater use of their carts.

Resort towns experience large seasonal changes in population. One distinguishing feature of our focus group participants is that they are permanent residents of Palm Desert. By early May, most non-permanent residents had moved back to cooler climes for the summer months. As permanent residents, our focus group participants expressed a greater sense of commitment to the local community than they were willing to attribute to seasonal residents. It should be kept in mind that the responses to new golf cart infrastructure of seasonal residents may differ from those of permanent residents.

Characteristics of the Electric Carts

It was the observation of both City staff and our focus group participants that virtually all the golf carts in Palm Desert are electric. The reason given for this was the quiet they afford on the golf course The State of California's motor vehicle descriptions proscribes the top speed of a golf cart to 15 miles per hour. Most of our discussants felt the top speed of their cart was about 15 miles per hour on level ground and perhaps 20 mph on a down hill. Some concern was expressed about this limited speed capability. In mixed traffic or in lanes crossing or next to faster moving traffic many drivers indicated concern about motor vehicle drivers seeing slower moving carts. Yet the group was emphatic that carts not be designed to travel faster without other improvements also being made, such as improved brakes, suspensions and passenger protection. The vehicles were viewed as too light and too open to the elements to be traveling faster. Concern with vehicle speed was related to differences in speed between carts and motor vehicles and the inherent safety of the golf cart itself.

The driving range between charges of the carts was not well known for two reasons: carts were not equipped with odometers and most discussants never drive their carts anywhere near the point of complete discharge. Driving range estimates varied from ten miles (including 5 miles on a grass golf course) to forty miles on asphalt in a cart with new batteries. Two methods for arriving at these estimates were common—reference to the owners manual or some other expert opinion ("The manual says 30 miles.") or a summation of estimates for common trips ("From Portola near the wash, twice across town. Five or six miles each round trip, so at least twelve, fifteen miles.").

All participants agreed that age of the batteries was an important determinant of driving range, but none could provide details from their own experience as to how much it mattered. While it is quite true that battery age and the number of charge-discharge cycles are important to battery

performance, none of the discussants' carts was equipped with odometers and only two owners (of new carts) had state-of-charge meters on their cart No one had separate kWh meters on their rechargers. Most subscribed to a rule-of-thumb that called for the batteries to be replaced on a time schedule (approximately every 3 years), rather than according to the number of discharge cycles, miles or other measure of battery life or performance.

This ignorance of specific details of range and battery life was related to the manner in which the carts were used and recharged:

> "Thirty miles is a safe distance. You run around all day and very few people travel anywhere near that far. You always put it on charge at night anyhow. It isn't like an automobile where you fill up at the least convenient time."

This statement reflects the use of the cart, its recharging and the ease of home recharging compared to refueling a gasoline vehicle at a service station. It showed that the carts could be used for much of the in-town travel. Almost every one of the discussants plugs the cart into its charger every time they come home, regardless of how far they have driven. Of the two cart owners who had state-of-charge meters in their cart, one would wait for the batteries to be discharged 50 percent before recharging. All felt that recharging at home was easy and convenient. All the carts were recharged at home and the recharging appliance was left at home—no one carried it with them to facilitate away-from-home recharging. The lack of a uniform plug type was the overwhelming reason for not recharging away from home.

Cart maintenance required minimal time and attention. The batteries required the most frequent maintenance: monthly checks of the water level. Most owners had their carts inspected and serviced once a year. These inspections included steering, brake and wheel checks and battery maintenance. All the cart owners had replaced batteries in their carts (if not in the cart they now own, then in previous carts). The cost of six batteries for these carts is about $300, and as noted above, the batteries are generally replaced every three years.

All told, the cost of owning and operating a golf cart was perceived as much less than that of owning and operating a car. Maintenance costs and frequency were minimal, and again, much less so than for any of their motor vehicles. Insurance was carried as part of a homeowner's or business policy, not an automobile policy. The cost of this insurance was hidden in the cost of the homeowner's policy—none of the respondents knew the cost to insure their cart.

Electric Cart Use: Formation of a *Golf Cart Space*

Despite the new infrastructure, most respondents still used their carts primarily to access golf courses and to play golf. However, two people used the carts for business-related errands all

over town. In one of these cases, the golf cart was purchased to replace a car. This person typically makes two trips a day around town to run business-related errands. Because he drives the cart so often, he made the most extensive exploration of the cart network of any of our focus group participants. His familiarity with the cart lane network and his extensive use of the cart translated into the most extensive and diverse *golf cart space* of any of the focus group participants. The activity locations in his golf-cart space included his home, bank, post office, office supply stores and personal business locations; it does not include golf courses as he does not play golf.

The greatest impediments to increased use of the carts by the other participants were confusion about the new golf cart lane and path infrastructure, a perceived threat of theft of personal items from an unlocked (and unlockable) cart, and concerns about the safety of the cart in traffic. Most participants were still concerned with finding a safe, comfortable route to their favorite golf courses. All had driven some parts of the network that lead to other activity locations, such as the regional mall or the shops on El Paseo (a retail shopping district), but they were clearly not yet comfortable connecting activity locations using only the golf cart network Routes they would typically take in their cars were not always feasible in their carts. The carts have no locking storage, so that linking errands, which often required leaving items in the cart while engaging in another activity, was viewed as less feasible in a cart than in a car. Unfamiliarity with new routes heightened the unease that these people felt when driving their carts in traffic.

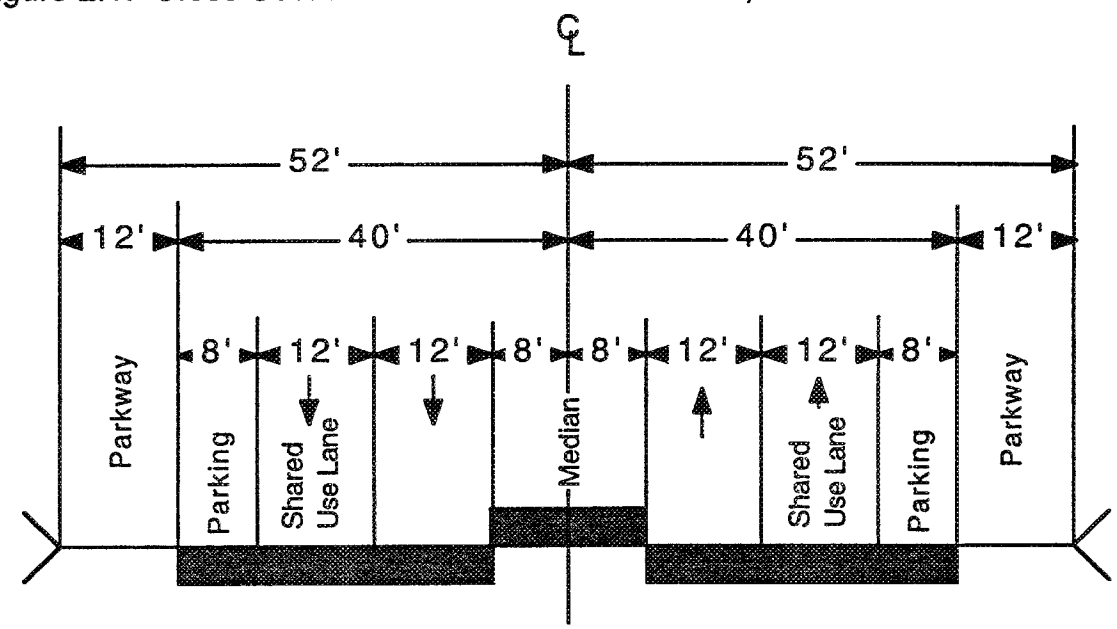
Effect of Golf Cart Infrastructure on Cart Use

Virtually all the discussants were still learning the network of golf cart lanes, paths and streets. Unfamiliarity with the network is a source of discomfort, but may not have been as limiting a factor as was their unease with driving the cart in traffic. The two people who drive their carts throughout a large part of the network expressed the greatest familiarity with the network and the greatest comfort with driving their carts. Thus a period of learning and familiarization may ease both problems, but specific problems were expressed that may require further infrastructure development.

El Paseo and State Highway 111 run parallel to each other for several blocks and contain the town's major retail and commercial developments along their lengths. Though separated by one short block, they represent two extremes of golf cart accessibility and each, in its own way, represents a barrier to cart use. El Paseo is a busy, crowded, relatively low speed street bordered mostly by small retail stores and boutiques. There are two traffic lanes and a parking

lane in each direction, separated by a planted median strip. (See Figure 2.1.) El Paseo is designated as a Class III Permitted Golf Cart Street, that is, it is considered acceptable for golf carts to drive in the traffic lanes as it is a low speed street (posted speed limit ≤ 25 mph). In contrast, State Highway 111 is a much wider route, with much faster moving traffic, bounded by larger retail and commercial businesses. Not only are golf carts not permitted to travel along SH 111, but there are only three locations, separated by roughly three-quarters of a mile, where crossing between the north and south sides of the highway is permitted in a cart.

Figure 2.1: Cross-Section of El Paseo. Palm Desert, California



While it is a Class III route, El Paseo was very much a psychological barrier to cart use. Discussants were near unanimous in the opinion that the crowded traffic conditions made cart use uncomfortable. The presence of parked cars along the curb made drivers feel hemmed in and increased the traffic hazard as cars pulled in and out of parking spaces. Despite the low posted speed and high traffic levels, the disparities between the speed of golf carts and the speed of motor vehicles was seen as too large. One respondent described his experience thus:

> "We [cart drivers] have no cart lanes and they [automobile drivers] drive very, very fast on there. There is parking on street, so it [the travel lane] is very narrow. No place for the cart but to travel in one of the auto lanes. And boy I'll tell you, they are very impatient."

State Highway 111 is one of three routes that are significant physical barriers because of cart crossing restrictions. The other two are State Highway 74 and Fred Waring Drive. Cart crossings of State Highway 111 are specifically proscribed by the enabling legislation. Carts may only cross SH111 at "intersections that are either controlled by traffic signals or are grade separated." These physical impediments can cause cart users to either take different, more circuitous routes in their carts than they would take in their automobiles or to make crossings at unauthorized intersections. In particular, SH 74 creates small residential enclaves from which residents must either travel well out of their way or make an illegal crossing of the highway in order to use their cart to connect with the rest of the cart network. Of the twelve intersections that discussants identified as either feeling unsafe or creating uncertainty about what were permitted movements, eight were on SH111, SH74 or Fred Waring Drive. Four others are on Portola Avenue. A list of these perceived "hazardous" or "uncertain" intersections is provided in Appendix C.

The City of Palm Desert is well aware of the physical barrier that SH 74 represents and has plans to provide a legal crossing at a signalized intersection (SH 74 and Haystack Road). Problems at the other intersections listed in Appendix C have to do with lane widths, lane continuity, and signal timing. One cart driver insists that the currently illegal crossing of SH 111 at Deep Canyon Road was safer than the permitted crossing at the east end of El Paseo because he believed the green time was longer at the signal at Deep Canyon Road.

Cart Driver Evaluation of City of Palm Desert's Efforts

Despite complaints about specific routes and intersections, the majority of discussants view the City's efforts favorably and appear willing to support continued efforts to expand golf cart transportation. Several commended the city's efforts and the progress made in a short period of time. Rather than expanded or redesigned infrastructure, many discussants suggested that education and publicity should be a higher priority at this point. It was suggested that these efforts would overcome two of the main impediments to increased cart use—safety perceptions and knowledge of the network. A great deal of the discomfort expressed by discussants resulted from the perceived ignorance and inattention of automobile drivers. Publicizing the golf cart demonstration program and educating all residents as to the increased presence of carts on the road, the vulnerability of cart occupants, and the rights of carts to be in designated

places was viewed as more important than more lanes and signs. Also, better information about the extent of the network would encourage people to use their carts for more local travel.

Implementation Issues

Interviews with city staff focused primarily on issues around the golf cart permit process, the enforcement of permit requirements and the golf cart specific infrastructure. Permits were required by the enabling legislation and were intended both to insure carts met the safety requirements established by the City and that cart drivers obtained information about the program and the network of cart paths. The cart path network and its associated infrastructure went through a lengthy process to identify desired cart network links and design appropriate lanes, paths and signs.

As the physical infrastructure for carts was still very new, the initial feedback from automobile drivers—who indicated some initial confusion—was not unexpected. Questions regarding proper positioning of the automobile on the road (is the golf cart lane simply a narrow automobile lane?) and the presence of golf carts in the "automobile" lane (in particular along the Class III route on El Paseo) appeared to be the most significant problems.

The development of cart specific signs was undertaken according to established procedures for developing such new signs. The City of Palm Desert has worked with Caltrans and the Federal Highway Administration (FHWA) to develop a new symbol for golf carts and other signs and sign elements specific to golf carts. The vehicle symbol is of special importance because it is a basic element for many other traffic control devices. In accordance with the Manual on Uniform Traffic Control Devices (1988 Edition), the City of Palm Desert sent a formal "Request to Experiment" to Caltrans District 8. This request was then forwarded to the Federal Highway Administration. This request stated the City of Palm Desert would conduct surveys of golf cart symbol recognition by both residents and non-residents of Palm Desert and golf cart sign size and legibility to motor vehicle drivers, summarize and analyze the survey data, and report results and make recommendations. The surveys of symbol recognition have been completed. Recognition that the symbol represented a golf cart was high: 91 percent among residents of Palm Desert and 97 percent among residents of a non-golf resort town in a neighboring county.

The issues of cart permit and travel restriction enforcement were raised both in the focus group and in the Golf Cart Transportation Oversight Committee meeting. Two focus group discussants complained of neighbors driving their carts without first obtaining permits. In response to a question in the Oversight Committee meeting, the Riverside County Sheriff's

office indicated that at this early stage of the Demonstration Program, citing non-complying carts was a low priority. Tacit assent from the remaining committee members indicates that all interested parties recognized the need for flexibility during this early stage of the program.

Driving In Palm Desert

Three tours of the golf cart infrastructure, one of them in a golf cart, proved instructive regarding the accessibility provided by the network and provided experience operating a golf cart in mixed traffic. Our golf cart tour included Class II and III lanes, crossings of both Fred Waring Drive and State Highway 111 and trips in each direction along the entire length of El Paseo. The automobile tours demonstrated the spatial extent of the network and allowed us to observe a variety of lane alignments, the full range of Class I, II and III lanes, and the varied situations in which information must be conveyed to cart and automobile drivers.

Initial impressions from the golf cart tour indicated that lanes and routes are well marked and easily distinguishable from the cart The slow travel speed of the cart aids in timely identification and comprehension of signs, lane stripes and stencils. Travel along El Paseo reinforced the comments of our focus group discussants. Both the high level of traffic on this street and the position of the cart in the traffic lane made both driver and passenger very aware of the fact we were in a cart and not an automobile. This feeling was increased by the fact we were in the only cart we saw during this tour. An increased number of carts on the road may provide a very different experience. In addition to other traffic calming measures that could be implemented, a larger number of carts would themselves insure a slower flow of traffic and reinforce the right of carts to travel this, and other, routes.

When crossing State Route 111 at El Paseo, the cart was unable to clear the intersection in the allotted green time, though it was well clear of the intersection before the amber time expired. Crossing an intersection during the amber time is not an unusual experience in an automobile. That the event is worthy of mention when traveling in the cart is a reflection of similar events described by focus group participants. Those who crossed SH 111 in their cart also remarked that if their cart was the only vehicle waiting to cross, they could not cross before the green time expired. The perceived note-worthiness of this event, when none could recall the last time they had crossed an intersection on amber in a car, might be attributed to a heightened sensitivity while driving the cart. Such an increased awareness, if it does exist, may decline as cart and automobile drivers become habituated to carts driving throughout town. Yet this awareness is probably a good thing—it does not appear to be an actual barrier to cart use and probably serves to help insure the safety of cart drivers.

The automobile tours of the city allowed us to see the extent of the entire golf cart network, catalog the various instances in which uniform signs and lane widths were applied to create the cart network, and to observe the few locations (listed in Appendix C) that focus group respondents indicated were unclear or poorly marked. It is apparent the City has created a network that provides a high level of accessibility to potential cart drivers. At the same time, the few locations where problems do remain offer insights into the difficulty of retrofitting a new set of lanes to existing roads. The intersection of Portola Avenue and Haystack Road provides one example. The class II cart lanes disappear as they approach the intersection from the West on Haystack. Eastbound, Haystack Road narrows dramatically as the 14 feet dedicated to a paved shoulder and golf cart lane disappear entirely, leaving only the 12 foot automobile lane. The southbound class II cart lane on Portola Avenue disappears at this intersection as the left hand turn lane (onto Haystack Road) forces the through automobile lane over toward the curb. The solid white stripe separating the automobile lane from the cart lane pinches off the cart lane and no clear directions are provided to cart drivers: should they stay as far right as possible or merge into the automobile lane?

Situations such as these raise questions in the minds of cart drivers. Our focus group participants indicated a strong desire to follow the rules and regulations to which they had agreed. Ambiguous implementation of these rules created a sense of frustration and anxiety. The onus, in situations such as the one cited here, appears to be on the City to alleviate this frustration by making changes to the infrastructure or providing clear information.

Palm Desert Summary

The Palm Desert Golf Cart Demonstration Program illustrates one possible path toward development of a local transportation system that accommodates small, low-speed electric vehicles. We observe in Palm Desert institutional and physical elements necessary to allow residents to use electric golf carts for local travel. The infrastructure developments, oversight committee and State enabling legislation are all necessary because golf carts are currently prohibited from traveling along, or crossing, streets with posted speed limits higher than 25 miles per hour. Following existing procedures and guidelines for transportation infrastructure development, the City has created a three tier system of cart routes, lanes and paths. In addition to this system, signs and lane stencils have been developed and submitted to the Federal Highway Administration for approval as uniform golf cart symbols. The procedures followed by the City are generally applicable to any new infrastructure development regardless of vehicle type. Golf carts and other vehicles characterized by low speeds and a virtual absence of crash protection for occupants clearly require careful attention, as has been given in Palm

Desert. Vehicles of moderate speed capability, say up to 45 mph, that meet most if not all of Federal Motor Vehicle Safety Standards may only require signs and stencils indicating travel limitations or prohibitions from existing high-speed highways and expressways. A precedent exists in the prohibition of bicycles and power-driven cycles from high-speed facilities.

The experience in Palm Desert highlights the extent to which existing roadway infrastructure can be transformed to accommodate small, low-speed vehicles. Much of the town is now accessible by electric golf cart. It also highlights the perceived importance of even small non-uniformities in the application of new infrastructure. Though we did not ask them directly about this point, it is likely our focus group respondents have driven through the intersection of Portola Avenue and Haystack Road in their automobiles any number of times without paying particular attention to the narrowing of both roads as they approach the intersection. Now that they are in their carts though, that narrowing puts them in a more precarious position. The existing non-uniformity only became a problem with their shift of perspective from car to cart.

This does not mean the problem is not important. It does mean that surveys of existing driving conditions conducted before the implementation of programs such as Palm Desert's may not reveal these types of problems. This highlights the need for interaction, feedback and experimentation in demonstration settings in which implementation issues can be addressed and generalizable solutions to specific problems developed.

At least one issue, with ramifications for insurance, safety and liability, is left unresolved by the Palm Desert Golf Cart Demonstration Project. The enabling legislation for the Palm Desert project does not allow for the carts to registered and licensed as are any other vehicles. Permits are granted by the City of Palm Desert, not the State of California. In the long run, the merits of uniform state licensing versus city-specific permits for such vehicles must be resolved.

Sun City, Arizona

We were not the first to travel to Sun City, Arizona looking for non-freeway vehicles. Garrison and Clarke (1977) conducted case studies of Sun City and four other towns throughout the United States in their evaluation of "aid-to-walking" (ATW) vehicles. Changes to Sun City during the intervening 15 years were largely of scale, not of substance. In 1993, Sun City was much as Clarke described it in 1977, but Sun City West, Youngstown and other retirement communities had grown up around it. These communities were similar to Sun City: private, residential developments complete with their own fire districts, homeowner associations, recreational facilities and concomitant governing boards. These private towns

have resisted suburban influx from the nearby city of Phoenix, while continuing to welcome retirees from colder climes.

These towns developed since the early 1960s in a laissez faire atmosphere. Neither state nor local governments have intruded upon the development process in such a way as to limit the widespread use of golf carts by residents for general travel purposes. We found, as did Clarke in 1977, no specialized roadway infrastructure to accommodate either golf carts or bicycles. With the exception of a prohibition against impeding the flow of traffic, golf carts are free to drive on, and cross, any street irrespective of speed limits. Thus, while it is rare to see a cart driving along the high-speed thoroughfares, one does occasionally see carts on these roads and such roads do not serve as legal barriers to cart travel.

This laissez faire approach extends to the treatment of the carts and their drivers. Golf carts driven by residents of Sun City are registered as recreational vehicles and carry the same State of Arizona license plates as do motorcycles. A driver's license is required, but all respondents knew people who drove carts without a valid license. This illustrates the general hands-off attitude taken by federal, state and local authorities. The carts do not meet federal vehicle safety standards, yet freely use public roads. State vehicle license plates are issued in a way that renders cart records indistinguishable from those of markedly different vehicles. Barring an actual traffic incident, local traffic enforcement appears to be administered with a light hand.

Among the stronger conclusions Clarke drew from his 1977 study was that:

> "Our earlier thinking tended to assume that substantial road space differentiation and adaptation would be required for safe and attractive use of the ATW mode. But the Sun City example dramatically demonstrates that traffic mix is quite possible assuming that street networks have been designed to impede thru [sic] traffic, broad streets have been provided, and speed is effectively controlled through traffic regulation and street design." (ibid., p. 12)

In short, the more all vehicles are made to drive at low speeds and the more room there is for informal space buffers between travel modes, the more amenable the roadway infrastructure is to low speed vehicles. We return to this point in the conclusions to this chapter.

Results Of Focus Groups With Golf Cart Drivers

We held three focus groups with a total of 32 residents of Sun City and Sun City West. The focus group outline was nearly identical to that for Palm Desert (Appendix B). Unlike Palm Desert though, most of the golf carts in the Sun City area were gas-powered, not electric. But this had not always been the case. Golf cart retailers indicated that in the past ten to fifteen years sales of carts swung from predominately electric to predominately gas. To explore the

advantages and disadvantages of both cart types, one focus group consisted only of electric cart owners, another of only gas cart owners and the third was a mixed group.

Characteristics of the Golf Carts: Choices between Electric and Gas Carts

All three focus groups concurred on the basic distinctions between electric and gas carts. Electric carts are quiet and fume-free; gas carts go faster and farther. Just how fast and how far either type of cart would travel were points of considerable discussion. No carts were equipped with odometers. Drivers estimate driving range by summing known trip distances. A trip across town, the distance between home and a certain golf course, the distance of a round of 18 holes of golf on a particular course, and other such trips were used to construct driving range estimates. The driving range of electric carts was not measured on a scale of distance so much as a scale of activities. When asked how far they can drive on a charge, respondents told us what they can do before they have to recharge. Gas cart owners were likely to measure "distance" in units of time, e.g., the number of weeks between trips to a gasoline station.

Owners of electric golf carts preferred them for their quietness and lack of emissions and fumes. The driving range limit did not prevent them from making all the use of the cart they desired. Owners of gas carts emphasized their greater speed. This was particularly important for accessing more distant golf courses as a gas cart could nearly halve round-trip travel times. A round-trip between home and a golf course on the opposite side of town might take 40 minutes in an electric cart, but only 25 minutes in a gas cart.

Golf Cart Purchase and Use: Formation of a *Golf Cart Space*

The first-time visitor to Sun City is immediately struck by the number of golf carts on the road; evidence of the large number of residents in this community who have constructed *golf cart spaces*. According to our focus group participants, their carts provided them access to a wide variety of activities with only minor adjustments in route choice and activity linkages. More so than in Palm Desert, Sun City residents used their carts as general purpose transportation vehicles rather than simply a means to access golf courses. Some of the focus group participants had either quit playing golf or never had played, yet used golf carts to access many activities throughout Sun City.

Few indicated that the cart changed whether they linked errands or took single-purpose trips. This was due in large part to an apparent propensity for households to make single-purpose trips regardless of mode choice. Yet there did appear to be some relationship between the type

of activity, its distance from home, and the preferred travel mode. Cart drivers who would drive five miles in their cart to play a round of golf would not drive that far in the cart to do errands, shopping or other non-golf activities The cart was used to access non-golf activities only if they were located within a mile or so of home. Also, non-golf activities were not usually linked with golf itself. As the carts have no locking compartment to store golf equipment, people tended to return directly home from playing golf. They then removed their golf equipment from the cart if they used it to run non-golf errands later.

In half the households that participated in the Sun City focus groups, a golf cart had replaced an automobile. The following are typical comments from these households:

- "I don't play golf, but I use a cart for local travel."
- "I use it for everything except going to Phoenix."
- "I put as many miles on my cart as I do my car."

Newer arrivals to Sun City recounted how they had owned two motor vehicles when they moved to Sun City. Within one to two years, they had sold one car and purchased a golf cart. None complained of being cut off from their desired activities as a result of this choice. All acknowledged that within the specialized setting in which they lived, the golf cart was an inexpensive and desirable transportation tool.

Effect of Golf Cart Infrastructure on Cart Use and Safety

As there was no specialized roadway infrastructure for golf carts in Sun City, the discussion of whether these cart drivers would like to see certain types of infrastructure was necessarily hypothetical. They were asked in particular to consider special lane designations for golf carts. The idea for special golf cart lanes was universally unpopular. None of the respondents wanted to see such lanes if it meant removing a motor vehicle lane. Such cart lanes would give them no access they did not already enjoy; many expressed the fear they might be restricted to driving only in such lanes.

Since cart drivers face no prohibitions on where they can drive, special infrastructure was viewed more as a possible safety improvement. Driving through intersections, not driving along a traffic lane, was viewed as the primary safety hazard. This perception is supported by a traffic safety study performed by the Maricopa County Department of Transportation The county reviewed all reported traffic accidents involving golf carts in the unincorporated parts of the County (which includes Sun City and all other private communities in the county) for the years 1991 and 1992. Twenty of the 29 accidents occurred at intersections. In nearly half the accident reports, the golf cart driver was reported to have failed to yield the right-of-way. This

contradicts the focus group participants statements that they were more careful when driving their cart and that the primary hazard was inattentive motor vehicle drivers. The County's report supports our sample's belief that the winter months, when the population swells with part-time residents, were more hazardous than the summer. Eighty-two percent of the accidents occurred between the dates of October 1 and April 30. Thus with the possible exception of their own culpability, the traffic safety perceptions of our participants coincided with the limited official statistics.

Because their golf carts were perceived as less safe than their cars, most cart drivers indicated they were more circumspect in their choice of travel routes when they drove their carts than when they drove their cars. In their carts, they would avoid higher speed streets. Most would choose to cross high speed streets at signalized intersections. Wide streets, almost all of which have left turn lanes, eased golf cart use. There is ample space for faster cars to pass and the cart driver is less exposed to traffic approaching from behind while making left turns.

Sun City Summary

Within the context of the historical development of golf cart use in Sun City, infrastructure and safety issues do not themselves prevent or limit access to non-golf activities in golf carts. Minor adjustments in route selection and real or imagined increases in attention to traffic suffice to allow golf cart drivers to access non-golf activities. The limits on activity choice appear to be the specialized nature of the vehicle. A payload capability constraint (i.e., the absence of locking storage) precludes linking several activities and the speed capability constraint limits access to more distant activity locations. As proxies for NEV drivers, the shift from electric to gas powered carts in Sun City suggests that a minimum top speed capability of 25 mph is desirable for NEVs. A driving range of 30 miles may bring a few more activities within the *NEV space* than the 20 to 25 mile range of electric carts, but the real limit on the spatial extent of this space is travel time, not distance. We echo Clarke's conclusion from 15 years ago: if all traffic can be made to move at a lower speed and there exists ample road space, then specialized infrastructure for low-speed modes may not be required. We speculate though, that travel speeds and traffic levels have increased since 1977, making carts comparatively less safe than they were then. Even in Sun City, golf cart drivers would benefit from infrastructure improvements to protect them at intersections.

Lessons from Golf Communities

In the towns of Palm Desert, California and Sun City, Arizona, we find that vehicles of minimal performance capabilities can provide valuable transportation services. We see this is

true in Sun City, even with no specialized infrastructure to accommodate low-speed vehicles. The two towns share similar roadway infrastructure networks. At least as important, the households who drive golf carts in both towns are subject to few authority or coupling constraints—as retired adults without children at home, they are subject to few of the work, school and social schedules that jobs and children impose on household travel.

Due in large part to this lack of authority and coupling constraints, golf cart drivers in both case study towns have constructed *golf cart activity sub-spaces* : sets of activities that they regularly access by golf cart. In some of these households, this activity space is quite simple and is limited to two types of activity locations—home and golf courses. (This does not mean golf is the only activity accessed by golf cart. Golf courses often serve as the center of other social and recreational activities for these households.) But in many other households, including those who do not play golf at all, the golf cart provides access to a wide variety of activities, e.g., social, shopping, personal and professional business. The existence of a set of activities regularly accessed by golf cart and the purchase of a golf cart to replace a car both argue for the existence of mode-specific activity sub-spaces in these households.

The limits of those *golf cart spaces* are determined by attributes of the vehicles, the transportation infrastructure, and the activity choices of the household. The capability constraints on speed, distance and payload restrict the distance people are willing to travel and their sequences of activities. The more important constraint on how far people will travel in their carts is speed and not driving range. Distance (driving range) is less relevant to travel choices in these communities where all the daily activity locations are within a few miles of home The specialized design of these particular vehicles makes linking several activities more difficult of the absence of lockable storage makes them a target for theft.

The households in these case studies are almost all households of retired persons. They have fewer coupling constraints with other household members than we expect to find in households with children. They also face far fewer authority constraints, especially activity scheduling constraints. As their time and activities are more discretionary, we do not see cases in which the capability, coupling and authority constraints eliminate a desired or required time-space path. Some of these households eliminated an ICEV and replaced it with a golf cart because the combination of an ICEV and cart is a better set of travel tools for these households than are two ICEVs.

Palm Desert is developing special infrastructure to facilitate golf cart travel. Golf cart drivers in Sun City wanted no special infrastructure. In Palm Desert, golf cart infrastructure is seen as

enabling golf cart travel. In Sun City, carts have nearly unlimited access to the transportation network, and special infrastructure was viewed as potentially limiting this access. The difference in perceptions is linked to the historical process of development in the two regions and speaks to the differences between retrofitting NEV infrastructure in existing communities versus building new communities for NEVs.

As we compare Palm Desert and Sun City, keep in mind Clarke's conclusion from his 1977 case study in Sun City He and Garrison had assumed that substantial roadway development would be required to make ATW vehicles practical. The process of route, lane, path and sign development in Palm Desert reflects this assumption. We found in Sun City in 1993 what Clarke found in 1977: golf carts co-exist with cars and trucks in a setting of informal traffic separation, limited through traffic in neighborhoods, and effective speed regulation.

Still, it is possible that Sun City does not disprove the assumption of the need for specialized infrastructure for different travel modes. Sun City developed from the start as a community in which golf carts were an expected part of the traffic mix; thus its lessons may apply best to new developments in which NEVs are also an expected part of the traffic mix. Palm Desert's program was designed in response to specific legal and institutional requirements imposed at the behest of state transportation and safety agencies. Palm Desert may be an appropriate model for retrofitting NEV infrastructure in existing communities. But we should recall that the golf cart infrastructure in Palm Desert is being developed in response to constraints on the town's objective spatial structure imposed by agencies charged with designing roadways and enforcing traffic and vehicle safety laws and regulations, not solely in response to requests by drivers of electric golf carts.

III. RIDE-AND-DRIVE CLINICS WITH EV HOBBYISTS AND ENVIRONMENTALISTS: Hypothetical Early Market Segments for Electric and Neighborhood Electric Vehicles

Everett Rogers. The Diffusion of Innovations.

"...the innovator plays an important role in the diffusion process: that of launching the new idea in the social system by importing the innovation from outside of the system's boundaries."

This is a study of the perceptions and reactions of hypothetical early market segments to a variety of NEVs. The literature on the diffusion of innovations hypothesizes that the growth of the market for new products can be broken down into the sequential adoption of the innovation by distinct groups of people (See Rogers (1983) for an extensive review of the diffusion of innovations literature.) EV hobbyists and environmentalists are frequently discussed as likely early buyers of EVs. EV hobbyists are assumed to be knowledgeable regarding EV technology and the performance characteristics of the vehicles, and to be habituated to, or accepting of the shorter range and long recharge time of EVs. This interest and familiarity are hypothesized to translate into a greater willingness to buy original equipment manufacturer's (OEM's) electric vehicles. Environmentalists are hypothesized to be among the early buyers of EVs because of their interest in the potential for clean air.

To test these hypotheses and to assess how these groups perceive NEVs compared to small, freeway-capable EVs, members of the Sacramento chapter of the Electric Automobile Association (EAA) and recruits from attendees at the Whole Earth Festival (WEF) held on the UC Davis campus, were given the opportunity to see, ride, and drive a variety of EVs and NEVs. At the drive clinics, participants completed a pre-survey, were conducted through a tour of the vehicles by an interviewer who recorded their responses to the vehicles, and then filled out a post-test drive questionnaire and scheduled a time to return for a focus group.

Ride-and-drive clinics focused on participants' evaluations of vehicle attributes, while the focus groups explored the effects of these attributes on participants' ability to access desired activities and to form a *NEV space* or an *EV space*. In the focus groups, participants were guided through a series of questions on how each of the types of vehicles they had seen at the

drive clinic would, or would not, fit into their lives. Each group then discussed in a more general way the advantages and disadvantages of EVs. EV and NEV purchase intentions were explored last.

The question of whether the members of these two groups would ever buy an EV, much less be among the first buyers, was asked in an information context that provided the participants the opportunity to reflect on and confront vehicle attributes with which they are largely unfamiliar; in particular driving range, recharging regimes and the inability to travel on freeways. The four EAA members who now drive their own EVs are well informed regarding most of these attributes. Despite their interest in EVs, the remaining EAA members do not have direct experience by which to judge the effect of say, limited range, on their ability to access desired activities. Thus they may not have the requisite information to assess their vehicle purchase intention. The WEF recruits are even further removed from this information context. The drive clinics, questionnaires and focus groups were designed to: allow for the limited testing of a variety of vehicles and elicit initial impressions; allow a few days for reflection upon this experience; and engage participants in discussion of the vehicles within a social setting. In this way the information context is enriched by each person's experience and the experience of the other people in the focus group. Only at the end of this process are people asked to discuss their purchase intention.

The Ride and Drive Setting

The Vehicles

The vehicles represented a broad spectrum of performance and body styles. EAA members reviewed and evaluated the following vehicles:

- City Com City-El;
- Kewet El-Jet;
- Solectria Geo Metro conversion;
- Horlacher City and Sport prototypes; and the
- Esoro prototype.

WEF recruits reviewed the same vehicles with the exception of the Kewet which was unavailable for that clinic. As presented to participants in these clinics, the basic attributes of the vehicles were somewhat different from those described in Table 1.1. The top speed and driving range of the Horlacher and Esoro vehicles were described to the participants in this study as being higher than those given in Table 1.1. This was done to create a clear distinction between the non-freeway capable City-El and Kewet and the other, freeway capable vehicles.

The City-El represents the lowest performance vehicle on several scales: it seats only one person, has a top speed of 30 to 35 miles per hour, a driving range of 20 to 30 miles and a limited payload capacity. The Kewet offers two seats, a more traditional, upright driving position, a top speed of 40 miles per hour and a driving range of 40 miles[1]. The remaining vehicles are all freeway capable, with top speeds between 65 and 75 mph and driving ranges of 60 to 80 miles. All the freeway capable vehicles (the Solectria, Esoro and both Horlachers) seat at least two people; only the Esoro offers 2+2 seating. All the vehicles charge from a standard 110 volt outlet; the Horlachers and the Esoro can also recharge from a 220 volt outlet.

The Participants

EV hobbyists were drawn from the members of the Sacramento chapter of the EAA. They were informed at their meeting on 22 May 1993 that they would be afforded the opportunity after the meeting to ride and drive several EVs. They simply had to be willing to spend the time that afternoon to attend the clinic and attend a focus group on the evening of 25 May. Twenty EAA members stayed for the drive clinic and 17 of these attended the focus groups. The sample of EAA members included four persons who now own EVs they had converted or built themselves. All the other EAA members had joined within the previous 18 months. These newer members had joined the EAA to inform themselves about EVs. Some had joined because they wished to convert a vehicle themselves, but most had joined simply to learn more about EV technology in hopes of making more informed choices about a future EV purchase.

A group of environmentalists was recruited at the 1993 Whole Earth Festival (WEF) held May 7-9 on the University of California, Davis campus. ITS-Davis staff put a City-El on display and collected names of persons interested in driving it and other small EVs. The recruits filled out a brief questionnaire designed to identify those who were most concerned with air quality and active in environmental organizations. The "green market" was assumed to be made up of those people who agreed with the following statements:

- air quality is an important problem in my community;
- reducing petroleum consumption will benefit the environment;
- actions taken by individuals can affect air quality;
- I donated time or money to an environmental organization in the past year.

Nine WEF recruits completed the "green market" drive clinic and focus group.

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[1] This range is longer than that shown in Table 1 1 It is based on published figures. The data in Table 1 1 is based on our actual experience with the vehicle

The Test Drives

The test drives were conducted on a three-tenths mile course on the local streets at the Sacramento Municipal Utility District headquarters in Sacramento for EAA members and on a half mile course on the UCD campus for the WEF recruits. All participants drove a City-El. EAA members also drove the Solectria or the Kewet. WEF recruits also drove the Solectria. All participants chose one of the two Horlacher vehicles or the Esoro in which they wished to ride. Vehicles in which participants rode or drove were given stationary and dynamic evaluations. All vehicles in both clinics were given stationary evaluations by each participant. Stationary evaluations included entry and egress, styling, and instrumentation. Dynamic evaluations included acceleration, braking, sound, steering, and safety perceptions.

Who is Likely to Buy EVs and NEVs?

There is a great deal of enthusiasm for OEM EVs, especially among the newer EAA members. However, all participants expressed purchase intentions that were sensitive to the ability of the various vehicles to provide adequate access to desired activities, personal desires to continue "tinkering" with EV technology, and purchase price. Long term members of the EAA were not interested in buying an OEM vehicle because they wanted to continue to build and modify their own EVs. Differences in the response to EVs and NEVs between the environmentalists and hobbyists had more to do with where they lived than with characteristics of the people themselves. There is little evidence to suggest either EAA members or WEF recruits are willing to pay a premium price to be among the first owners of new OEM electric vehicles, but strong evidence they will buy EVs if they are offered at prices that are competitive with prices of gasoline vehicles.

During the focus groups, respondents made three choices from the EVs and NEVs they had seen at the test drive clinics. First, each chose the vehicle he or she would select if it were offered to them free of charge. Next, each chose a "second best" free EV, as if their first choice was not available. They were asked to explain the differences between the vehicles that led to this priority of choices. Finally, each group was asked to make a hypothetical purchase decision. The vehicles were offered at a variety of prices. The absolute price levels were changed from group to group to observe choices made at different price levels. In each group, the rank order of prices was maintained. The price order from least to most expensive was: City-El, Kewet, Solectria conversion, Horlacher City, and Horlacher Sport and Esoro (tie). Table 3.1 shows all the vehicle choices for each focus group participant.

Table 3.1: Transition Table of EV Choices during the Focus Groups

Sample to which the respondent belonged	First Choice of a Free EV	Second Choice of a Free EV	EV Choice to Purchase at Offered Prices
EAA	Esoro	Solectria	Esoro
EAA	Esoro	Solectria	Solectria
EAA	Esoro	Horlacher Sport	none
EAA	Esoro	Horlacher Sport	Solectria
EAA	Esoro	Horlacher Sport	City
EAA	Esoro	Solectria	Solectria
EAA	Esoro	Horlacher Sport	none
EAA	Esoro	Horlacher Sport	none
EAA	Esoro	Solectria	none
EAA	Esoro	Horlacher City	**City-El**
EAA	Esoro	Solectria	Solectria
EAA	Esoro	Horlacher Sport	Solectria
EAA	Solectria	Esoro	City
EAA	Solectria	none	none
EAA	Solectria	Horlacher City	Solectria
EAA	Horlacher Sport	Esoro	none
EAA	**Kewet**	none	**Kewet**
WEF	Esoro	Horlacher Sport	none
WEF	Esoro	Solectria	Solectria
WEF	Esoro	Horlacher City	Solectria
WEF	Esoro	Horlacher City	Esoro
WEF	Esoro	Horlacher Sport	none
WEF	Esoro	Horlacher Sport	Esoro
WEF	Esoro	none	none
WEF	Solectria	Horlacher Sport	none
WEF	Horlacher Sport	none	none

As shown in the right-hand column of Table 3.1, 11 of the 26 focus group participants chose not to buy any EV at the offered prices. Some of these people expressed a desire to convert their own vehicle rather than buy a completed conversion or an OEM vehicle. Seven people chose to buy the Solectria conversion, one person chose to buy a City-El, and one a Kewet. Only five people opted to buy the other EV prototypes at the prices offered.

The choices of EAA members reflect their current EV ownership status. Three of the four members who now own EVs chose to do their own conversion rather than purchase an OEM EV. No price was specified as this choice was volunteered by these participants. The fourth EV owner chose the Solectria conversion as his first choice of a free vehicle because he felt free to modify it. Two other EAA members who chose to buy the Solectria expressed this desire to modify the vehicle. The Horlacher and Esoro vehicles were viewed as finished products, less amenable to modification.

More than half the WEF recruits rejected the purchase of any EV they reviewed at the drive clinic; none were interested in the NEVs. All of our environmentalist sub-sample lives in Davis. Davis is separated from other towns by 8 to 10 miles of agricultural land. A primary reason for these Davis residents to drive any car was to travel out-of-town. Bicycling and walking suffices for much of their in-town travel. Owning a vehicle such as the City-El and Kewet for local travel was not viewed favorably. The rejection of the freeway capable vehicles was linked to vehicle price, current household vehicle ownership patterns and the perception that better options than EVs exist for them to express their address air quality concerns. More of the WEF recruits live in households that own only one car or in households of unrelated adults who each own their own vehicles. Thus to own an EV (subject to the assumption the household always retains ownership of one ICEV) meant adding cars to the household fleet. Since buying any new car was viewed as unlikely, buying an EV or a NEV was also unlikely.

Thus the participants in both sub-samples do not appear to belong to market segments that are so strongly motivated to be among the first owners of OEM EVs and NEVs that they are willing to pay premium prices over those of gasoline vehicles. An examination of each sample both separately and in contrast to each other provides some explanations for this.

Characteristics Of The Hobbyist And Green Market Samples

Perceptions of Electric Vehicles

Innovators for specific products are usually identified well after markets for the new product have matured. Retrospective analyses of sales of new products distinguish the earliest buyers,

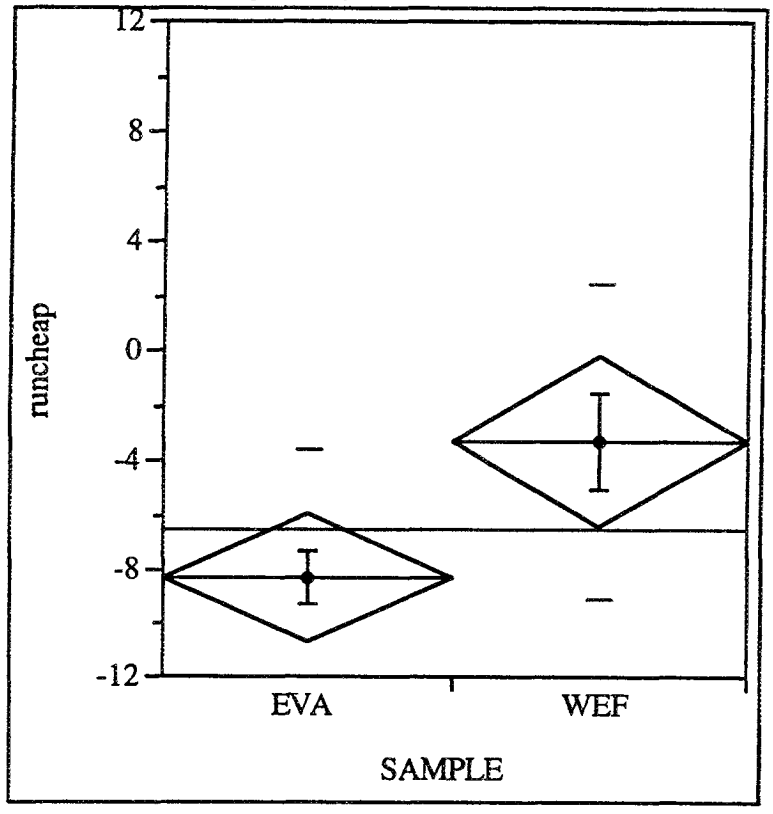
who by definition are the innovators, from later buyers. These early buyers may be motivated by a particular knowledge of, or interest in, the new product They may be able to derive especially large benefits from the new product. Socio-economic and attitudinal measures may be used to differentiate earlier from later buyers. Also, the information sources used by earliest buyers are likely to be different from those used by later buyers.

Such differences as appear between early and later adopters may also appear between different early market segments. If EAA members do possess advanced knowledge regarding EVs, we expect they may hold different perceptions of EVs than do the WEF recruits. To test this hypothesis, both groups were asked to compare their perceptions of EVs to the cars and trucks they now drive on scales that measured perceptions of: size, speed, safety, pollution, convenience, cost to run, cost to buy, practicality, and stylishness.

We find very few differences in the general perceptions of EVs between the two groups. The only difference in group means occurs on the perception of the cost to run EVs compared to gasoline vehicles. Figure 3.1 shows that while both groups believe EVs are cheaper to run, EAA members believe EVs are much cheaper to run. On average, members of both groups believe EVs are: smaller, slower, much less polluting; as safe, convenient, and practical; and somewhat more expensive to buy, more stylish and more futuristic than the gasoline vehicles they are now driving.

When asked about the impact of EVs on air quality, a few subtle differences emerge between the groups. Hobbyists are more likely to believe that EVs are an effective means to address air quality issues. Regarding the preparedness of EVs to replace gasoline fueled vehicles, EAA members on average are more likely to disagree with the statement "EVs are *not* yet practical to replace gasoline fueled vehicles" than are WEF recruits. When asked to agree or disagree with the statement "EVs are the key to solving air pollution in the Davis-Sacramento area," no EAA member and only one WEF recruit disagreed with this statement. However among those who agreed, a greater percentage of EAA members strongly agreed than did WEF recruits, so that the average level of agreement that EVs are the key to solving air quality problems was significantly higher among EAA members (Figure 3.2).

Figure 3.1: Cheap to Run EVs by Sample



Notes:
Scale from -12 to 12. -12 indicates strongest belief that EVs are cheaper to run than ICEVs.

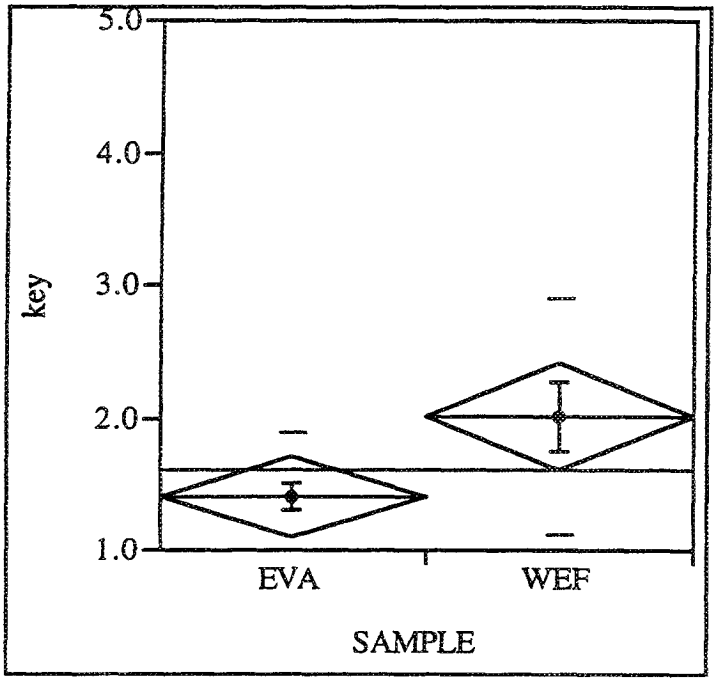
The estimate of the mean for all respondents is shown by the gray line across the width of the chart Estimates of the group means are shown by the solid black dots. The vertical bars through the means dots indicate the standard error of each estimate. The top and bottom points of the diamonds show the 95 percent confidence interval around the means estimates The short gray bars above and below the diamonds indicate one standard deviation above and below the means estimates.

The values of the group means are shown below The t-test indicates the means are significantly different at a significance level of $\alpha = 0.0168$.

Group	Mean	Std Error	t-test	DF	Prob.>|t|
EAA	-8 30	1.1587	2.537	29	0.0168
WEF	-3 36	1.5624			

Immediately following their test drives, both groups were asked again to agree or disagree whether EVs are *not* yet practical to replace gasoline vehicles. The changes in responses before and after the drive clinics measure the impact of the drive clinic experience on this important building block of purchase intention. The WEF recruits showed a statistically significant shift toward disagreement with the statement, while EAA members on average showed no change (Figure 3.3). The distributions reveal that half the WEF recruits remained unchanged in their

Figure 3.2: EVs are the Key to Solving Air Pollution By Sample



Scale from 1 to 5 1 = strongly agrees that EVs are key to solving air pollution 5 = strongly disagree.

Level	Mean	Std Error	t-Test	DF	Prob >|t|
EAA	1.40	0 149	2 406	29	0 0227
WEF	2 00	0 200			

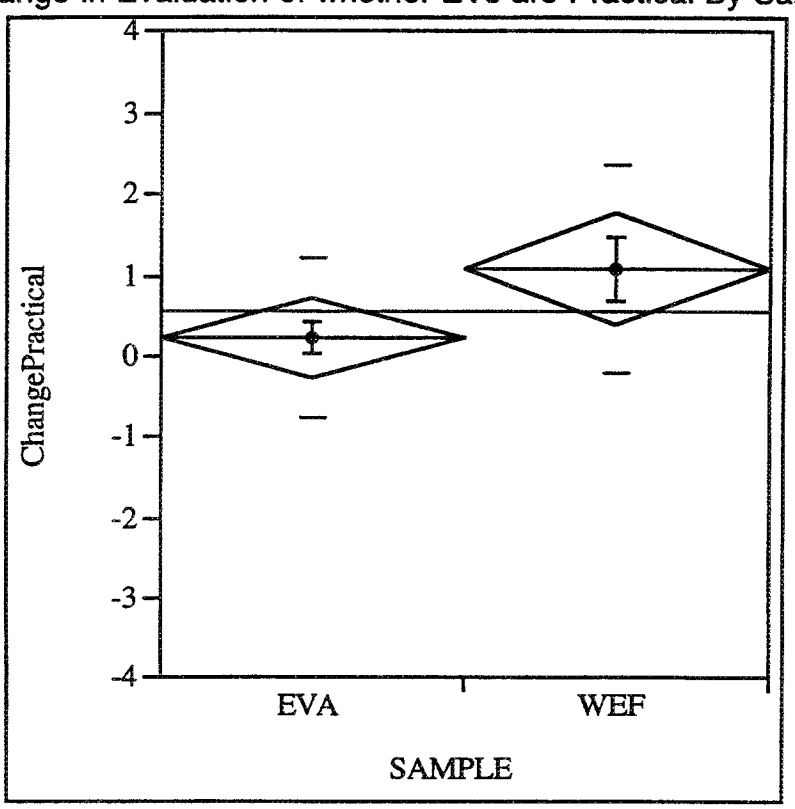
assessment of the practicality of EVs, but the other half shifted 1, 2 or 3 points toward disagreeing with the statement the EVs are not yet practical on the 5-point scale. Among EAA members, half showed no change. Among the other half, some indicated the drive clinics led them to believe EVs were more practical, but some EAA members came away from the drive clinic with worse assessments of ready EVs are to replace gasoline vehicles.

Information Sources

Simply by their membership in the EAA, the sample of hobbyists was expected to have used different information sources regarding EVs than did the WEF recruits. The distribution of information sources in Figure 3.4 shows this is true. "Electric vehicle clubs" were listed as a primary information source by 18 of the 20 EAA members; only one WEF recruit mentioned electric vehicle clubs. SMUD's involvement with the Sacramento chapter of the EAA likely explains the high number of EAA members who listed their electric utility as an important

information source. Only a few WEF recruits cited their electric utility. Among the WEF recruits the most important sources were mass media such as television news and specials and newspapers. They were also more likely than EV hobbyists to cite environmental organizations. The fact that a market for EVs does not yet exist is reflected by the fact that almost no one cites either EV manufacturers or major automotive manufacturers as important sources of information.

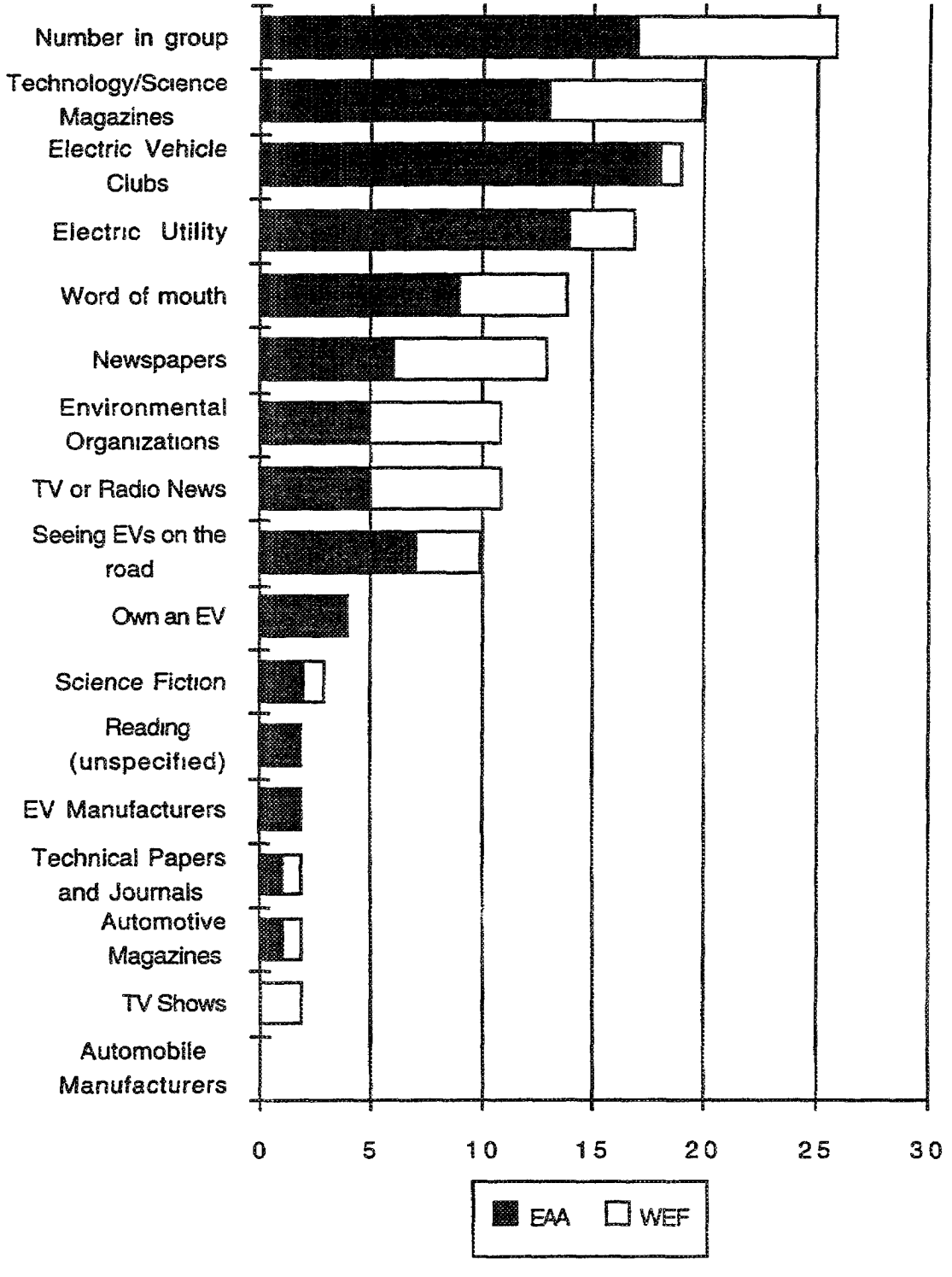
Figure 3.3: Change in Evaluation of whether EVs are Practical By Sample



Note The variable "ChangePractical" is the difference between each respondent's evaluation of whether EVs are practical to replace gasoline vehicles immediately before and after the ride-and-drive clinic. The variable can range from -4 (much less practical) to 4 (much more practical). Actual range of scores is from -1 to 3.

Level	number	Mean	Std Error
EAA	19	0.263	0.252
WEF	10	1.100	0.347

Figure 3.4: Sources of EV Information by Sample



The difference in the types of information sources used by the two samples indicates differences in their movement through a simple innovation-decision model. In this model, people move through several stages: initial awareness of a new technology or idea; formation of an initial evaluation; decision whether to adopt; implementation; and confirmation. Certain feedback loops are observed in the model, in particular an initial implementation decision is often an experimental trial which can lead to a re-evaluation of the adoption decision

Our environmentalists indicate most of their information regarding EVs came from mass media sources. Such sources provide general information and create initial awareness of a new technology or idea. Thus our sample of environmentalists appears to be in a state of initial awareness of EVs. They may not yet have identified a problem that they believe EVs will solve. The EV hobbyists on the other hand, cite sources of specific and detailed information. They have moved beyond awareness and are seeking information that will allow them to act to adopt EVs.

These interpretations are substantiated by the focus group results. The WEF groups spent more time debating the merits of EVs to address environmental problems and had less specific information about EVs. The members of the EAA group who did not already own an EV had joined the group specifically to gather information about how to do their own conversions and to keep abreast of breaking developments in OEM vehicles.

Given the differences in information sources, the similarity in pre-test drive electric vehicle perceptions of the two groups is all the more remarkable. One explanation may be mass media sources of information are portraying EVs in a manner that is consistent with the more specific information available to EAA members through the Association and SMUD.

Personal and Household Characteristics

The two samples show few differences on personal and household characteristics. All but one EAA member described themselves as particularly handy in a way that makes them more adaptable to owning and using EVs. WEF recruits were also more likely than not to describe themselves as handy. There is no substantive difference in the average number of vehicles per driver in the households; there is one vehicle per driver in most households in both groups. Despite this, and the fact noted above that the WEF sample contains a higher number of households of unrelated adults, WEF households are only slightly less likely to engage in vehicle swapping than are EAA households. Vehicle swapping is an important adaptive behavior to limited range identified in other studies at ITS-Davis (Kurani, Turrentine and Sperling, 1994a). Household incomes were similar and the median and modal income groups

were $25,000 – $40,000. The environmentalists who participated in the drive clinic were all Davis residents with one exception. As a group, they were younger than the EAA group.

The two groups do show differences in employment and residential tenure. Whereas 75 percent of the EAA sample was employed either in or out of their home, 60 percent of the WEF sample were students. EAA members have lived in their current home for an average of 8.6 years, but this average is inflated by two households whose residential tenure is 31 and 40 years. The student population in the WEF group is largely responsible for the shorter residential tenure of 4.4 years. The average time each group has lived in the Sacramento-Davis areas was even more disparate. On average, EAA members had lived in the area for 20.7 years; WEF recruits, 5.1 years. Members of both groups plan on remaining in the area

Identifying A Green Market

An initial premise of this study w: iat a group of environmentalists could be identified who are likely to be among the first buyers of EVs and NEVs. The WEF sample was intended to represent this green market segment. Given the difficulty of identifying green markets for EVs in other studies (see for example Buist, 1993), the issue of how the WEF sample differs from the EAA sample warrants some attention.

Based on the attitudes and actions used to select the WEF recruits as environmentalists, there was little difference between the two samples. Nearly identical proportions of both samples identify themselves as belonging to, or working for, environmental groups. More than 75% of both groups agree or strongly agree that air quality is an important problem in their community. Ninety percent of each group agrees or strongly agrees that reducing petroleum consumption will benefit the environment. Both groups believe motor vehicles are a significant source of air pollution. More than 80% agree or strongly agree that they buy environmentally "friendly" products whenever possible. Last, every person in both groups agrees or strongly agrees that actions taken by individuals can affect air quality. In short, these two samples are virtually indistinguishable on these measures of environmentalism. We conclude that our sample of EV hobbyists consisted of people who were themselves environmentalists.

Why is an "environmentalist" market segment so difficult to differentiate? The answer lies at least in part the definition of environmentalism. In a 1989 Roper poll, 75 percent of Americans identified themselves as environmentalists. Thus self identification as an environmentalist no longer distinguishes Americans, one from another The answer in this study may lie partly in the fact our sample of hobbyists contains so many environmentalists. This conclusion does not invalidate the findings of this report. It simply means that the differences reported here

between the two samples have to do with membership status in the EAA and land use features of the city of residence, not distinctions between hobbyists and environmentalists.

Attributes Affecting Specific Vehicle Choices

It seems plausible given the results of these clinics that the market for EVs and NEVs will first be segmented by household responses to new vehicle attributes—limited daily range, low top speed, small passenger and payload capacity, and environmental benefits. Responses to other new attributes of EVs—home recharging, new maintenance regimes, and new cost schedules—will likely affect the market too, but these were not explored in the ride-and-drive clinics. The attributes that determined choices *between* vehicles were of two basic types—those that determined classes of vehicles and those that determined a choice within a given class. The most important attributes to defining classes of vehicles were speed, range and load carrying capacity. The City-El and Kewet were distinguished from other vehicles primarily by their exclusion from freeways and highways because of their lower top speeds. Last, the City-El in particular was viewed as far too limited in its passenger and load carrying capacity. The interaction between passenger capacity and the coupling constraints imposed by household roles and social contacts made the City-El unusable to all but one of the participants.

The four freeway capable vehicles—the Solectria Metro conversion, Horlacher City and Sport, and Esoro—were chosen by half the respondents as the vehicles they would buy at prices offered at the end of each focus group. These vehicles meet expectations of a vehicle this person would be willing to buy. Even within this class, the extreme limits of capability—the highest top speed and longest range—determined the choices of some respondents. More generally though, once the participants had determined they could use a vehicle of the minimum speed (60mph) and range (50 miles) capabilities of these vehicles, their choice between vehicles was determined by driver comfort, exterior and interior styling, and color—in short, many of the same attributes by which they already choose cars.

Purchase price primarily affected the choice whether to "buy" any of the EVs. Choices between the freeway capable vehicles were typically based on the driving range and styling features of the vehicles and the attitudes toward, and experience with, vehicle conversions of the respondent. Seven of the 19 people who chose the Esoro as their first choice of a free EV switched to the Solectria when asked to express a purchase choice, and 7 more of those 19 chose none of the vehicles.

Overall lifestyle choices determine consumers' vehicle body style choices (and will affect consumers' choices between NEVs, EVs and ICEVs). Once these choices have been made,

individual vehicle features, brand loyalty, dealer reputation and brand experience determine choices of a specific vehicle of the general vehicle types. Approximately half the participants in the study rode or drove an electric vehicle that appears to satisfy their lifestyle demands. The choice of vehicles based on lifestyle considerations was expressed repeatedly in the focus groups. Several participants expressed their choice of vehicles would be the Horlacher Sport, if they were still single. But the presence of spouses and children influenced choices toward the Esoro, with its 2+2 seating or toward the desire for a modified Solectria with a back seat.

Conclusions

This study attempts to answer three questions. First, can we identify members of early market segments for electric vehicles prior to the existence of markets for vehicles? Second, do these potential early buyers express positive purchase intentions when presented with the opportunity to ride and drive a variety of electric vehicles? Lastly, what attributes of either the vehicles or the participants' activity spaces determine choices between the vehicles?

The first question is of fundamental importance because most studies of the diffusion of innovations are based on retrospective analyses. This study of innovators differs in that it hypothesizes the existence of two market segments for a product not yet widely available. The only definitive answer to the first question is that, as the terms "innovator" and "early adopter" are used in the diffusion of innovation literature, members of these groups cannot be identified a priori because the very definition depends on comparisons of persons in these groups to later buyers of the product.

This circular reasoning highlights the importance of the type of market analysis performed in this study. Hypothetical early adopters must be identified, their responses to electric vehicles assessed, and adjustments made to either or both our hypotheses or the product. Acceptance of the NEV concept and a willingness to promote it, to become an innovator in the sense of fostering the idea and importing into one's own social setting, first requires the recognition of NEVs as an appropriate solution to a pressing problem. In these clinics, the persons who chose to be NEV innovators were those for whom NEVs could provide access to an important set of their routine activities.

It should be noted that the group of environmentalists cannot be distinguished from the EV hobbyists on several attributes. Notably, both samples are very similar on precisely those characteristics used to identify environmentalists. This fact indicates that concern with air quality, and the desire to do something about it, has become a part of a more general social fabric of Sacramento and Davis than just our sub-sample of environmentalists.

Who calls themselves environmentalists? Rice growers who belong to Ducks Unlimited, contribute to maintaining the western flyway for migratory waterfowl and drive full size sports/utility vehicles and pickup trucks may identify themselves as environmentalists. Traveling artisans leading semi-nomadic lifestyles, while keeping aging VW campers and Volvo station wagons running may identify themselves as environmentalists. Young, urban professionals who hike, bike, and ski in the mountains on weekends and carry their gear on roof racks on top of their BMWs and Acuras may identify themselves as environmentalists. Little is common to all these people, certainly not the lifestyle choices that determine vehicle choices. What will distinguish these people into market segments for EVs and NEVs will be their response to the capability constraints of the vehicles: a distance budget imposed by limited vehicle range, low top speed, and limited passenger and cargo payload. The search for early buyers of electric vehicles will have to find new ways to segment the market based on these new vehicle capability constraints (See Kurani and Turrentine, 1995, for an expanded discussion of EV market segments.)

The answer to the second question is yes, and no. The participants in this study are ambivalent concerning choices of electric vehicles they rode and drove. Some strong, positive purchase intentions are expressed. Fifteen of the 26 participants chose one of the vehicles they had tested in a hypothetical purchase decision. However, eight of these 15 chose the Solectria conversion, not an OEM vehicle. Further, 11 participants chose none of the vehicles. With respect to NEVs, only two participants selected these vehicles from the variety of EVs presented to them.

Concerning the last question, the vehicle attributes that determined choices were top speed, driving range, price, and styling. Vehicle price determined whether any EV was considered for purchase, and to a lesser degree, choices between vehicles. Top speed and driving range separated the smaller, slower City-El and Kewet from the freeway capable Solectria, Esoro and Horlachers. The two NEV "buyers" both lived in downtown Sacramento. The non-freeway capable vehicles could access a large number of their activities because of the dense distribution of activity locations near their homes, connected by a dense network of lower speed streets. Low speed, limited range and low cost NEVs were perceived to be a superior transportation option to freeway capable, but more expensive, EVs. Within the group of respondents who indicated they would prefer to buy a freeway capable vehicle, their vehicle choices tended to maximize either top speed or driving range, and then to select for specific styling features.

Compared to larger, faster EVs, the City-El and El-Jet were perceived to eliminate desired or required time-space paths between activities by most EAA members. Our sub-sample of EV

hobbyists were mostly residents of Sacramento, where higher speeds and long distances are more typical of the transportation system and the urban structure than in Davis. In Davis, the WEF recruits perceived that the NEVs neither sufficiently increased their time-space prisms nor allowed sufficient access to new activities within their existing prisms. Because the NEVs did not allow for a new *NEV space* that could not be accessed by bicycle, the greater expense of NEVs compared to bicycles could not be justified. The next chapter, on the household NEV trials, further examines the difference in responses to NEVs in Sacramento and Davis and provides the most in-depth assessment of the effect of NEVs on households' activity spaces.

IV. HOUSEHOLD NEV ACTIVITY SPACE: Neighborhood Electric Vehicle Trials

Charles Olson. Call Me Ishmael. Quoted in Dettelbach.

"I take SPACE to be the central fact to [people] born in America...I spell it large because it comes large here. Large and without mercy...a hell of a wide land from the beginning."

Results from the household NEV trials illustrate the use of the activity space concept and the processes through which households learn how vehicle range, speed and size constraints shape their *NEV space* and ultimately their NEV purchase intentions. These trials explore how households use a vehicle that is not intended for highway travel, but intended to fill the specific niche of local travel on surface streets. By providing a NEV to a household for a week, we allow them to begin to explore how they would incorporate such a vehicle into their vehicle holdings. Changes in vehicle assignments to drivers and trips, changes in routes to activity locations, and changes in timing and sequences of activities are all examined. This study makes the most detailed use of the activity space concepts developed in the introductory chapter of this report. It is also the study in which we make the most in-depth examination of the basic premise outlined there—that households must be able to construct a *NEV space*—a useful set of activities to which the NEV allows them access—before they will consider buying such a vehicle. These households inform us about whether they can overcome space with a set of specialized travel tools that includes a NEV.

The test drive and interview process uncover the households' *routine activity space, critical destination(s)* and mode-defined *activity sub-spaces.* Recall we defined the routine activity space as that set of activities that the household accesses on a daily and weekly basis (including all the other associated activity space dimensions—location, mode and route to access, etc.). The critical destination is a destination that a household member feels they must be able to reach even if the "unlimited range" gasoline vehicle is not available. We hypothesized that mode-defined activity sub-spaces exist within each household's overall activity space.

The vehicle trials allow households to answer for themselves our central research questions:

- "Will households create NEV activity sub-spaces?"
- "Is the existence of a NEV activity sub-space a sufficient condition for those households to include NEVs in the set of vehicles they consider when making vehicle purchase decisions?"

We assume that households' choices of activities and activity locations will not change within the trial week. In the longer run, it is quite likely that households will change some activities or locations in response to a NEV. However, we assume that households not would explore such changes in a one week trial. The household interviews supported this assumption. We also constructed this study around households' actual experience with the NEV rather than have them speculate about some future state. Only if a household volunteered such a speculation, did we ask them to elaborate on their possible actions in a world where NEVs are more common. This restriction appears to have the strongest implications for interpreting safety perceptions related to relative vehicle size and speed. If future traffic mixes contain many more NEVs, some of our NEV drivers speculated they would feel more comfortable in traffic. The implications of these perceptions for a transition from the present (zero) levels of NEV traffic to the future are explored in the concluding chapter of this report.

Study Design

Each household in the study progressed through three phases: recruitment, vehicle trials, and interviews. Once a household was selected and a trial week scheduled, travel diaries were prepared for each driver in the household. For the trials, households were given either a City-Com City-El or a Kewet El-Jet to use for a one week period. Each driver in the household maintained a travel diary for that week and the household participated in an interview afterward. For each trip, drivers recorded all dimensions of the activity space: trip purposes (activities), travel modes (including alternatives to the NEV if it was used), trip times, routes, trip sequence, and activity links with other household members. Respondents recorded their routes on maps for each trip. The diaries served as the basis for the interview that explored the households' travel, assessment of the NEV, and NEV purchase intentions.

Participants

Fifteen households participated in the NEV vehicle trials, seven from Davis and eight from Sacramento. Since the UC Davis Medical Center is in Sacramento and the UC Davis campus is in Davis, we placed vehicles in households in both cities. In this way, we explored differences in household response based on spatial scale, traffic levels and speeds, and the prior existence of mode-defined activity sub-spaces within the households' activity space. Household size ranged from one to four persons. A wide variety of household types were included in the study: households containing one adult, two adults without children at home, two parents with a child or children, and single parents of a child or children. Ages of participants ranged from mid-twenties to mid-fifties.

All households had at least one member who was an employee of the University of California at Davis (UCD) or the UCD Medical Center (UCDMC). The UC employee and their spouse and children (if they held a driver's license) were permitted to drive the NEVs. This selection criterion was required by the University for liability purposes. While all UCD and UCDMC employees were eligible to take part in the study, participants were not randomly selected. Names for potential Davis area participants were collected from interested parties at the Whole Earth Festival in May 1993 on the UCD campus. Names for potential Sacramento area participants were obtained through surveys distributed at the Medical Center. Recruitment forms for both groups asked for information on vehicle and home ownership, home location, basic daily travel patterns and environmental attitudes.

Potential participants were selected based on 1) residential location, 2) ownership of at least one working automobile, 3) availability of a logical place to charge the NEV at their place of residence, and 4) the presence of a second car or second driver in the household. Potential participants were telephoned in the order of their priority and selected based on willingness to complete the travel diaries and interviews. Participants were asked specifically if they would like to drive the City-El or the Kewet. Thirteen households chose to drive the Kewet. Two factors contributed to this overwhelming preference. First, many households made peremptory judgments that the City-El was too small or too slow to be attractive. Second, the City-El was not available for the entire study period.

Limits on the study conclusions given the recruiting process

The highly selective nature and small size of our sample have several implications for the appropriate inferences that may be drawn from this study. Self-selection and sample size are concerns if we wish to make generalizations about some population from which our sample is drawn, i.e., if we wished to make NEV market size estimates based on this study. It is not our intention to make any such estimates based on these trials alone.

Of much greater concern is the requirement that at least one household member be an employee of the University of California and the effect of this requirement on the variety of travel that we are able (or unable) to observe. All our households have one member whose travel is dominated by travel to the UC campus in Davis or to the UCD Medical Center in Sacramento. In Sacramento, one of our primary selection criteria was that the household had to live close enough to the Medical Center that travel between home and the Medical center in the NEV was at least a possibility. All households in Davis satisfy this criterion with respect to the campus. Thus the nature of the households' activities and their locations within each of the study areas

are not representative of the whole population of those areas. In particular, households who live in the same neighborhoods as our participants, but do not make work trips to the UC Davis campus or the UCD Medical Center, will have very different activity spaces. The extension of the results from these 15 case studies to other households and other regions will be qualitative. These extensions will point to the existence of market segments based on generalizable characteristics of households, vehicles and urban infrastructure. However, these extensions must be regarded as hypotheses to be evaluated elsewhere. Some of them are tested in the following chapter that reports the results of our statewide survey.

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Each driver in the household received a map-based travel diary[1]. Each map included a small table to record trip beginning and end times, travel mode, EV recharging information and other trip information. Davis participants received diaries with maps of the entire city of Davis. Maps were custom made for households in Sacramento. Their maps included the household's most-frequently visited destinations such as home, work, shops and stores, religious sites, homes of family and friends, etc. The need for custom maps in Sacramento arose from the larger size of the city and the need to keep the maps legible. Maps were reproduced such that individual street names could be read.

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The Interview

Participants were interviewed within two weeks of the NEV trial week (usually within one week). Before the interview, all travel in the household's diaries were transferred to a single, large, composite map. The trips were color-coded according to the mode of travel. Routes were drawn with lines weighted to show frequency of travel along them. The composite map serves two purposes. First, it is an *aide-memoire* for households to discuss the details of the diary week. Second, the map serves as the basis for the household to assess likely hypothetical changes in travel due to hypothesized changes in characteristics of the NEV, the household's vehicle fleet, and the household's activities. The note-taking forms for the interview are included in Appendix E. Briefly, each interview moved through four main parts:

- An orientation in which the map was explained to the household and the household's travel was reviewed. This included an assessment of how representative the diary week was of the household's activities. Travel that may be regular, but not weekly, e.g., vacation, holiday or weekend travel, was discussed. Occasional use of travel modes not represented in the diary were identified. An account of the household's last car purchase and gasoline refueling behavior were included in this section too.

- The second part explored how the household used the NEV and how the NEV did or did not meet travel needs. How the NEV changed the households travel, which trips were made in the NEV, what mode would have been used if not the NEV, whether the NEV caused any changes in route choice, trip timing or other trip characteristics were all discussed. The household was asked to identify specific trips and locations on their composite map to illustrate each point.

- Third, a NEV purchase decision was discussed with the household. At this point a defining or limiting attribute of the NEV or the household's travel was often identified. Households were asked to identify the specific activities that were excluded by the NEV, that is, were outside the *NEV space*. For example, it was not enough for the household to tell us the vehicle did not have adequate space for passengers. They needed to identify specific activities or sequences of activities that required additional room. The vehicle

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types of places NEVs can be used, the types of travel that NEVs might accomplish, and the types of households that will buy NEVs.

Summary Evaluations of Changes in Travel due to the NEVs

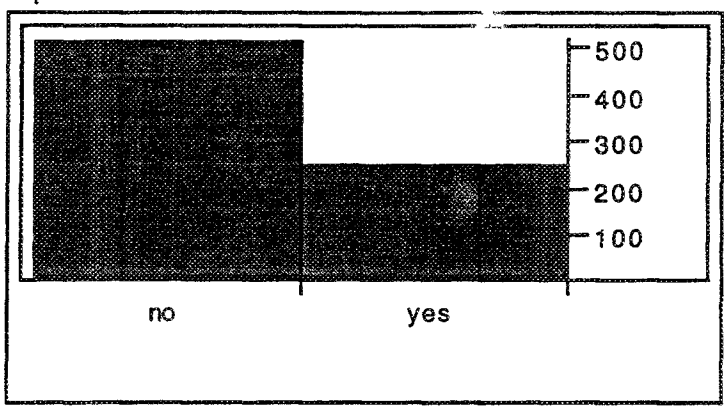
We present summary evaluations of the households' use of the NEVs in this section. Because of the small sample size, these relationships are treated as hypotheses for further research. Never the less, this section provides an overview suitable for a discussion of the impacts of NEVs on household travel. We begin with a general exploration of the aggregate effect of the new constraints imposed by NEVs on our sample of households. The most readily identified of these constraints are the capability constraints imposed by the vehicles limited range and speed. As we will discuss in the following sections though, passenger capacity is an equally important constraint in some households. While speed and range may restrict the activities of the NEV driver, limited passenger seating may create conflicts through the coupling constraints that exist to other household members.

The Impact of Authority and Coupling Constraints on Travel

Much of this chapter discusses the impact of new capability constraints imposed by NEVs on household travel and the role of range, recharging and speed constraints in producing the mode choices we will discuss in the next section. Before proceeding to that discussion however, we briefly examine the effects of authority and coupling constraints on travel by our households. As part of their travel diary, households recorded whether each trip could have been made at a different time and how long they had known they would be making this trip. Trips were also coded to indicate whether they were made solely to provide transportation service to another person, i.e., the driver would not have made the trip at all if not for the need to deliver another person to an activity. By examining the answers to these questions, we can summarize how the authority and coupling constraints imposed on households shape their travel choices.

To provide an overall sense of how much of the travel by our sample was subject to authority and coupling constraints, we summarize responses to the question whether trips could have been taken at another time in Figure 4.1. Two-thirds of all trips were either themselves constrained to the particular time at which they were made, or linked to another trip that was constrained to the time at which it was made. While this figure does not summarize all the reasons why these trips could not be made another time, it does illustrate that within our sample, most travel takes place under authority and coupling constraints that require that most trips be made within small windows of time, and that the constraints on these trips can affect other trips made in sequence with the constrained trip.

Figure 4.1: Can trip be made at another time?

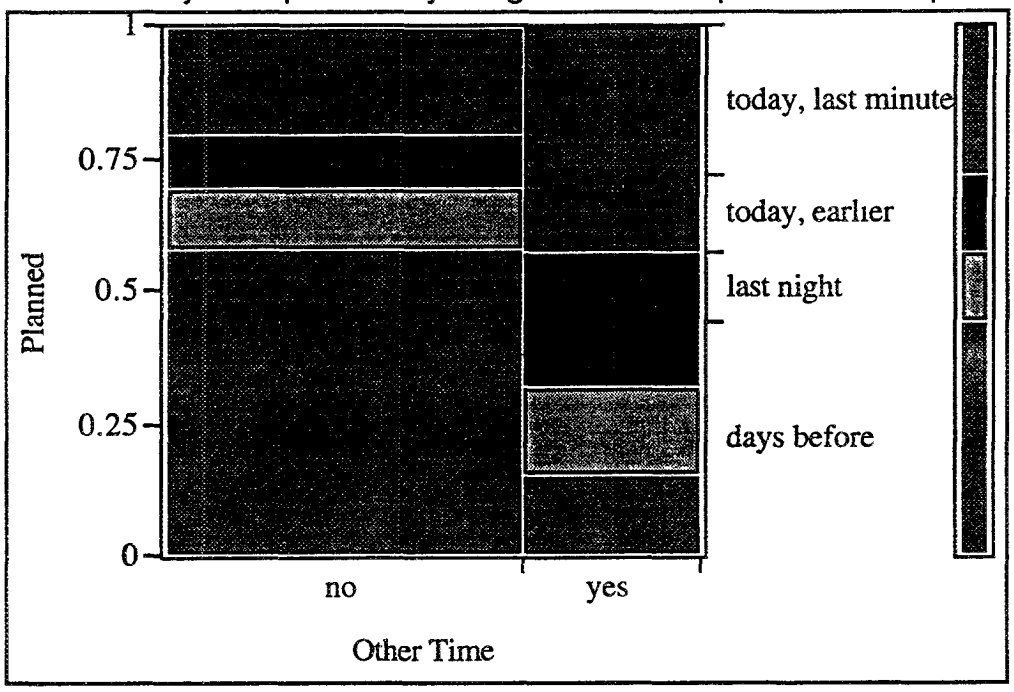


When we examine the time for which people had known they would be making specific trips, we see that a great deal of travel was planned far in advance (Table 4.1 and Figure 4.2). Forty-four percent of all trips had been scheduled to take place for many days. Also, there was a relationship between how long trips have been expected and the flexibility of their timing. Figure 4.2 is a mosaic plot of the data on flexibility of trip time and how long the trip had been anticipated. Fifty-five percent of all trips that could not be made at another time had been anticipated for several days. In contrast, forty-five percent of all trips that could have been made at another time were made at the last minute.

Table 4.1: Length of Time for which Trip had been Expected to be Made

How long has trip been expected?	**Count**	**Probability**	**Cumulative Probability**
1 = many days	331	0.440	0.440
2 = last night	99	0.131	0.571
3 = earlier today	113	0.150	0.721
4 = last minute	210	0.279	1.000
Total	753		

Figure 4.2: Flexibility of Trip Times by Length of Time Trip had been Expected



Note The horizontal axis is proportional to the number of trips that could, or could not, be made at another time. The vertical axis measures the proportion of trips that fall into each of the four categories of trip anticipation. The column on the right represents the proportion of trips in each category of "Planned" across the whole sample This is the same as the proportions in the "Probability" column in Table 4 1 Thus, we seee that approximately three-fourths of all trips could not be made at another time and sixty percent of these had been anticipated for several days.

Authority constraints lead to routines in household behavior. These routines are manifested by travel that is known and scheduled far in advance. These relationships are explored further in Tables 4.2 and 4.3. The relationship between whether a trip could have been made at a different time and the time for which the trip had been expected is summarized in Table 4.2. (This is the data in the mosaic plot in Figure 4.2.) It allows us to test the null hypothesis that there is no relationship between the two measures of trip flexibility. A chi-square test performed on the data in Table 4.2 rejects the null hypothesis. Among trips that had been expected for many days, the number of trips that could not be made at another time far exceeded what we would expect under our null hypothesis. This is statistical confirmation of the apparent relationship in Figure 4.2—trips that are inflexible in their timing tend to be expected in advance.

Table 4.2: How Long Trip Had Been Expected By Whether Trip Could be Made at Another Time

Trip Anticipated	Can trip be made at some other time?		Total
Observed Count Expected Count	No	Yes	Observed Row Total
days before	292 221.03	38 108.97	330
last night	58 66.31	41 32.69	99
today, earlier	50 75 68	63 37.32	113
today, last minute	103 139.98	106 69.02	209
Total	503	248	751

Chi-Square Test	Chi-square	Prob.>chi-square
Likelihood Ratio	137.902	0 0000
Pearson	128.151	0 0000

The role of authority and coupling constraints imposed by work and school is highlighted in Table 4.3. The number of trips to different destination types is cross-tabulated by how long the trips to those destinations had been expected. Below each count of observed trips is the number of expected trips under the null hypothesis of independence. Almost twice as many trips to work or school had been anticipated for several days than expected under the null hypothesis. Further, three-fourths of all work and school trips had been anticipated for many days. In contrast, only 2 of 41 trips made to dine had been expected for many days, far fewer than the expected 17.52 trips.

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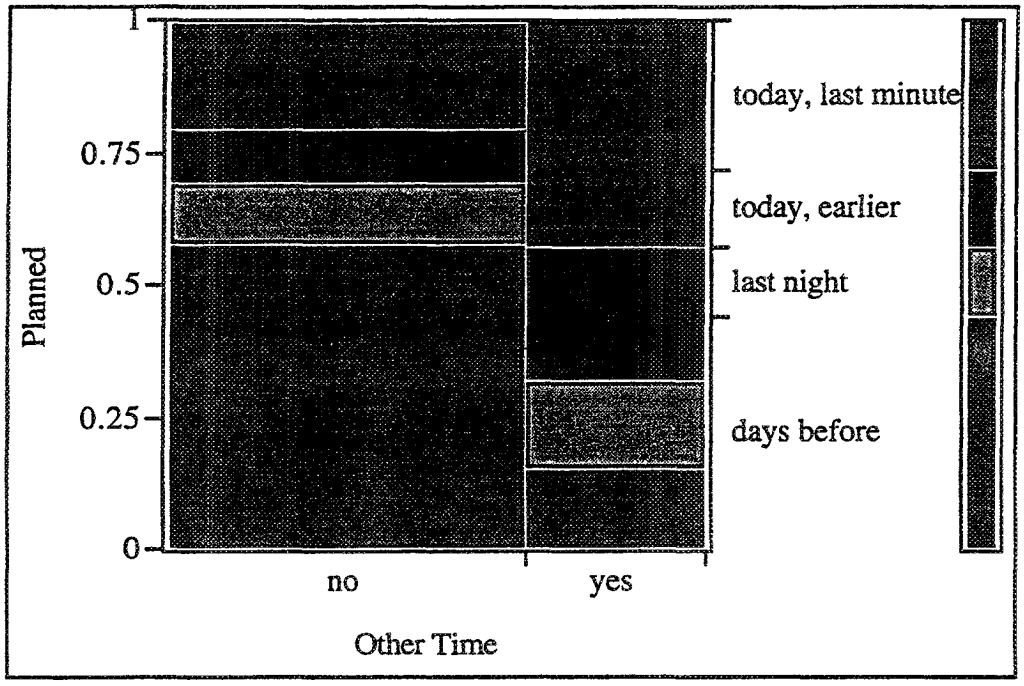

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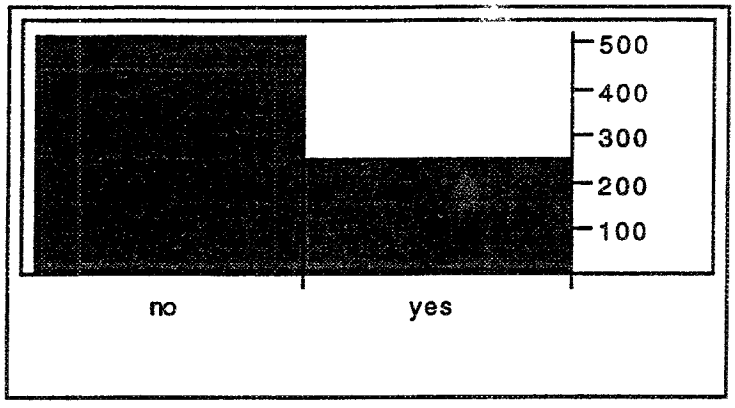

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[1] In an *activity* diary respondents record all activities, in a *travel* diary they only record activities that require a change of location. There is some evidence that activity diaries describe travel more accurately than do travel diaries, apparently because people more accurately recall what they have done than where they have been (Jones et al, 1983). However, we chose a travel diary format for two reasons. First, since travel diaries require recording fewer activities, the burden on respondents is reduced. Our travel diary is more complex than most because we ask respondents to draw their travel routes on maps in addition to recording the usual details of trip purpose, travel mode, trip time and distance, etc. Second, we knew we would have the opportunity to recover forgotten trips during the household interview.

All households had at least one member who was an employee of the University of California at Davis (UCD) or the UCD Medical Center (UCDMC). The UC employee and their spouse and children (if they held a driver's license) were permitted to drive the NEVs. This selection criterion was required by the University for liability purposes. While all UCD and UCDMC employees were eligible to take part in the study, participants were not randomly selected. Names for potential Davis area participants were collected from interested parties at the Whole Earth Festival in May 1993 on the UCD campus. Names for potential Sacramento area participants were obtained through surveys distributed at the Medical Center. Recruitment forms for both groups asked for information on vehicle and home ownership, home location, basic daily travel patterns and environmental attitudes.

Potential participants were selected based on 1) residential location, 2) ownership of at least one working automobile, 3) availability of a logical place to charge the NEV at their place of residence, and 4) the presence of a second car or second driver in the household. Potential participants were telephoned in the order of their priority and selected based on willingness to complete the travel diaries and interviews. Participants were asked specifically if they would like to drive the City-El or the Kewet. Thirteen households chose to drive the Kewet. Two factors contributed to this overwhelming preference. First, many households made peremptory judgments that the City-El was too small or too slow to be attractive. Second, the City-El was not available for the entire study period.

Limits on the study conclusions given the recruiting process

The highly selective nature and small size of our sample have several implications for the appropriate inferences that may be drawn from this study. Self-selection and sample size are concerns if we wish to make generalizations about some population from which our sample is drawn, i.e., if we wished to make NEV market size estimates based on this study. It is not our intention to make any such estimates based on these trials alone.

Of much greater concern is the requirement that at least one household member be an employee of the University of California and the effect of this requirement on the variety of travel that we are able (or unable) to observe. All our households have one member whose travel is dominated by travel to the UC campus in Davis or to the UCD Medical Center in Sacramento. In Sacramento, one of our primary selection criteria was that the household had to live close enough to the Medical Center that travel between home and the Medical center in the NEV was at least a possibility. All households in Davis satisfy this criterion with respect to the campus. Thus the nature of the households' activities and their locations within each of the study areas

Table 4.3: Trip Destination by How Long Trip Had Been Expected

Trip anticipated for how long?	Destination					Total
Observed Count Expected Count	Dining	Personal Business	Shopping	Social or Recreation	Work or School	Observed Row Total
days before	2 17.52	51 47.86	8 25.64	39 45.29	91 54.69	191
last night	4 5.60	16 15.28	14 8.19	15 14.47	12 17.47	61
earlier today	7 6.15	17 16.79	13 8.99	17 15.89	13 19.19	67
last minute	28 11.74	28 32.07	25 17.18	35 30.35	12 36.65	128
Total	41	112	60	106	128	447

Test	Chi-square	Prob.>chi-square
Likelihood Ratio	113.049	0.0000
Pearson	105.273	0.0000

Serve Passenger Trips—a Coupling Constraint

"Serve passenger" trips are trips made by one person solely to provide transportation services for another person. These trips most often arise out of household responsibilities that are a form of coupling constraint. For example, adult household members who, on their way to work, deliver children to school or daycare, are making a serve passenger trip—they would not be driving to the school or daycare center unless they were providing a ride for the children. The effects of these coupling constraints are summarized in Tables 4.4 and 4.5.

Most "serve passenger" trips are subject to rigid time constraints. Table 4.4 cross-tabulates whether a particular trip was a "serve passenger" trip by whether the trip could have been made at another time. A total of 141 "serve passenger" trips were made. Of these, 128 trips could not have been made at another time; only 94 are expected under the null hypothesis of independence. Thirteen of the "serve passenger" trips could have been made at another time;

47 would be expected. The chi-square test on this data is significant. When coupling constraints result in one household member providing transportation services to others, the transportation provider becomes subject to the authority and coupling constraints of the travel-dependent person.

Table 4.4: Serve Passenger Trips by Whether Trip Could Be Made Another Time

Serve Passenger: Observed Count Expected	**Could trip be made at another time?** No	Yes	**Total:** Observed Row Total
No	387	244	631
	420.94	210.06	
Yes	128	13	141
	94.06	46.94	
Total	515	257	772

Test	**Chi-square**	**Prob.>chi-square**
Likelihood Ratio	53.512	0 0000
Pearson	45.005	0 0000

Data on whether a trip was a serve passenger trip and how long the trip had been expected to be made are cross-tabulated in Table 4.5. The chi-square test on these data rejects the null hypothesis of independence. Rather, serve passenger trips tend to be expected well in advance. The coupling constraints that result in serve passenger trips tend to produce routines in which those trips are anticipated for several days.

Table 4.5: Serve Passenger Trips by How Long Trip has been Expected

Serve Passenger: Observed Count / Expected	**How long as trip been expected?** Many Days	Last Night	Early Today	Last Minute	**Total:** Observed Row Total
No	256	81	100	186	623
	273.43	81.05	94.15	174.37	
Yes	78	18	15	27	138
	60.57	17.95	20.85	38.63	
Total	334	99	115	213	761

Chi-Square Test	**Chi-square**	**Prob.>chi-square**
Likelihood Ratio	12.584	0.0056
Pearson	12.410	0.0061

Travel by NEVs and other Modes

Here we explore the impact of the NEVs' capability constraints on the households' ability to access desired activities. We examine the total amount of travel by our sample and how this travel was apportioned to different travel modes. In this way, we begin to assess households' abilities to form *NEV spaces*.

Trips and Miles Traveled in the NEVs

As expected based on their limited speed and range, NEVs replaced a greater proportion of trips than of miles in almost every household. Across all households, the Kewet and City-El accounted for an average of 19% of the total distance households traveled during their diary week, yet they were driven, on average, for 41% of all trips. The percentage of household trips for which a NEV substituted ranged from a low of 10% to a high of 72%. The percentage of miles for which a NEV substituted ranged from a low of 6% to a high of 43%. The number of miles traveled by a household in a NEV during its diary week ranged from a low of 12 miles to a high of 106. As we expect, there is a moderately strong statistical correlation between the number of trips and the number of miles. However, there is no such association between the proportion of trips and the proportion of miles. That is, the households move through such different activity spaces, that the substitution of a NEV for a given proportion of trips does not lead to a predictable proportion of miles the NEV travels.

difference in the proportion of travel assigned to different modes is within the effect of NEVs on bicycle use. Since there are no bike trips in Sacramento, the NEV replaced no bike trips, but in Davis, 48 of the 242 (20%) of the NEV trips replaced bike trips

Table 4.7: Travel Mode for which the NEV Substituted by City

Mode for which the NEV Substituted	**City**		
Observed Count	**Davis**	**Sacramento**	**Total**
ICEV	151	93	244
NEV	34	26	60
Bicycle	48	0	48
Walk	9	7	16
Total	242	126	368

Note ICEV1 and ICEV2 combined into a single category

Table 4.8 shows the near complete dominance of automobiles in Sacramento. This dominance demonstrates itself both in the higher proportion of travel accomplished in motor vehicles and the limited number of different travel modes used by households in Sacramento. Even with the NEV, households in Sacramento relied on their own gasoline cars for 61% of their trips, while households in Davis used their own motor vehicles for only 28% of trips. While Davis residents used a total of 7 different modes, Sacramento residents used only 3. The modes that were used in Davis, but not in Sacramento, were used relatively infrequently compared to motor vehicles. However, collectively they accounted for 18% of trips made by our Davis households.

Table 4.8: Total Travel Mode Frequencies by City

	Davis			Sacramento		
Mode	**Count**	**Probability**	**Cumulative Probability**	**Count**	**Probability**	**Cumulative Probability**
ICEV 1	114	0.24	0.24	174	0.49	0.49
ICEV 2	18	0.04	0.28	42	0.12	0.61
NEV	240	0.51	0.79	124	0.35	0.97
Bicycle	67	0.14	0.93	0	0.00	0.97
Carpool	12	0.03	0.96	0	0.00	0.97
Other	2	0.00	0.96	0	0 00	0.97
Transit	3	0.01	0.97	0	0.00	0.97
Walk	16	0.03	1.00	12	0.03	1.00
Total	472			352		

Note Cumulative probabilities may not sum due to rounding

Ultimately, these differences in mode choices represent differences in travel networks and land use. A wider variety of modes are used in Davis because the travel networks and land use are more amenable to non-motorized travel. Recall though our caveat about the effect of using only UC employees in the study. Especially in Davis, we have selected households with at least one member who travels daily to the UC campus. The campus is the central hub of the town's transit system and is specifically designed to encourage bicycle and pedestrian access, while excluding automobiles. With this reminder, we note that the NEVs were used for 51% of all trips in Davis. In contrast, in Sacramento the NEVs were used for 35% of all trips.

Household Response to the NEVs: Overall Impressions

For the most part, impressions of the NEVs were remarkably consistent across households and between the two cities. Virtually all the households found the NEVs to be quiet, easy to handle and park, and enjoyed knowing that driving a NEV was less polluting than driving their car. Charging the vehicles at home was an easy task and a convenience for most households. Most participants felt the NEVs have tremendous potential, but that at the state of development represented by the Kewet and City-Com vehicles, NEVs were inadequate to provide for many daily needs. Some concerns had to do with vehicle attributes that households already consider

in their vehicle purchases: body style vehicle size and impact on safety and payload. Other concerns had to do with new attributes — short ing range, low top speed, and home recharging. The week trial allowed the household to begin to learn what these new attributes may mean to their vehicle purchase decisions.

Our respondents expressed several reservations regarding the NEVs they drove. Safety was a concern Poor acceleration and slow top speeds made participants feel unsafe in fast moving traffic. In a few households, the short range and long recharging time combined to limit travel in the vehicle. Several participants noted that during their trial week they tended not to combine trips in the NEVs out of fear of running out of charge. Finally, virtually all households with children felt that the passenger room in both vehicles was inadequate for their family.

This excerpt from the notes of the interview with AC (a household made up of a single adult, who owns one car) summarizes common responses to two of the capability constraints (speed and range) imposed by the NEV:

> "AC thought the Kewet was fun, but overall she found it was not very useful for her daily travel. One round trip between home and work exhausted the NEV's range. If she took it to work, she couldn't make any additional work-related or personal trips that day without returning home to get her gasoline car. She did not look for a place to recharge the vehicle at work to extend the vehicles daily range. In addition, she makes regular, weekly trips to visit family that require longer range. The driving range constraint required too much advanced planning for her lifestyle.
>
> "The slow speed of the vehicle forced her to take a new, non-freeway route to work. She often felt that she was holding up traffic, that other drivers were impatient with her and that she might get hit.
>
> "On the positive side, AC liked the fact that the Kewet was non-polluting and quiet. She felt she would need 50 miles of range and 40 mph top speed for her to consider buying it. Even then, it could not be her only vehicle."

The interview with AC also highlighted social processes in the early market for NEVs. Her week-long trial was a neighborhood event. On several evenings she was questioned at length by her neighbors about the vehicle and she gave children from the neighborhood short rides around the block, too.

AC was not able to create a *NEV space* because of the range and speed constraints imposed by the NEV. The round trip distance between her home and work was at the limit of the NEVs driving range. Thus the NEV would have to be a commute only vehicle; her workplace would be the only destination in her routine (weekday) activity space. Conversely, if she did not commute to work in the NEV, then her usual after-work destinations could be in her *NEV*

space, but only if she returned home first to switch vehicles. In the following section we explore how households constructed, or failed to construct, a *NEV space* . We also explore how a NEV might be incorporated into the households' vehicle holdings.

Changes in Household's Activity Space

The previous section examined changes in travel across the whole sample of households to highlight aggregate changes in travel. We saw that the NEVs replaced a higher proportion of trips than of miles. We determined that activities that impose strict scheduling requirements through authority and coupling constraints result in travel that tends to be inflexible in its timing and regular in its occurrence. In this section, we treat the households more as single entities. We use them as case studies to illustrate the existence of mode specific activity sub-spaces, to discuss the variety of adaptive strategies to driving range, to highlight the interaction between travel mode choice, infrastructure and land use, and to explore how these households might incorporate a NEV into their vehicle holdings.

Mode Defined Activity Sub-Spaces

In Davis, we find evidence of activity sub-spaces accessed by different travel modes. In Sacramento, we do not find these sub-spaces. Our small sample of Sacramento households uniformly and regularly accesses virtually all out-of-home activities by automobile. Thus, the kinds of trips the NEV was used for, and the modes of travel that it replaced, differed systematically between the two locations as we saw in Table 4.8. Most participants in Sacramento rarely left home by any means other than their cars. They did not have mode-defined activity sub-spaces; their activity spaces were almost entirely accessed by private passenger cars. In contrast, some of our sample households in Davis used bikes extensively. These households consistently access a distinct set of activities by bicycle than they access by car. Their bicycle and automobile activity spaces have regular and well-defined (if sometimes overlapping) boundaries. The existence of mode-defined activity sub-spaces does appear to be an organizing principle for travel in some Davis households.

Travel in Sacramento was dominated by a single mode—the automobile. Only one UCDMC participant walked regularly (to work) and no one biked regularly (to travel to some activity or as an activity itself). Public transit was perceived as being directed toward locations outside the households' activity spaces and as imposing too strict scheduling constraints. This was especially true regarding trips to workplaces. Transit was rarely used by any participant, even when available near home or work. Specific problems included indirect routes and multiple

transfers required to get to work and transit schedules that did not meet work schedules. The NEV almost exclusively replaced automobile trips in Sacramento.

Residents in Davis were more likely than those in Sacramento to already have mode-defined activity sub-spaces. Bicycles provide access to work (the University campus), grocery and other shopping, especially to the university campus and downtown. Trips to run errands during the day before returning home were made on foot or bike, if bike was the mode taken to work. Cars and bikes were used for local trips, but only cars were used for out-of-town travel. In addition, many Davis households noted they had altered their lifestyle to reduce the number of local automobile trips and had consciously chosen to cycle as much as possible. E and G made a conscious decision to sell three of their four cars and remain a one car household. J and K noted that if they expected their son to get around town on his bike, they had to be willing to do the same. Public transportation was rarely used by any of the Davis participants, although one household had a member who carpooled to work in Sacramento.

Therefore, in Davis, the NEV replaced both bike and car trips. These trips included trips to UCD, downtown, some shopping, the post office, bank and other local activities. Trips out of town, trips within town that required travel on high speed streets (speed limits in excess of 35 mph), and trips with more than one passenger could not be made in the NEVs.

The NEV most often replaced bike trips when the main reason for riding a bike was environmental, not convenience. Participants perceived that the NEVs provided "guilt-free" driving, an opportunity to take a "car" without worrying about polluting the environment. If the bike was used for a specific trip because it was more convenient than a car, households speculated that bikes would be chosen over NEVs too—even if the NEV was a permanent part of their repertoire of travel tools. For example, the UCD campus does not allow motor vehicle traffic in the campus core. For UCD employees who live in Davis and work in the campus core, travel to work by bicycle is generally faster than by car and parking is easier and much less expensive (free for a bike). Under these conditions, the NEV is unlikely to be substituted for their bike.

Several subjects noted that the Kewet felt like a cross between a bike and a car: it had larger cargo area and protection from the elements like a car, but the slower speed and perceived vulnerability of a bike. J and K felt the City-El was so small, so vulnerable and so limited in storage space that they simply stopped driving it by the end of their trial week. They preferred to ride their bikes along off-road paths and quiet streets.

The specific existence of a "bicycle activity space" does indicate that households will create activity sub-spaces distinguished by travel modes, but does not itself appear to be positively associated with desire to buy a NEV. The NEV must sufficiently distinguish itself from a bicycle to trigger a purchase intention. In several households this means the vehicle must be sufficiently larger and faster than a bicycle, while remaining sufficiently less expensive than an automobile. For many of our Davis households, a vehicle must have the requisite performance to reach nearby towns before it is sufficiently distinguished from a bicycle to be seriously considered for purchase. This performance level is well beyond the NEV examples that these households drove. This echoes the response of the Davis residents who took part in the ride-and-drive clinic, as reported in the previous chapter.

NEV Space and the Routine Activity Space

Capability constraints (vehicle range, speed and payload), as well as coupling and authority constraints, determined the boundaries of the *NEV space* and the overlap of this space with other mode sub-spaces. We identify four types of activities important to mode-defined activity sub-spaces:

1) Activities that define the boundaries of each mode defined sub-space;
2) Activities within the sub-space;
3) Activities outside the sub-space; and
4) Activities that belong to more than one mode-defined sub-space.

The activities at the boundaries between sub-spaces highlight important constraints. The other three types of activities determine the value a household might place on the travel mode that defines the space. They determine the activities to which each mode allows access, those activities to which another mode must be taken (or the activity rescheduled or forgone), and whether each mode clearly differentiates itself from other modes.

Almost every person in Davis who drove the Kewet indicated the entire town was accessible to them in that vehicle, but any activity location outside town was not accessible because of the capability constraints imposed by the NEVs driving range and top speed. Parts of town to which they did not travel in the Kewet were seldom visited by any mode. The question remains, to what extent do the boundaries of Davis, which formed the boundary of the *objective spatial structure* that can be accessed in a NEV, coincide with the boundaries of the household's *routine activity space*? That is, we expect the boundary of the *NEV space* of Davis residents to be no larger than the city limits. What we must determine is:

- the importance of trips beyond the town's boundary to the lifestyle choices of the households;
- whether they construct a set of travel tools that includes a NEV; and
- how they differentiate the use of NEVs, cars, and bikes within the town limits

Our sample of households in Davis contains some households that leave Davis less than weekly and others that travel beyond the city limits daily. However, this simple distinction alone does not determine which households construct a useful *NEV space* from those that do not. The frequency of such trips, the usual travel mode, the activity for which the trip was being made and the household's vehicle holdings all contributed to whether a vehicle that was limited to in-town travel alone would be seriously considered.

Within the spatial boundaries of their *routine activity space*, almost every household discovered activities for which some capability constraint other than driving range eliminated some activities from their *NEV space*. The limiting constraint was almost always the passenger or payload capacity. Serve passenger trips to chauffeur children or other family members, trips that linked chauffeuring and shopping, and trips to haul bulky items could not be made in the NEVs. In multi-car households, another vehicle was available to make these trips and the possibility exists a NEV could displace one of the vehicles in the households' current holdings. In households who own one car, the NEV would have to be an additional vehicle.

Of the activities within Davis to which the NEV did provide access, it competed with cars and bikes. Distinguishing the NEV from these two modes was often difficult for households, and even after a week, most were still weighing the tradeoffs. The NEV offered a travel mode that some households described as "guilt free" compared to driving their car. But the NEV was also perceived as less safe than automobiles by almost all the drivers in Davis. Safety concerns were expressed both with vehicle size and acceleration capability. Compared to a bike, the NEV was more comfortable and could carry larger loads, but only inclement weather rendered the NEV superior to a bicycle for many households. Bicycles were often more convenient because NEVs were subject to the same restrictions as cars, especially on parking. Bicycles were certainly perceived as less expensive. There was no consensus perception of the relative safety of the NEVs and bikes. Some people felt much safer in the NEV, others felt safer on their bikes.

The important distinction between in-town and out-of-town trips and the inability of NEVs to access out-of-town trips meant three households in Davis would not now buy a NEV. Two of the three speculated that as children came of driving age, a NEV might be the vehicle they

would add to their vehicle holdings to accommodate increased demand for a vehicle One household speculated that if NEVs were offered as compact pickup trucks, they might buy one. However, since this would be a vehicle for hauling materials for home, garden and art projects, the possibility existed that the locations of the supplies might be outside the range and speed capability of a NEV. The household that drove the City-El was simply unable to construct a meaningful NEV-space. They concluded a bicycle was a superior travel mode for virtually any trip for which they might use this particular NEV.

Two of the households constructed "large" NEV spaces. They accessed many activities on a daily basis in the NEVs, and these activities included a substantial portion of all activities in which the households engaged. In both cases, most activities accessed by the NEV had previously been accessed by automobile. In one household, the NEV would be an additional vehicle. In the other, the NEV would exactly replace the travel of an ICEV already assigned only to in-town trips.

Respondents in Sacramento could not access the entire *objective spatial structure* of the conurbation in which they live (the entire metropolitan Sacramento area) in a NEV. The distinction between in-town or out-of-town trips did not determine the practical limits of the *NEV space* as it did in Davis. Rather the interplay between vehicle performance capabilities and roadway infrastructure define the limits of households' *NEV-spaces* in Sacramento. In this setting, coupling or authority constraints (most commonly associated with trips to work and serve passenger trips, but also some social and recreation trips) played a more important role in determining the boundaries of the *NEV space.*

While changes to roadway infrastructure and land use patterns in Davis might enhance the operating environment for NEVs, the existing conditions are not prohibitive to NEVs. In contrast, so much of the existing infrastructure and land use in Sacramento is not amenable to NEVs that changes to some elements of the *objective spatial structure* may be necessary to make NEVs attractive to many households. In the absence of these changes, NEVs may have to be selectively marketed in specific neighborhoods. We could always build bigger, faster NEVs, but at some point the vehicle ceases to be a neighborhood vehicle. We explore the impact of roadway infrastructure and land use on NEV travel in the following sections.

Changing Routes to Activities

The inability of NEVs to travel on freeways, urban expressways and other high speed roads required several participants to search for alternative routes to activities that were otherwise within the driving range of the NEV. Whether an acceptable alternative could be found was

crucial to households' ability to create a *NEV-space*. Finding such routes was typically more difficult in Sacramento than in Davis.

In an attempt to deal with the NEV's speed limitations, many Sacramento participants altered their regular routes, leaving the freeway to drive on surface streets. For example, CL had to drive a very different route to UCDMC from her North Sacramento home to find a safe bridge to cross the American River. Her usual commute route was almost entirely along Interstates 5 and 80. She made an active search for a new NEV-route to UCDMC. This involved extensive driving through the grid-like network of low speed downtown streets to access one of the two bridges across the American River on which the NEV could be driven. Any of these alternative routes added time, but little distance, to her commute trip.

In addition to searching for entirely new routes, households switched to alternate routes that were already used occasionally. YC often commutes to work on surface streets, but commutes home on the freeway because it takes her past one of her usual grocery stores. In the Kewet, she commuted both to and from work on her usual surface street route. Thus she changed her route home from work and to the grocery store to a route she sometimes used anyway.

Land Use and Infrastructure Limits on Route Choice

A household's ability to find an alternative route was heavily influenced by the types of roads available and the speed and acceleration capabilities of the NEV. In Sacramento in particular, we see the effects of existing urban infrastructure on households' ability to create a useful *NEV space*. Some households were located in residential enclaves surrounded by high-speed roads. The high-speed streets served as barriers to access to all but a limited number of activities. Even the larger, higher speed El-Jet (as compared to the City-El) was not a comfortable vehicle for many households to use. Unfortunately, these land use and transportation infrastructure patterns are typical of the majority of the suburban communities surrounding downtown and midtown Sacramento. Indeed, this land use pattern is typical of suburbs throughout California and the nation.

Household 15 lives in a suburb typical of these residential enclaves surrounded by high-speed roads. Virtually all retail and commercial activity near this neighborhood can only be accessed by entrances from these roads. Within this land use pattern, this household was almost completely unable to construct a meaningful *NEV space* with the City-El. To access almost any activity, they had to travel on at least one of these high-speed streets. After a few experimental trips, the City-El was largely relegated to visiting garage sales and other trips within the neighborhood. Its one substantive use was for the work commute of the female

head of household, but as this trip is usually made by walking or carpooling, using the NEV for this trip was not viewed as a use that would trigger a NEV purchase.

Household 15 faced patterns of land use and roadways hostile to NEVs, but such ubiquitous patterns were not required for barriers to exist to NEV use. A single roadway or geographic feature can represent a sufficient barrier to a household creating a useful NEV-space. We saw examples of this in Davis and Sacramento. To access the university campus and downtown Davis, residents of west Davis must cross State Highway 113, to access the Medical Center and downtown Sacramento, residents of north Sacramento must cross the American River. In both cases, only a limited number of options are available to make the crossing. The City-El was judged to be a poor replacement for a bicycle in one west Davis household because the choice of routes across Highway 113 dictated that the City-El be driven on a busy street with several traffic signals, whereas a bicycle allowed access to the rest of town by way of quiet, residential streets and a pedestrian and bicycle over-crossing of the highway. Similarly, the American River represents a linear element of the *objective spatial structure* of Sacramento across which traffic flow is restricted to a few bridges. As discussed above, this affected CL's ability to access UCDMC from her home north of the river.

Of the households in the two cities, Davis residents were more likely to feel the NEV could accommodate most of their daily travel. The city is small and relatively compact, there is easy access to most locations within the city, it has many of low speed streets, and alternative transportation options, such as biking, are readily available. In contrast, Sacramento is much larger, has many busy, high speed streets, and it is more difficult to use alternative forms of transportation unless your destination is downtown. In addition, many of the lower speed roads are intentionally designed not to connect different activity locations themselves, but rather to be collector streets for major roads that connect activity locations.

Household Response to a Distance Budget

Within the one week trials, we did not expect to observe "stable" adaptations to distance budgets. Households did not always explore the full extent of the NEV's range (though one driver did run out of charge two blocks before reaching home and two others drove the Kewet far enough that it switched into its reduced performance "limp home" mode). We expect that in the long run, the actual *NEV space* that these households create will be different from those in the one-week trials. Therefore, we do not analyze the extent of those spaces per se, so much as we examine the adaptive strategies used to create those activity sub-spaces.

A short driving range imposes a distance budget on household travel choices. Just as different households have different financial budgets and time schedules, households will have different responses to this new budget. An important tradeoff between whether to drive the NEV or a car centered around driving range and the amount of pre-trip planning required to adapt to this new capability constraint. Adaptations to the distance budget included pre-planning the day to decide which driver (if any) would take the NEV, switching vehicles between drivers during the day, planned changes in trip linkages, unplanned interruptions of trip linkages and daytime recharging. Because of the short range of the vehicles and the long charging time, travel had to be planned in advance. With no place to recharge besides home (and occasionally work), last minute changes in plans required greater attention to whether the NEV was sufficiently charged than would be paid to whether the car had enough gasoline. Along with planning individual trips, daily travel plans had to be made conservatively; attempting too many trips or trips of too great a length might mean being stranded.

The decision as to which person would drive the NEV was based on the expected activities for each person that day, moderated by any underlying propensity for unexpected daily variation, e.g., last minute trips. Typically, multi-driver, multi-vehicle households decided at the beginning of the day who would drive the NEV that day. In household 8, LK and DA both had travel that on any given day could be accomplished in the Kewet. DA is self-employed and his travel can be much more varied and spontaneous. Some days he will have unplanned trips well beyond the range and speed capability of the Kewet, whereas LK's trips to the Medical Center are regular in occurrence and distance. Her work-related activities that require longer travel tend to be known in advance and she can reserve a University car for these trips This household had several options. The simple choice was for LK to drive the NEV to the Medical Center everyday, but this does not maximize the NEV use (thus minimizing household travel cost). DA makes more trips and drives more miles than LK almost every day. On those days when he *can* drive the Kewet, the household (and society) derive greater benefit if he does drive it. The household determined that DA would drive the NEV most days, switching cars with LK at the hospital if he unexpectedly needed for longer range, higher speed or greater passenger and cargo payload capacity.

Unexpected daily variation in activities can cause the NEV to be left home altogether. Some participants (households 9, 11, 13) took their car rather than the NEV to work on one or more occasions because the *possibility* existed that they might have to stay late or run errands during or after work. In household 10, CL and SL both work at UCDMC, but on different, overlapping shifts. Thus they each drove separate cars each day to the Medical Center and it

was not unusual for them to switch cars during the day at the hospital. Both concurred that this switching allowed them to solve almost any problem created by the Kewet's range.

The desire to link several activities can cause the NEV to be left home or change the intended sequence of activities. For example, LK and DA stated they took a gasoline car on one weekend day to do errands, shopping and go to the movies because they were concerned the Kewet did not have sufficient range to make this sequence of trips. However, DA stated that by the end of the week, he had enough confidence in the vehicle's range, that if he were making the same tour of trips again, he would take the NEV.

Alternatively, if the NEV is taken on a series of linked trips, the list of intended activities can be changed to accommodate the NEV. In a different household, SD usually leaves the Medical Center, picks up her son at school, completes other errands, then travels home. On one day, a stop at the Post Office that normally would have occurred in the chain of after-work trips was rescheduled to a day when she would be driving her gasoline car anyway. In some instances, the NEV may force unplanned interruptions in the activity chain In yet another household, after a trip to work, to lunch and a number of errands, DD had to return home to recharge the Kewet and switch to a gasoline car to finish his last activity before returning home for the day.

Four households recharged the NEV during the day in addition to recharging the vehicle overnight. Two of these households had access to the recharging facility on the UC Davis campus and recharging there was primarily a convenience. However, two households used day time recharging to overcome perceived range limits. One driver in a household in Davis felt uncomfortable driving across town to the UC Davis Medical School on less than half a charge. Also, she links several activities in longer, home-based trip sequences as a conscious trip-making strategy. She felt the Kewet's range limit inhibited this strategy. In response to these, she began recharging the vehicle when she arrived home during the day so that it always had the greatest possible range. Lastly, CB in Sacramento began recharging at the Medical Center after running out of charge of few blocks from home. This required she park illegally and would have required a more acceptable solution if the NEV were a permanent part of her set of household travel tools.

Daily activity planning, strategies to deal with day-to-day variability in travel, and day-time recharging are likely long-term adaptations to the distance budget imposed by the driving range limits of NEVs. On-going interruptions of activity sequences are less likely to be tolerated. Vehicle specialization makes the choice of which vehicle to drive—the NEV or a gasoline car—easier, as does the availability of other viable travel alternatives to a household vehicle.

Passenger and Payload Capacity: Authority and Coupling Constraints Revisited

While range and speed determined which activities could be contained within the *NEV space*, the overlap between the *NEV-space* and the car and bike sub-spaces was often determined by the passenger or payload capacity of the vehicle. In combination with limited passenger capacity, coupling constraints to other household members (or persons outside the household) often determined whether the NEV was used for a particular trip. With the possible exception of one of the single-adult households (who drove the two-seat Kewet), all the households felt a one-seat vehicle such as the City-El was too impractical. The coupling constraints between people (e.g., chauffeuring children, doing errands, carpooling to work, going to parties with friends) cannot be overlooked. Although travel surveys indicate many of us travel alone in our cars for most trips, the inability to travel with another person was often as important a constraint on use of a NEV as was range or speed. Less often, the payload capacity of the NEVs made them better choices than bikes, but impractical for some trips assigned to a car.

The Impact of Children in a Household

The number and age of children in the household affected the ability of the Kewet to fulfill certain "chauffeur children" trips (a sub-set of "serve passenger" trips). Infant children take up a great deal of space in a vehicle. Child seats, strollers, diaper bags, toys, changes of clothes, coolers for milk and food all mean an infant child regularly occupies much more space in a vehicle than their small size would indicate. Because it has only one seat, the City-El was precluded from ever being used for chauffeuring children regardless of age.

CL often stops at daycare to pick up her young son and then stops at the grocery store before going home after work. In the Kewet this sequence of activities was not possible because there was not room for her son, all his gear, and groceries. Since she had to return directly home from daycare to switch cars before making the grocery shopping trip, the Kewet was much less convenient than her own car. This sequence highlighted the NEVs passenger and cargo limits. BMP and MP also indicated the Kewet was too small for them and their young children. However, in this household, vehicle size was rarely a problem alone. Most trips for which the Kewet was too small were also too long for the Kewet. The trips they all take together are usually out of Davis. GM and GH could use the Kewet to get anywhere in Davis. The passenger limit came into play in fulfilling carpool obligations (a form of coupling constraint) when taking their daughter and her friend to school

YC makes a least one trip a week in which she and all three children are in the car. If for no other reason than she must carry four people, this weekly trip must be put in her car-space, not her NEV-space. SD believes that the speed and range of the Kewet are very nearly adequate, but for as many as 70% of her trips she has her son and a friend in the car with her. This precludes use of the Kewet. Parents who are unwilling to leave young children at home, couples who do errands together, even a desire to take a pet along for the ride—all required more seats or space than either the City-El or Kewet provided. In these cases, activities that could otherwise easily be accessed in the NEV based on its range and speed, were instead accessed in a gasoline car.

Many households travel to a grocery store every week to two weeks to make what they commonly called "the big shopping trip". These trips entailed the purchase of as many as ten bags of groceries. The City-El was clearly inadequate for such a trip. Whether the Kewet would suffice for this trip often depended upon whether another person was expected to accompany the driver. If not, then the passenger seat and foot space could be used to hold groceries that would not fit behind the seat. If another household member was expected to make this trip, then the NEV was left home and a car taken for these shopping trips. Rather than add this activity to the *NEV space*, some households keep it in their car-space because of the coupling constraints arising from household roles of individuals.

Taken separately, none of these examples means a *NEV space* cannot be constructed, but taken together, they illustrate the basis for the ambiguity between cars, NEVs and bikes. As the number of activities for which the NEV cannot be used grows, it becomes more difficult for households to see the value of the vehicle. We explore how *NEV space* formation affects NEV purchase intentions in the conclusions of this section. First though, we examine how safety perceptions of NEVs are formed and how they affect *NEV space* formation.

Perceptions of NEV Safety

The perceived safety of the NEVs was dominated by three characteristics of the vehicles—their size, acceleration, and top speed. Safety perceptions were an absolute barrier to NEV purchase intention in only one household, but were a source of some reflection in almost all households. In general, the NEVs were perceived as less safe than automobiles; a clear consensus was not apparent among bike riders whether they felt more or less safe in a NEV.

Unease over the small size of the NEVs manifested itself both as a fear of injury in an accident and a belief that the vehicle might not be seen by other drivers. The first was common to both the Kewet and the City-El. Visibility was an issue only for the City-El.

Acceleration was widely identified as a problem when making left turns across traffic, right turns merging into traffic and pulling away from stops. The ability to maintain speed up grades was also cited as a problem. One railroad over-crossing in Davis, which is a short but steep grade, was cited by every household in Davis as a place where they were made aware of the limited power of the NEVs they drove One solution to the problem of making left turns across traffic involved making a series of right turns to travel around a block. This may sound like an extraordinary adaptation, but in very high traffic conditions some households made this maneuver in their gasoline cars. Merging into traffic in the NEV required greater patience to wait for a longer gap in traffic. Pulling away from stops required pushing the accelerator pedal to the floor and waiting. As cited in the notes from the interview with AC, this can result in a feeling the NEV driver was holding up traffic. This contributed to an increased level of anxiety and unease. This feeling was also manifested in frustration with the vehicles' top speed by some households.

For some households, e.g., most households in Davis, these safety perceptions only limited access to a few activities. For others, e.g., household 15 in Sacramento, it meant a *NEV space* that contained almost no activities. Several households did speculate that they might feel more comfortable if there were more of "them" on the road. A larger percentage of NEVs in the traffic mix might serve as their own best traffic calming devices.

NEV Ownership: Changes in Household Fleets of Vehicles

Households that expressed a positive purchase intention toward a NEV generally viewed it as an additional vehicle in their household fleet, not a replacement for an existing vehicle. A few households explored in detail how the type and number of vehicles they owned would change with the addition of a NEV. Only household 6 expressed an unequivocal positive NEV purchase intention. Household 6 was a single adult who owned three cars. The NEV would replace a gasoline vehicle that is already used only for trips within Davis. This household's high degree of vehicle specialization, pattern of vehicle use, and lack of coupling constraints with other household members allowed the NEV to replace the exact use of one gasoline vehicle. We expect that such one-for-one substitution of a NEV for an ICEV will be rare.

At the other end of the spectrum of vehicle specialization, household 7 has two adults and one child. They own one car. They sold their fleet of four used vehicles and bought one, new vehicle. The style of vehicle, a mid-size sedan, was selected as a general purpose vehicle—it satisfied all their travel needs. They perceived that the NEV provided additional flexibility for trips in Davis and was a potentially very low cost vehicle. However, for this household to

commit to owning a second vehicle, that vehicle would have to be capable of trips out of Davis. Travel to the nearby town of Woodland and a daily commute to Sacramento were both part of this household's *routine activity space* and any vehicle the household owned had to be capable of making these trips. Their routine activity space extends well beyond the range and speed capabilities of a NEV and they own only one vehicle capable of accessing this entire space.

Household 8 illustrates how households might restructure their vehicle holdings around a NEV. They owned a late model, compact sedan and a new sport-utility vehicle. The female head of household typically commutes to work in the sedan. The sport-utility vehicle was used as the male head of household's business car and for hauling supplies for household projects. Either vehicle was used for out-of-town travel. They used the sedan for local errands because it is less costly to drive. The Kewet was not seen as a suitable replacement for either vehicle. His business takes him well out of the Kewet's range at least once a week. The Kewet cannot travel out-of-town or haul large loads. They did not want to give up the compact sedan because they were reluctant to use the sport-utility vehicle for the sequences of local activities they typically undertake together on weekends. They did however construct a new, hypothetical household fleet made up of the sedan, a used compact pickup truck and a NEV. This fleet provided them all the travel tools they wanted. The sedan and NEV would be used for virtually all their travel; the pickup truck might make only one trip a week to a hardware store, garden nursery or other such location. They speculated that given how they would use these vehicles, the used truck and a NEV would be cheaper to own and operate than the sport-utility vehicle.

Inclusion of a NEV in Households' Vehicle Choice Sets

Beyond the issue of how households might reorganize their holdings of vehicles to include a NEV is the issue of the characteristics of a NEV that these households would consider for purchase. Households in both Davis and Sacramento felt that improvements would have to be made to the vehicles before a NEV would be purchased. Most participants felt that increased range (at least 40 miles per charge), increased speed (a minimum 40 mph), additional passenger room, and improved acceleration were necessary.[3] In Davis, these enhanced vehicle capabilities would bring some trips beyond the Davis city limits into some households; *NEV spaces* and alleviate speed-related safety concerns. In Sacramento, these enhanced levels of

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[3] Though the descriptive literature that accompanies the Kewet indicates it has a range of 40 miles and a top speed of 40 miles per hour, the range of our vehicle was between 25 and 30 miles and the top speed about 35 miles per hour

performance were viewed by all households living outside the downtown area as minimal performance level. This level of performance was viewed as necessary to access the Medical Center from outside its immediate environs. It also allowed safe travel along the high speed roads that connect most activity locations in the urban area. The longer range made possible links between non-work activities and the work trip. Longer range also brought into the *NEV space* those (usually few) activities that were beyond the speed and range capabilities of the vehicles used in this study.

In Sacramento, a higher top speed and greater range were perceived as necessary because the households' routine activity space includes places that are relatively further away from home (than in Davis) and are most conveniently accessed by travel on high speed roads. Some Davis residents also desired a top speed of at least 50 mph, primarily for trips to the nearby town of Woodland and for traveling along the few higher speed roads in Davis. Range was less of a problem in Davis, due to the small size of the town. Families in both groups desired additional passenger seats so they could travel together. Faster acceleration was desired primarily for safety purposes, for example, when merging onto a busy street.

Overall, most participants felt the NEVs were promising and fun, but neither powerful nor large enough to displace any of their current vehicles. Given the current market prices for the NEVs used in this study, an automobile was seen as a better value because it is an all-purpose vehicle. Nonetheless, the requested improvements in NEV performance were relatively modest. What is more important, participants were not simply asking for a neighborhood gasoline vehicle.

NEV Buyers? Some Counter-Examples

The image we have developed of likely NEV buyers is that of a single person or couple (with or without children) whose activity space is amenable to access by a NEV. They have few authority constraints imposed on them. They own a specialized fleet of vehicles, and thus have travel tools to overcome coupling constraints. These characteristics allow the household to construct a *NEV space*. Below, we discuss one household that completely defies this image, yet had a positive purchase intention toward NEVs and another household that matches this profile, yet adamantly rejected the NEVs.

NEV Use In A Tightly Constrained Activity Space

Household 9 is not our prototypical NEV buyer. The female head of household is a single mother of three. She owns one car—an aging, compact station wagon. The station wagon is

becoming increasingly unreliable. She is currently looking to replace it with a newer (but still used) mid-size sedan because she needs the additional room as her children grow older. To her, the single most positive characteristic of the NEV was its ability to reduce her travel costs. This was dramatized for her when she realized she had not put gas in her car the week she had the Kewet.[4]

In many households, flexibility, due to an absence of coupling and authority constraints and the presence of multiple vehicles, was the key to adapting to a NEV. In contrast, in this household, multiple constraints created a very regular and tightly confined time-space prism in which YC can move. The limited geographic extent of her activity space is highlighted by the fact this was the only household in which the proportion of miles replaced by the NEV exceeded the proportion of trips. YC traveled 43% of all her miles during the diary week in the NEV, while using the NEV for 38% of her trips. The presence of children and the absence of another parent to share responsibilities imposes very tight coupling constraints on her activities Her mobility is limited, her routine activity locations are located within a few miles around home and she very rarely makes spontaneous out-of-town trips. Her work schedule at the hospital imposes a strict authority constraint. In addition, she lives approximately 10 miles from work, well enough within the round trip range of the Kewet to allow her to complete one or two other activities on her way to and from work.

Three specific activity locations and one trip whose activity was not specifically defined lay outside the *NEV space* she created during the week she had the Kewet. Weekly trips to her mother's lay slightly beyond the distance she was willing to travel in the Kewet. Weekly trips to her church required travel on a freeway. Twice yearly trips to the San Francisco Bay Area were well beyond the reach of the vehicle. Last, once a week, for various reasons, she has all the children with her in the car. These might be shopping trips, trips to the dentist, etc. These are always local trips.

YC indicated that with certain improvements to the vehicle (a back seat and slightly longer range) and better local transit, the Kewet could be a serious option for her *only* vehicle. She would only have to discover another route to church and rent a car for trips out of town (an adaptation to her aging vehicle that she was already considering) to maintain the activity space through which she now moves. Though the NEV's low top speed was something she had to

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[4] She of course had not yet had to pay for the electricity she used and we are well aware the proper cost comparison between gasoline and electric vehicles contains much more than fuel prices We report this observation because it was the event she reported that impacted her perception of the NEV

get used to, she discovered more and more uses for it as the week progressed. Alternatively, an inexpensive NEV would make a suitable second car, allowing her to reserve her gasoline car for those few trips per week when she might really desire increased room, speed or range.

Beyond travel: Cars as defensible space

Given their age, occupations, and resources, the members of household 13 belong to precisely the market segment that more simplistic market analyses predict will buy electric vehicles—young, affluent environmentalists. Given their activity space, centered in downtown and midtown Sacramento, our activity analysis indicates there is little reason they could not use a NEV for the vast majority of their travel. J is a senior administrator at a major environmental organization; E owns her home and works close to it. Both are in their late twenties. Each owns their own vehicle. They often travel together for social activities.

This household will not buy a NEV. Safety was the major concern of this household. Rather than primarily thinking of vehicles as modes of travel, both E and J oriented their thinking around personal safety. Their response to the Kewet centered on the questions "how vulnerable am I in this vehicle," "can someone injure me intentionally or by accident," and "does this vehicle have the capacity to respond quickly if I need to get out of a dangerous situation?" Their answer to these questions for the Kewet was "No."

For these single women, living in downtown Sacramento, their cars were extensions of defensible space. Both talked of their neighborhood, the environs surrounding their workplaces, and downtown in general, as unsafe places. They moved from place to place through an environment that they felt was generally hostile. This was also manifested in their general refusal to walk to any but the closest activities—being hassled on the street was too common an occurrence.

E thought of the Kewet as a fun novelty item, but because she felt vulnerable in it, she didn't drive it very much. The thought of driving the Kewet made E uncomfortable, not because of a low top speed, but rather because the small body size made her feel vulnerable to injury in an accident and its slow acceleration felt dangerous in what she perceives as the high crime area around the Medical Center at night. Though the NEV would otherwise be well suited for commuting between home and work, E would take her car in the event she had to work late. J would not drive or ride in the NEV. She had been severely injured in an automobile accident a few years ago and she was very wary of small vehicles. She bought the vehicle she now owns because it is the same type of vehicle as that in which she survived the accident. The Kewet

was too small. The changes to the Kewet that would address these concerns would yield a vehicle that could no longer be considered a NEV.

Conclusions

Within the context of one week trials, households explored the meaning of NEV ownership. NEVs are very different vehicles than those with which any of our households had prior experience. NEVs introduce unfamiliar constraints on the travel of households. Reduced driving range, speed capabilities, and passenger and cargo room require households to use NEVs differently than they would automobiles.

We have conceptualized these constraints and their impact on vehicle use in terms of household *NEV spaces*. A *NEV space* is a subset of the household's activities that can be accessed in a NEV. In addition to the capability constraints of the vehicles themselves, the schedules and routines that households develop in response to authority and coupling constraints affect household's ability to conceptualize a *NEV space*. The existence of bicycle-spaces in Davis households suggests that, given the option of a variety of travel tools, households do construct sets of activities that they routinely access by different modes. These sets of activities are what we have defined to be mode-defined, activity sub-spaces.

Travel by all households was controlled to a very large degree by routines formed in response to schedules and activity links imposed by authority and coupling constraints. As we would expect given the capability constraints of the vehicles, they replaced a higher proportion of trips than of miles in all but one of our participant households.

Predicated on the performance capability of the vehicles used in this study, our 15 households can be organized into three groups. One group we call *pre-adapted*. These three households live within land use patterns and roadway networks amenable to NEVs and have sufficient travel options to both overcome the capability constraints of NEVs and resolve conflicts arising from schedules and routines imposed by authority and coupling constraints. Work and school schedules, daycare centers' hours, movie schedules, medical appointments and other activities all impose constraints that vary in the degree to which the constrain the time as well as the place of activities. Pre-adapted households may have a great deal of flexibility to shape their NEV space or their existing activity space may be so tightly constrained that a NEV can provide ready access to most all activities. One pre-adapted household expressed an unequivocal NEV purchase intention. The two others were strongly positive.

Another group of six households can *easily adapt* to a NEV with some change in vehicle ownership, vehicle use, or activity scheduling. If a household is willing to restructure its holdings of vehicles, a NEV could be a part of a new household vehicle fleet. In other households, reassignment of vehicles to different drivers, either as part of a permanent reallocation of vehicles within the household or as part of periodic trip planning, solves any problems created by the capability constraints of NEVs. In rare instances, activities may have to be rescheduled to a time when a suitable vehicle is available. These six households all required some change—an increase in top speed, range or passenger and cargo capacity—in order to use a NEV with no lifestyle or behavioral adaptations.

Lastly, we have a group of six households for whom adapting to a NEV would be difficult. We call these six households *non-adapted*. These households face significant barriers to using NEVs. Land use and roadway barriers may sever access any activities outside their immediate neighborhood. Significant barriers in the form of coupling constraints between household members may require a larger vehicle. The need to provide transportation service to other people is often compounded by the authority and coupling constraints to which the transportation-dependent person is subject. In *non-adapted* households, the capability constraints on the speed, range or size of the NEVs rendered the vehicles virtually useless.

The important barriers to be overcome by our households in Davis to access their routine activity space relate to the existence and importance of activity locations outside Davis and to the households' ability to distinguish a *NEV space* distinct from bike-spaces and car-spaces. A technical solution to the problems created by speed and range limitations are possible—but the resulting vehicle is no longer a NEV according to the definition we are using here. Sustained, highway speed driving is required to travel to Sacramento; vehicles capable of such travel are not within our definition of a NEV. Increasing the distinction between NEVs, bicycles, and autos can be accomplished through vehicle design and marketing. NEVs with three or four seats could have been used for any trip in Davis for which the City-El or El-Jet were not used because of a passenger capacity limit. Only in households with only one or two people in them was a two seat vehicle considered a practical alternative; one seat vehicles were not sufficiently distinct from bicycles. Thus, the design solution is slightly larger vehicles with more seats. The marketing solution is to target two seat vehicles at market segments for which the seat limit is likely to be unimportant. These households include both retired and working adults without children living at home. Even households with children may not require more than two seats in a NEV, so long as the household owns more vehicles than it has licensed drivers.

In a city such as Sacramento, it is difficult to imagine a vehicle with range less than 40 miles and top speed less than 40 mph making serious in-roads into households living in existing residential development (with the possible exception of the downtown and midtown areas). Existing land use and transportation infrastructures appear to present formidable barriers to household's gaining access to their desired activities in truly low-speed vehicles. However, areas of new development can be designed to provide households with adequate access to activities. Such developments would mimic Sacramento's downtown, or even smaller towns like Davis. They must have a high density and variety of activity locations, accessible by low speed roadways.

V. HOUSEHOLD MARKETS for ELECTRIC and NEIGHBORHOOD ELECTRIC VEHICLES: A Statewide Survey

Sandra Rosenbloom. "Why Working Families Need a Car." Cited in Wachs, M. and M. Crawford (eds.)

"...yet much of our increasing reliance on the car reflects the way that two-worker and single-parent households juggle the complicated responsibilities of home and work in suburban residential and employment locations. The car offers the flexibility and convenience essential to working parents, particularly mothers, who often carry the double burden of working at both work and home. It is hard to see how any other option could serve the complex travel needs of such families."

In the essay from which the above quote is taken, the author weaves together several trends in American life—increasing reliance on automobiles for daily travel, increasing involvement of women in the paid labor force, and increasing suburbanization of homes and jobs. She concludes that only automobiles provide the flexibility and convenience that the confluence of these three trends demands. While she accounts for the increased average ownership of automobiles across all households, she does not address the potential for specialization of travel tools due to increased ownership of automobiles within households. It is this potential for specialization though that opens possibilities for vehicles that are not *cars* or *automobiles* in the sense we usually imagine them.

To test whether households in California are willing to incorporate a vehicle that is clearly not a *car*, into their household stock of vehicles, we included NEVs in a study of the statewide market potential for electric and natural gas vehicles. Households throughout California were introduced to NEVs and assessed their merits compared to other electric, alternative fueled, and gasoline ICE vehicles. We administered the survey during the spring and fall of 1994. A fundamental premise of our research design was that, since these new vehicles will have characteristics completely outside the experience of most people, research into consumer responses must create an appropriate information context. EVs have driving shorter ranges than gasoline vehicles. They can be recharged at home rather than only refueled at an away-from-home location; however, they will require hours, not minutes, to refuel. They are being promoted for their positive impact on air quality. The most important shortcoming of previous studies of the electric vehicle market is their failure to address fundamental information issues around these new vehicle characteristics—consumers are well informed about gasoline vehicles but poorly informed about electric vehicles (Turrentine and Sperling, 1992).

We took several steps to develop a rich decision making context for our respondents—a context we believe better represents the information consumers will have when EVs and NEVs are actually introduced into the market. The survey instrument we designed not only queried consumers, but also educated them about both the design features of electric vehicles and the effects of a daily driving range budget and home recharging on their lifestyles. Lacking such a basis to evaluate these characteristics of EVs, consumers cannot competently imagine how such vehicles might fit into their lives. Thus EV market research that fails to create a learning experience and a rich information context does not measure preferences or purchase intentions, but only consumer conservatism in the face of a new, expensive, and unfamiliar technology.

Our prior work has convinced us that households make vehicle purchase decisions based on the characteristics of the vehicles they are considering for purchase and the characteristics of vehicles they already own. Thus each household's stock of vehicles must serve as part of the context for consumer decision making about EVs, NEVs and other alternative fuel vehicles. Households who buy electric vehicles will be hybrid households, owning two very different types of vehicles that they use to access distinct sets of activities. Hybrid households will create activity sub-spaces defined by the types of vehicles they own. We see this even in households that own only gasoline vehicles. Some already buy specialized vacation vehicles or commute vehicles. Thus the utility a household gains from, for example a NEV, is not a function solely of the attributes of the NEV. Rather, its utility can only be assessed within the context of all the travel tools available to the household and the activity space of the household.

In this chapter, we report the use of the activity analysis concepts in the statewide survey and the response to NEVs. The body of research that led to the development of the statewide survey is reported elsewhere (Turrentine, Sperling and Kurani, 1991; Turrentine, Lee-Gosellin, Sperling and Kurani; 1992; Kurani and Turrentine, 1993; Kurani, Turrentine and Sperling, 1994). A more general summary of results from the statewide survey is available (Turrentine and Kurani, 1995)

Implementing Activity Analysis Concepts

The household NEV trials reported in the previous chapter and our previous work (see in particular Kurani, Turrentine and Sperling, 1994) provided us with the information and impetus to implement important activity analysis concepts in a mail survey. All our previous EV and NEV market research had involved a high degree of interaction with our respondents. We had conducted focus groups and lengthy phone and personal interviews. To test our

preliminary conclusions on a larger sample, we needed to extract important concepts from these previous studies that could be implemented in a less interactive survey tool[1].

The important concepts around which we built the survey instrument were:

- household vehicle purchases are made within the context of the household's fleet of vehicles rather than individual vehicles;
- households must have access to comparably detailed information regarding all the types of vehicles considered for purchase;

Further, to understand the impact of limited range, home recharging and limited top speed on their lifestyles, households must reflect on:

- their routine activity spaces;
- whether their activity space can be subdivided by different travel modes; and
- their critical destinations.

We believe that households who can construct *NEV spaces* will perceive NEVs as viable travel tools based on the case studies of golf communities, ride-and-drive clinics and household NEV trials. Certain household characteristics appeared to facilitate the formation of this *NEV space*. These included the presence of additional travel tools (in suburban cities this primarily means ownership of more than one car) to overcome potentially binding coupling constraints and *NEV spaces* that contained important routine activities located near home or work. The objective spatial structure also affected *NEV space* formation. Households must be able to access their routine activities via networks of NEV-amenable roadways.

In our prior studies of household adaptation to driving range, we found three concepts determined the minimum driving range households would accept for one of their vehicles (Kurani, Turrentine, and Sperling, 1994)

- The household's *routine activity space,* defined by the set of activities that the household accesses on a daily and weekly basis (including all the other associated dimensions—location, mode, route, etc.);
- A *critical destination* is a destination that a household member feels they must be able to reach even if the "unlimited range" gasoline vehicle is not available.

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[1] We did not design a survey instrument which required less effort from our respondents than did our previous interviews. The survey respondents provided themselves, and were provided by us, with a tremendous amount of information How much of this they used to make their decisions regarding electric vehicles was up to them. But in keeping with our research premise, we and our respondents needed to create an information context in which they could competently imagine using and buying EVs and NEVs.

- A *range buffer* is the minimum distance the vehicle must still be able to travel when it arrives home at the end of the day[2].

In that study, we also observed that many households changed their driving range choices as they began to explore what it meant to be a hybrid household. The three building blocks households used to determine the minimum range vehicles they could use, the shifting of range choices within households, and the different range choices made by different households all suggest an EV market segmented by driving range.

We used this idea of market segmentation by demand for driving range to create four classes of electric and hybrid-electric vehicles in our survey. These vehicle types are summarized in Table 5.1. The descriptions of electric vehicles provided to the respondents are in Appendix F. The vehicles with the shortest driving ranges are NEVs. They are also defined to be non-freeway capable. *Community electric vehicles* (CEV) have longer ranges and top-speeds that make them capable of traveling on freeways. *Regional electric vehicles* (REV) have still longer ranges and higher top speeds. We also offered our respondents a *hybrid electric vehicle* (HEV) that has the longest (total electric plus ICE) driving range of any of the electric vehicle options.[3]

Table 5.1: Range and Top Speed Characteristics of EVs in the Statewide Survey

EV Type	Driving Range, miles	Top Speed, mph
Neighborhood Electric Vehicle (NEV)	40	40
Community Electric Vehicle (CEV)[1]	60 to 80	75
Regional Electric Vehicle (REV)[1]	120 to 150	85
Hybrid Electric Vehicle (HEV)[1,2]	140 to 180	85

Notes:
1. Vehicle range depends on body style and choice of battery options.
2 The battery-only driving range varies from 40 to 80 miles.

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[2] The range buffer did not change much between households: across many different kinds of households in many different locations, the range buffer was about 20 miles

[3] The HEVs we offered to our respondents were designed as "range extenders". The vehicles operate on battery power until they reach a pre-determined depth of discharge. At that point the IC engine provides power for battery charging. Of all the possible hybrid designs, we chose this as a representative hybrid because it is relatively simple to explain and the design is intended only to extend range, not to provide either base power or peak power, or to meet some other performance goal.

The Survey Sample

We sampled from those households whom we believe make up the single largest group of *potential hybrid households*—that is, potential buyers of electric vehicles. Household selection criteria included: own two or more vehicles; buy new vehicles; own one 1989 or newer vehicle *and* one 1986 or newer vehicle; and at least one of their vehicles is not a full-sized vehicle. The ages of recruits were matched to age distributions in the California new car market. The households sampled in this study represent about one third of the annual light-duty vehicle sales in California.[4]

Seven hundred and fifty households were recruited by market research firms in six metropolitan areas of California: the San Francisco Bay Area, Sacramento, Fresno, Los Angeles, Santa Barbara and San Diego. Participants were paid a 50 dollar incentive for completed surveys because of the time demands of the survey and to prevent the study from being biased toward those interested in the subject. A total of 454 households returned completed surveys at the end of the survey administration period. The response rate of useful surveys was 69 percent.

Because of the sampling scheme, we did not expect many households to choose a NEV. We did not sample households based on whether the objective spatial structure in which they lived was amenable to NEV use nor did we sample from households whom we *a priori* expect to have activity spaces amenable to NEVs. We did not sample in communities especially designed for NEVs (such as Palm Desert) nor in places that are otherwise very suitable for NEVs (such as Davis). Thus, the image that the households created of their own activity space during the survey is not only useful to them in their decision making, but is crucial to our interpretations of these households' vehicle choices.

The Survey Instrument

Households were recruited by phone, sent a survey packet, and the packets returned via mail. This survey was divided into four parts and was designed to be completed over several days to encourage critical evaluation of the options. The four parts were:

- Preliminary survey of household vehicle holdings, purchase intentions for next new vehicle, demographics, and environmental attitudes;

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[4] Baseline studies of the California auto market do not include all of the household demographic criteria used in this study to select households Therefore we cannot give a more precise estimate We have crossed referenced sales figures for California with a 1990 Newsweek study of the auto market to arrive at our estimate of the proportion of annual new light duty vehicle purchases made by our sample.

- Three day travel diary for two primary household drivers; survey of their travel and refueling patterns; and a map of the households activity space;

- Information video and reprinted articles from mass media that discuss emissions impacts of electric vehicles and demonstrate refueling and recharging routines and other features of electric and compressed natural gas vehicles; and

- Two vehicle purchase exercises for the household's next new vehicle purchase. The first was a choice between a gasoline and an electric vehicle. The second included six vehicle types: reformulated gasoline, compressed natural gas, hybrid electric, and three types of battery electric vehicles, including a NEV. Each vehicle type was described in detail, offered in a range of body styles and trim levels, and offered with several options. A price list was included. Participants recorded their choice and answered a few follow-up questions about their choice.

Creating an Image of the Household Activity Space

In part Two of the survey households created visual images of their activity space through a time-line travel diary and a road map of the region in which they live. These instruments were used to develop the activity analysis concepts from our previous EV and NEV market research work. Two drivers, usually the heads of the household, kept three day travel diaries for two of the household's vehicles[5]. Follow-up questions asked them to review the diary and assess how well it represented their travel. These questions concerned trip frequency, daily travel distance and the variability of travel from day-to-day. Also they were asked about certain important adaptive strategies, e.g., car swapping, carpooling, car rental, etc. They were also asked to review their diaries and tell us how feasible it would have been to access their activities without traveling on a freeway, highway or urban expressway.

Following the diary, these drivers sat down with a street map of their area and marked the locations of several of their routine activities—home, work, grocery stores, schools, religious sites, favorite recreation locations, restaurants, family and friends, usual locations where they bought gasoline—and the locations of medical and emergency services. In addition, the concept of a *critical destination* was explained to them and they were asked to locate this

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[5] This is a different scheme than used in the week-long household NEV trials where the diaries were used by each household driver to record each *person's* travel. We adopted the *vehicle* diary as an acceptable simplification of the diary process. Our previous work indicated that no substantial amount of travel in multi-car households would be lost if we did not have data on transit, bike or walking trips. This simplifying assumption is most likely to affect household choices around NEVs, which as the household trials have shown, compete with cycling and walking in some settings. The assumption makes our NEV results conservative. That is, if households had been asked to record walking and cycling trips, they may have been more likely to consider choosing a NEV.

destination on (or off) the map Once these individual locations were mapped by both drivers, they were asked to draw a boundary around the area that included these activities and any other activities they felt were important to their lifestyle.

Taken together, the diary and map build an image of the household's activity space, define certain critical dimensions of that space and provide the household with the context to explore the meaning of limited driving range. Images of the electric, neighborhood electric and natural gas vehicles were provided in the informational video produced specifically for the survey. Given strict time constraints, we were not able to incorporate as many images of different NEVs and EVs as we would have liked. We did include images of the Kewet El-Jet and AC Propulsions Saturn conversion.

The NEV compared to other vehicle choices

The definition of a NEV we provided to respondents is shown in Table 5.2. NEVs differ from all other vehicles offered in that they are not capable of freeway travel and only come in 2, 3 and 4 seat model sedans. A sedan body style was implied by the image of the Kewet shown as an example NEV in the video. Body styles ranging from compact to midsize sedans, wagons and sport-utility vehicles, as well as minivans, were offered for all other electric vehicles. Only gasoline and natural gas vehicles were offered in full-size body styles. The NEV differs from other EVs in its speed and range as described in Table 5.1. Also, neither *fast charging* nor a longer range battery was offered for NEVs. These options were not allowed because we wished to reinforce the image of a NEV as a vehicle for local travel. Battery life was warranted to 20,000 miles. NEVs were offered at prices much lower than any other vehicle. The least expensive NEV could by "bought" for one half the price of the least expensive gasoline vehicle (a compact pickup truck with the Economy trim level and no options). A 2 seat NEV with the standard trim package and no options could be "bought" for $3,500 (after a total of $2,000 in purchase incentives). The most expensive NEV offered was a four seat, convertible, with the luxury trim package priced at $9,400 after incentives.[6]

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[6] We make one further observation about vehicle prices in our survey. One difficulty with market research on EVs and NEVs is that prices at which vehicles will be sold in the future are extremely uncertain. In order to focus on how people respond to driving range, home recharging, and other unique features of NEVs and EVs, we designed choice situations in which respondents had little incentive to choose between vehicles based on price alone. With the exception of options specific to EVs (e.g. fast charging and battery replacement costs) the base price of all vehicles except NEVs were roughly comparable. The prices of reformulated gasoline vehicles were based on 1992 prices of gasoline vehicles. The base price electric, hybrid, and natural gas vehicles were higher, but tax credits and other incentives were offered which offset the higher purchase prices. We believe it is reasonable to assume NEVs will cost much less, thus they are priced lower than all other vehicles.

Table 5.2: NEV Description provided to Survey Respondents

Neighborhood electric vehicle: Designed for around-town driving. Easy parking, handling and use. Comes as two passenger version or with small rear seat for one or two additional passengers. Cargo room for four bags of groceries.

Vehicle length: is 11 ft, width is 5 ft, can park in small places, turning radius 15 ft.

Top speed: 40 mph.

Accelerates: 0-40 in 15 seconds.

Range: 40 miles.

Curb weight: 1200 pounds.

Composite structure: Fully crash tested and passes all federal crash safety standards.

Optional airbags: Yes

Electricity Costs: Less than 1 cent per mile for electricity.

Recharges: 2-4 hours on 110 volt **slow charge**. 1-2 hours on 220 volts **normal charge**. Replacement cost of battery back is just $500.

Fast charge: not available for neighborhood electric.

Optional solar panels: offers 7 miles extra of range on sunny day.

Standard air conditioning: Interior pre-cooled or heated while recharging

Optional air conditioning: High performance, high efficiency heat-pump

Maintenance and Service is minimal

Warranty: Motor and drive train warranted for ten years or 100,000 miles. Batteries are guaranteed for 20,000 miles.

***The neighborhood electric is not intended for highway driving.**

Meets California Zero Emissions vehicle standards for non-freeway vehicles. Qualifies for $2000 tax credits.

Standard: AM/FM radio, pre-cooled and heated seats.

Luxury: Standard features plus CD Stereo system, heat pump climate control, dual airbags, all power accessories, sunroof, keyless entry

Note. The format of this information has been changed from the original survey to fit the format of this report

The information we presented on safety represents the only non-conservative element regarding NEVs. We specified NEVs were fully certified as meeting the Federal Motor Vehicle Safety Standards—an assumption that may be difficult to meet in such a small vehicle, but not impossible. Given the response of some of our participants in vehicle demonstrations and trials, we expect some people who are initially enthusiastic about NEVs will change their minds when they confront the reality of how small NEVs can be. However, given the conservatism of all our other assumptions regarding NEVs and the extremely conservative sampling with respect to likely NEV markets, we are confident in the results we present next.

Vehicle Choices in a Future Market Scenario

The second vehicle choice situation in Part Four of the questionnaire immersed survey respondents in one plausible future market scenario for motor vehicles. In developing the scenario, we assumed consumers will be faced with a variety of internal combustion vehicles, electric vehicles and hybrid electric vehicles. Reformulated gasoline and natural gas vehicles will be offered in all body styles. Electric and hybrid vehicles will not be available in full-size body styles. NEVs will be available. The market for electric vehicles will be segmented by demand for driving range. The longest range offered in an EV will be 180 miles for HEVs. The longest range in a "pure" EV will be 150 miles. Within this scenario, our respondents' vehicle choices are shown in Figure 5.1 and summarized in Table 5.3. The percentage of respondents who chose a NEV as the vehicle they would next buy is 4.3 percent. NEVs, CEVs and REVs account for 37% of respondents' vehicle choices in this scenario. Adding the households that chose HEVs. brings the total electrified-vehicle market to 47% of our sample.

Figure 5.1: Vehicle Fuel Type Choices

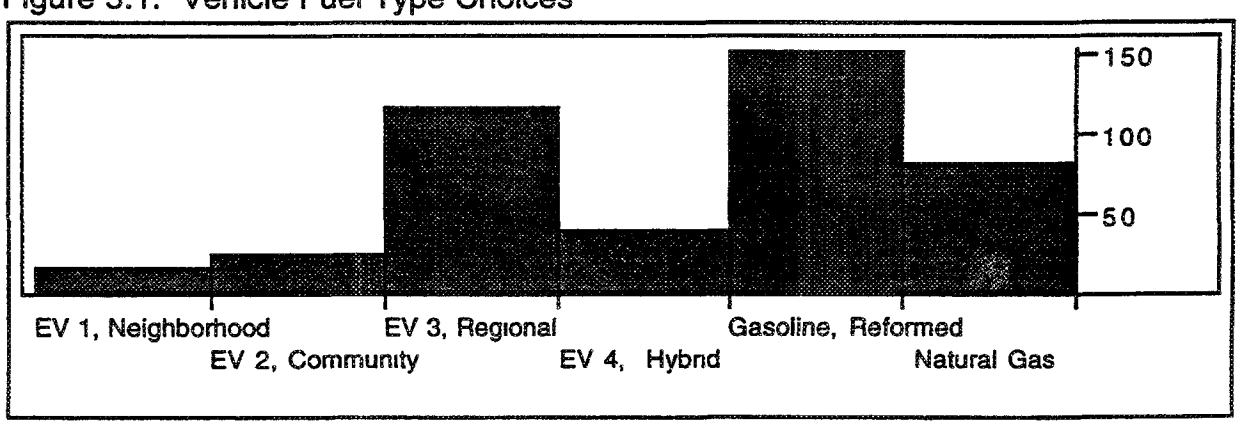

Table 5.3: Vehicle Fuel Type Choices

Vehicle Choice	Count	Probability	Cumulative Prob.
Neighborhood EV	19	0.043	0.043
Community EV	28	0.063	0.105
Regional EV	119	0.267	0.372
Hybrid EV	43	0.010	0.469
Gasoline, Reformed	153	0.343	0.812
Natural Gas	84	0.188	1.000
Total	446		

Hybrid Households

Our sample of households represents *potential hybrid households*. After they have chosen a vehicle type, our sample can be divided into three types. First, those who chose an EV are *hybrid households*. Those who did not chose an EV either remain *potential hybrid households* or are *non-hybrid households*. A *non-hybrid household* is a household that meets our criteria for inclusion in the study, but some other aspect of their vehicle ownership or activity space prevents them from believing they could use even one limited range vehicle. Some *potential hybrid households* will not choose to buy an EV for their next new vehicle, but will buy an EV at some time in the future. We have anecdotal evidence this group exists, but are unable to precisely estimate its size. However, we expect the majority of households that did not choose an EV in our choice exercises are still *potential hybrid households*, and are not *non-hybrid households*. We base this expectation on our previous PIREG interviews, where we found that less than 10 percent of the sample of *potential hybrid households* in that study simply could not adapt to any minimum range vehicle (Kurani, Turrentine, and Sperling; 1994). From Table 5.3 then, 47 percent of households are *hybrid households*, 43 percent we believe are still *potential hybrid households*, and 10 percent are *non-hybrid households*.

EV Shares of the New Light Duty Vehicle Market

The choice probabilities in Table 5.3 do not represent annual new car market shares. To provide a lower-bound estimate of annual market shares we must make two adjustments, subject to several strong caveats. First, recall our sample of *potential hybrid households* buys

about one-third of the new cars and light duty trucks sold in California every year.[7] Second, we hypothesize that over a long period of time (i.e., long compared to the period of time between new car purchases within a household), hybrid households will choose to buy an EV on every ***n*** occasions they buy a new car, where ***n*** is the number of vehicles they own. On average, the households in our sample own 2.43 cars. Third, we have found in previous work that about 8% of a sample of households meeting the same selection criteria as used in this study were unable to adapt to limited ranges because of their travel needs. Using these factors to adjust the choice frequencies in our sample, we estimate the lower bound on the annual market share for the neighborhood, community and regional EVs in our study to be between 13 and 15 percent of the new vehicle market. If we include hybrid EVs, the annual market share for electrified vehicles rises to between 16 and 19 percent.

This estimate is a lower bound estimate of the market for EVs because our sample of *potential hybrid households* does not include representatives of all households that might buy EVs and NEVs. Other *potential hybrid households* include:

- households which do not now buy new cars but would in order to buy an EV or NEV;
- households which become two car households by purchasing an EV or NEV; and
- households which do not now own cars of the likely EV or NEV body styles but would buy such a vehicle in order to buy an EV or NEV.

While this study sheds no light on the number of households in the first two of these categories, we observe that some households who chose EVs and NEVs in our choice exercises, chose smaller body styles than their "preferred" body style for their next new vehicle. If households in our sample will change body styles in order to choose an EV or NEV, we surmise households outside our sample may too. We return to this issue in a later section on household stocks of vehicles. Lastly, this market share estimate is extremely conservative because it does not include any potential EV or NEV sales to fleets.

Markets for NEVs

In practice, the 19 households that chose a NEV are too small a sample to form a suitable basis for market share estimates, so we present the estimate for NEVs simply as point of reference from which to make observations about markets for NEVs and marketing of NEVs. The 4.3

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[7] This does not mean that *potential hybrid households* represent only a third of the annual market It means only that we have sampled one group of *potential hybrid households* who represent one-third the annual new car market.

percent our sample who chose an NEV translates into an annual share of the new car market in California of just under 1 percent, based on the same adjustments and caveats just discussed.

We make several observations about this number. First, our sampling scheme made no effort to identify households who live in communities and neighborhoods amenable to NEVs. Despite this, some households discovered a NEV was a suitable replacement for one of their existing vehicles, others determine that a NEV was attractive as an additional vehicle. Lastly, more so than for the other types of EVs, the low cost of NEVs means sales of such vehicles may occur in the household market segments described above from which we did not sample.

Who Buys NEVs?

Because they are few, households that chose NEVs are difficult to statistically distinguish from households that chose other vehicles. We make the following observations though based on trends in our data that might be confirmed, or refuted, on a larger sample. Households that chose NEVs did so because NEVs provided them with practical, affordable travel tools, and not out of environmental motivations. The low cost of NEVs means more households than expected chose to add the NEV as an additional vehicle to their household fleet rather than displacing an existing vehicle from their fleet. Despite this, more than half the households that chose a NEV found they could displace one of their gasoline vehicles with a NEV.

Change in Lifestyles in Response to Environmental Problems

One question we asked about environmental attitudes rated the importance of environmental problems compared to other types of problems on a scale that indicates what level of effort should be expended to solve them and the degree to which those solutions will require lifestyle changes. The text of the question and answers was:

> "How would you characterize your feelings about the world's environmental problems?
>
> _____"The biggest crisis and challenge of our times. The solutions require immediate international effort and major changes in our economies and lifestyles.
>
> _____"Among our biggest problems. The solutions require cooperation of government and citizens. Time to reconsider our lifestyles and make changes.
>
> _____"Environmental problems exist and need some attention, but are minor compared to other problems in our world.
>
> _____"Environmental problems are not an important problem. There is no need to change the way we live."

The question was asked in the Part One of the survey, before any discussion of EVs per se. Respondents' vehicle choices are cross-tabulated by responses to this question in Table 5.4. For each vehicle type, the answer with more responses than expected (under the null hypothesis of independence) is shown in bold. Of the 454 respondents, only 3 stated environmental problems are simply not important. We treated them as statistical outliers and dropped them from this table. Responses to this question are missing for 10 households.

Table 5.4: Vehicle Choice by Impact of Environmental Solutions on Lifestyles

Choice2	**Magnitude of Environmental Problems**			Total
Observed Count	Biggest crisis	Among biggest problems	Minor compared to other problems	Row Total
Neighborhood EV	2	16	1	19
Community EV	3	**20**	4	27
Regional EV	15	**76**	22	113
Hybrid EV	**9**	19	**15**	43
Gasoline, Reform	16	90	**45**	151
Natural Gas	9	50	**29**	88
Total Count	54	271	116	441

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	20.149	0 0275
Pearson	18.792	0 0430

On the basis of the data in Table 5.4 we reject the null hypothesis of independence between vehicle choice and perceptions of the importance of environmental problems. Households that chose electric vehicles were more likely, than expected under the hypothesis of independence, to believe environmental problems are more serious and require greater and more immediate

lifestyle changes than are households that chose gasoline and natural gas vehicles[8]. On average, NEV choosers share this concern with other EV choosers. However, they are not inordinately concerned. They are not at all likely to state that environmental problems are our most important crisis, requiring immediate lifestyle changes. We conclude that those who chose NEVs are not so pre-disposed to making large lifestyle changes that such desire is necessary for them to choose a NEV.

The Effects of Age, Children, and Income

Life cycles are typically defined in terms of the number and ages of people in a household. The "cycles" are intended to capture the effects of: the presence or absence of children; children entering "school years"; children obtaining their licenses to drive; children leaving home; and the concomitant aging and retirement of their parents. Note that income is not an explicit element in the definition of life cycles, never the less, the definitions are correlated with income. We adapted the 10-category life cycle measure used by the Nationwide Personal Transportation Survey (NPTS). In our sample, only 6 of the 10 categories have an appreciable number of households in them because of our sampling scheme and the correlation between life cycle definitions, income and vehicle ownership. Our sample contains virtually no households of single adults—with or without children. Definitions of the life cycle categories that do appear in our sample are given below.

- NCAs = no children, two are more adults (not retired)
- C1As = youngest child age 5 or less, two or more adults (not retired)
- C2As = youngest child between the ages of 6 and 15 inclusive, two or more adults (not retired)
- C3As = youngest child aged 16 or older, two or more adults (not retired)
- C3SA = youngest child aged 16 or older, single adult (not retired)
- NCRAs = no children, two or more retired adults

In a previous study (Turrentine, Sperling and Kurani, 1991), we identified a group of middle-age adults who responded more favorably to EVs than people in other age groups. On the basis of that conclusion and other results from that study, we speculated that households in the life cycles containing middle-aged parents with children responded favorably to EVs because

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[8] We note that this conclusion does not contradict results we have reported elsewhere regarding the importance of environmental attitudes in defining markets for EVs We have previously argued that environmental attitudes are relatively less important to markets for EVs than are households' assessments of whether EVs are practical transportation tools The fact is, that across all six vehicle types, the majority of all respondents believe environmental problems are among our biggest problems.

they tended to: have higher household incomes; own more vehicles and have more vehicles per driver; have more routine driving patterns; and be more cognizant of fuel savings and life cycle costs. We also surmised they had stronger ties to their communities than households without children. What this reveals is a complex relationship between the market for EVs and life cycle. Thus, we do not expect response to EVs to be a smooth function of progression through a series of life cycle classifications.

When we examine the choices of our respondents and cross-classify them by our life cycle definitions, we see just the type of complex relationship discussed above. As seen in Table 5.5, it is impossible to discern an orderly, significant relationship. Cells in the table that have disproportionately too many responses (compared to the null hypothesis of independence) are shown in bold.

Table 5.5: Vehicle Choice by Life cycle

Vehicle Choice	**Life cycle**						Total
Observed Count	NCAs	C1As	C2As	C3As	C3SA	NCRAs	Count
Neighborhood EV	4	**6**	1	**5**	0	0	16
Community EV	**13**	2	5	2	1	1	24
Regional EV	38	**24**	**27**	17	1	4	111
Hybrid EV	**21**	**11**	3	6	2	1	44
Gasoline, Reform.	55	25	26	22	**7**	**9**	144
Natural Gas	32	11	15	12	3	**6**	79
Total Count	163	79	77	64	14	21	418

Notes: The five life cycle classifications are defined as follows.

- NCAs = no children, two are more adults (not retired)
- C1As = youngest child age 5 or less, two or more adults (not retired)
- C2As = youngest child between the ages of 6 and 15 inclusive, two or more adults (not retired)
- C3As = youngest child aged 16 or older, two or more adults (not retired)
- C3SA = youngest child aged 16 or older, single adult (not retired)
- NCRAs = no children, two or more retired adults

Chi-square tests are not presented since the expected cell frequencies of several cells are too small

We do make two speculative observations regarding the households that selected NEVs. First, households with two or more adults in which the youngest child is less than 5 years old or greater than 16 years old chose NEVs more often than we would expect if vehicle choice and life cycle were independent of each other. Second, neither those households made up of single parents whose youngest child is older than 16 nor those of retired persons were likely to haven chosen a NEV in the choice exercises.

These tentative conclusions point to the complexities of identifying market segments for such diverse vehicles as presented in this survey. Across our whole sample (not just NEV choosers), the C3As (two or more adults, not retired, with the youngest child older than 16) have the highest average household income (primarily because they have more wage earners). Both the groups from which no household chose an NEV—single, working adult with youngest child older than 16 and retired adults with no children—on average have the lowest incomes. Thus we might conjecture that higher income households are more inclined to buy NEVs than lower income households. However, the household category C1As (youngest child age 5 or less, two or more adults), contains more NEV choosers than we expect, yet also has an average income less than C3As.

The choices of other young families that did not choose a NEV provide further evidence there is no orderly relationship between income and vehicle choice. Households in category C1As were more likely to choose the more expensive (on average) regional and hybrid EVs than expected. In fact, we see in Table 5.5 that these households are as likely to choose a regional EV as they are to choose a reformulated gasoline vehicle.

Households with the lowest average incomes—retired adults and single parents with older children—disproportionately chose gasoline vehicles. This could be related to their income, as gasoline vehicles are marginally cheaper than other types of vehicles. On the other hand, retired households living on fixed incomes may be less willing to risk experimentation with a new vehicle type. In households of single adults with older children, it may be that household members make relatively autonomous decisions about vehicle purchases. Thus despite their high *household* vehicle ownership, individuals in these types of households may not have the same flexibility of vehicle use as individuals in households that make joint or cooperative vehicle purchase and use decisions.

As a final note on the role of life cycle on NEV choice and as an introduction to the next section, in Table 5.6 below, we look at which households decided their next new vehicle would be an additional vehicle in their household, not a replacement for an existing vehicle.

Across the whole sample, only 13.6 percent (57 of 420) of households indicate that the next new vehicle they purchase will be an additional vehicle. Of all the life cycle groups, only those households with two or more adults whose youngest child is older than 5 or older than 16 chose to add vehicles to their holdings more often than we expect. Nearly 27 percent of households made up of two or more adults whose youngest child is older than 16 chose to add another vehicle—nearly twice the rate of the whole sample. As we will see in the next section, a household's ability and desire to add more vehicles to its fleet facilitates the choice of a NEV.

Table 5.6: Life cycle by Whether New Vehicle will be an Addition to the Household Stock of Vehicles

Life cycle	**Next new vehicle an addition to the household fleet?**		Total
Observed Count	No, replace a vehicle	Yes, add a vehicle	Observed Row Total
C1As	**73**	7	80
C2As	64	**13**	77
C3As	47	**17**	64
C3SA	12	2	14
NCAs	**146**	18	164
NCRAs	**21**	0	21
	363	57	420

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	17.108	0 0043
Pearson	15.760	0.0076

Changes in Household Fleets

In the previous chapter on the household NEV trials, we discussed how households incorporated a NEV into their stock of vehicles. In some cases, there was the possibility of a simple one-for-one substitution. In other households, while the NEV could be incorporated

into the household fleet, we can not say the NEV "replaced" a vehicle because the household may have made substantial reassignments in how the household's vehicles were used. In such a household, we say the NEV *displaces* a gasoline vehicle. Several households discussed the possibility of the NEV being an additional vehicle. In a few households with younger children, parents speculated that such an addition might be coordinated with a child becoming old enough to acquire a license to drive. It is difficult to distinguish between replacement and displacement of a vehicle with the data in the statewide survey. However, as we stated in the previous section, we do have data on whether the chosen vehicles were additions to each household's fleet of vehicles. We cross-tabulate this data by vehicle choice in Table 5.7.

Table 5.7: Vehicle Choice by Whether Next New Vehicle will be an Addition to the Household Stock of Vehicles

Vehicle Choice:	**Next new vehicle an addition to household fleet?**		**Total**
Observed Count	No	Yes	Observed Row Total
Neighborhood EV	11	**8**	19
Community EV	23	**5**	28
Regional EV	103	16	119
Hybrid EV	**41**	3	44
Gasoline, Reform	**135**	19	154
Natural Gas	**78**	10	88
Total	391	61	452

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	12.332	0.0305
Pearson	15.978	0.0069

Though the test statistics indicate a significant relationship does exist between type of vehicle and whether that vehicle is an addition to the household fleet, the chi-square test depends almost entirely on differences in households that chose NEVs. Households that chose NEVs ere far more likely to state that this vehicle will be an additional vehicle in the household fleet we would expect if choice of vehicle type and the decision to replace or add a vehicle were nt. Among NEV choosers, 42 percent of households stated the NEV would be an

additional vehicle in their fleet. Further, if we cross-tabulate all three variables—vehicle type, life cycle, and add a vehicle—we find that among NEV choosers who belong to the two life cycle groups who choose NEVs more often than expected, 60 percent say the NEV will be an additional vehicle. Across the entire sample, only 13.5 percent of all households choose to add an additional vehicle and only 12.3 percent of households that choose a gasoline vehicle.

The high level of vehicle additions should not lead us to believe that NEVs were only chosen as additional vehicles. It is still true that most of all NEV choosers indicated the NEV will displace or replace one of the household's current vehicles. It is also true that virtually all the households in which the NEV was not an additional vehicle, already own more vehicles than they have licensed drivers. The availability of a "long range" vehicle is never a constraint on any of the households' drivers, thus it is relatively easy for them to adapt to a NEV.

The adaptations required by the households that chose a NEV may be relatively minor, given that some of the households are simply adding a NEV to their stock of vehicles. Further, most of those households in which the NEV displaced a gasoline vehicle already owned many cars and trucks. However, simply by choosing an NEV, most of these households are making an adaptation or adjustment, compared to their original vehicle purchase intentions as expressed in Part One of the survey.

In Part One of the questionnaire, we asked households to tell us about the next new vehicle they thought they would acquire. We asked them what the body style of that vehicle was most likely to be. We define this to be their *preferred body style*. We also asked respondents to consider a defining trip purpose for their choice of body style. We provided them with the example of a household that buys a sport-utility vehicle to make weekend ski trips, despite the fact the vehicle is used for commuting to work most of the time. In this case, the defining trip purpose that leads to the choice of a sport-utility vehicle rather than some other body style is "weekend trips". One adaptation we see is the choice of an entirely different body style and intended use for the next new vehicle. We examine these changes in body style choices and intended use of the next new vehicle below.

Changes in Body Style Choices

Since NEVs are not part of the choice set from which consumers now choose vehicles, the ice of a NEV in our survey requires a change of body styles. In Part One of the tionnaire, we asked our respondents about their most likely choice of body style for their v vehicle. In Part Four, we then offered them a variety of vehicles—but not all e offered in all body styles. No electric vehicle could be had in a full size body

style. Therefore we label all small, compact and midsize body styles (including minivans) as "EV body styles" and full size body styles as "non-EV body styles". We cross-tabulate their preferred (most likely) body style choice from Part One by their actual body style choice in Part Four (irrespective of motive power) in Table 5.8. We show the expected values for each cell, as well as the observed value, to highlight the strength of the relationship. Cells in which the observed value is larger than the expected value are shown in bold.

Table 5.8: Actual Body style Choice by Preferred Body style

Body Style of Chosen Vehicle Count Expected	**Body Style Preference for next New Vehicle** Non-EV Body Style	 EV Body Style	Total Observed Count
Non-EV Body Style	**60** 34.45	10 35.55	70
EV Body Style	150 174.70	**205** 180.30	355
NEV Body Style	8 8.86	10 9.14	18
	218	225	443

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	48.292	0.0000
Pearson	44.358	0.0000

We draw three conclusions. First, across the entire sample, people were far more likely to choose a body style in Part Four that was smaller than their stated preference for the body style of their next new vehicle in Part One. Second, there is almost no switching to larger cars. Only ten of the 225 people who stated their likely body style choice was one of the smaller EV body styles chose a larger, non-EV body style vehicle in the choice exercise. Again, across the entire sample, we reject the hypothesis that body style preference and body style choice are independent. Overall, there is a pronounced shift to smaller body styles. Forty-nine percent of the sample indicated their initial preference was for a full-size vehicle, yet only sixteen percent

choose a full-size vehicle in Part Four. When weighing desires, needs, options, and prices most people choose a smaller vehicle than when asked for an unrestricted preference.

The third conclusion has to do with the body style choices of the households that chose NEVs. Nearly half the households that chose a NEV indicated they wanted a full-size body style for their next new vehicle. Thus many households that chose NEVs changed from a preferred body style that in no way resembled the NEV the chose. The observed and expected values for NEV body styles in Table 5.8 are very close and these table cells contribute very little to the statistical significance of the overall table. This statistical independence signals that something substantively important is happening. While the statistical expectation is one of independence, substantively we expect that only people who are already considering the purchase of a small vehicle would consider a vehicle as small as a NEV. Yet nearly half the people who chose a NEV had previously stated they preferred a full size vehicle. These households provide examples of people willing to construct an entirely different household fleet when offered a NEV than they might otherwise.

Intended uses of the NEVs

Besides changes in body style, the choice of a NEV may change the intended use of the next new vehicle. After our respondents made their vehicle choice in Part Four of the questionnaire, we asked them to reflect on the defining trip purpose and tell us whether it had changed. These defining trip purposes are shown in Table 5.9 for households that chose NEVs.

Table 5.9: Defining Trip Purposes for Households which chose NEVs

Defining trip purpose for the NEV (from Part Four)	Defining trip purpose for the next new vehicle (form Part One)	Count
Commute to and from work	Commute to and from work	8
Commute to and from work	Weekend travel	1
Commute to and from work	Other	2
Chauffeur family members	Chauffeur family members	1
Business errands	Business errands	1
Run local errands	Commute to and from work	1
Run local errands	Weekend travel	2
Other	Other	1

Households who discover a NEV would be suitable commuter vehicle make up the largest single group. Two other households found that NEVs could be used for the trip purpose that defined their likely next new vehicle—chauffeuring non-driving family members and business errands. In each case, the defining trip purpose for the NEV was a trip or type of trip that entails travel on local, low-speed trips *for that household.*

Patterns of Daily Vehicle Distances

Identifying general characteristics of the households that choose NEVs, to identify likely NEV market segments, is made more difficult by the variety of different travel patterns that those households exhibit. According to the travel they recorded in their 3-day diaries, we can classify the NEV households into three broad categories based on the distances traveled and each driver's ability to complete the travel contained in their diary without traveling on freeways, expressways, or other high speed roads. We use the same categories we used in the previous chapter on the household vehicle trials. Each group must make progressively greater changes to accommodate an NEV in their household stock of vehicles.

Five households have travel that appears *pre-adapted* to NEV use. Neither of the household vehicles traveled more than 40 miles on any of the three days and both drivers indicated it would have been possible for them to complete all three days without traveling on a high speed road. The travel of four households could be *easily adapted* to a NEV. In these households, one vehicle in particular is usually used for long distance travel, even on a daily basis. The other vehicle therefore travels less than 40 miles every day. As with the previous group, both drivers indicate they could have completed all three diary days without traveling on a freeway or expressway. These two groups might make some minor adjustments in either their travel or vehicle ownership to accommodate a NEV, but do not necessarily have to make them.

The last group must make some adjustments to accommodate a NEV. To explain how the seven households in this last group could use a NEV requires reference to information other than the characteristics of the travel diaries. From the diaries we learn that on any given day, either or both of the following are true—neither driver could have completed more than one of their three travel days without traveling on a high speed road and at least one, and sometimes both, vehicles travel more than 40 miles. To use a NEV, these households must either make changes in their choices of routes or destinations, make an exclusive assignment of the NEV to one driver (with no opportunity to use vehicle swapping as a strategy to overcome a potential problem created by the range or speed limits of the NEV), the NEV must be an addition to the

household stock of vehicles, or if the NEV displaces one of the household's current vehicles, that household must already own more vehicles than it has drivers.

Conclusions

The small apparent market share won by NEVs in this study of new car buying households in California should not be taken as evidence that such a market is too small to be viable. The households sampled for this study represent a very difficult test for the NEV concept. These households live in highly suburbanized cities and towns. The dispersed land use development and roadway infrastructures in these communities have been designed for automobiles capable of long distance, high-speed travel. If the bad news is few households in our sample appear willing to buy NEVs, the good news is any households at all are willing. Within the expanses of our suburbanized metropolises, some households have made choices about home location and vehicle ownership that allow them to consider and choose a NEV.

While the number of households that choose a NEV is too small to allow definitive conclusions regarding the size of the market for NEVs within the subset of new car buyers sampled for this study, these households suggest that several of our premises and earlier conclusions are credible. We have emphasized the importance of the interaction between household activity space and physical infrastructure in defining markets for NEVs. The households in this survey that choose a NEV demonstrate that some households living in suburban communities around the state can visualize that NEVs provide them access to an important part of their activity space. They demonstrate that households are willing to construct entirely different household fleets of vehicles around a NEV, lending credence to our premise that household vehicle purchase decisions are based on the vehicles the household already owns as well as the vehicles they are considering for purchase. The households that choose a NEV reinforce the conclusion we have previously made regarding the EV market, namely that people who choose EVs regard them as practical transportation tools first, and as expressions of environmentalism second, if at all.

This sample of households that have considered a variety of vehicles and chosen a NEV demonstrates the difficulty in identifying markets for NEVs by more traditional descriptors of market segments. We believe that most households that chose a NEV did so because their travel and vehicle ownership patterns were already adapted to NEV use or the household was willing to add the NEV as an additional vehicle. We cannot ignore that NEVs cost less than other vehicle types within our experimental design. Never the less, a household would not choose a vehicle they could not use. These households appear to be no more motivated by

environmental concerns than are the households that chose any other EV and they are on average certainly no more likely to believe that large, immediate lifestyle changes are required to address environmental problems. Thus, to some households in suburban California, NEVs will be seen as entirely suitable means to maintain the mobility that comes with multiple vehicle ownership, but at a greatly reduced cost. Their minimal emissions are an advantage and home recharging a convenience—but we see nothing in the data to suggest that NEVs are chosen for any other reason than that they provide practical transportation.

The life cycle groups that do, and do not, choose NEVs must be interpreted with care. While we did expect households of middle age parents with children to be more responsive to EVs (based on prior research), the low cost of NEVs confounds any expectations we may have had based on household income. The apparent disinterest toward NEVs shown by households made up of retired persons should not dissuade us from believing that households of retired people will be an important market for NEVs. These households in particular highlight the importance of the specific community in which the NEV might be used. While it is possible that retired households in our sample did not choose NEVs because they do not foresee enlarging their stock of vehicles and may be conservative regarding new technology, we need only recall the case studies of Palm Desert and Sun City to know that within appropriate environments, retired households will be important NEV market segments.

VI. CONCLUSIONS: MARKETS FOR NEVs

Cynthia Dettelbach. In the Driver's Seat: A Study of the Automobile in American Literature and Popular Culture.

"...while the energy crisis may change consumer buying habits—from large, gas guzzling models to smaller, more economically run cars—it will never change the basic premises under which cars are bought in the first place. The phenomenon of space as well as the itch to conquer it will always be with us..."

One Size Does Not Fit All

Dettelbach develops four themes in her analysis of Americans' relationship to the automobile as expressed in literature and pop culture: youth, freedom, success and possession (Dettelbach, 1974). She develops each theme as thesis and antithesis. If the auto at first liberates, it also enslaves. If first we possess it, it ultimately possess us. As she makes clear in the quote above, her analysis of popular culture indicates that Americans buy cars (in part) to conquer space. While this is undoubtedly true, we would be incorrect to infer that all cars must conquer vast distances. The key to introducing small cars is dispensing with the "one size fits all" mentality that pervades the transportation system (Garrison and Clarke, 1977).

It is true that many, and perhaps most, Americans live in communities where activities are separated by spaces seemingly insurmountable to pedestrians and cyclists—further separated by the inhospitability to low speed modes of the roadways that conveniently link activities via automobiles. However, we recognize that not all vehicles that can link activities within a city, must also be able to travel from one city to the next. As we and others have cogently argued elsewhere, the opening of markets for NEVs requires changes in rigid safety regulations that discourage innovation, auto maker hostility to small cars, standardized infrastructure designs that discriminate against small vehicles, and traffic control rules that serve only large vehicles. The point we make here is that opening markets for NEVs also requires households to specialize their vehicle holdings. We may still wish to drive the open road, but as a matter of gaining daily access to activities, NEVs may serve us well one travel tool among many.

Defining Neighborhood Electric Vehicles

The general defining characteristic of NEVs is their specialization for local travel. As such, they will have limited range and low top speeds and thus, low energy storage and low power needs. Consistent with keeping energy and power requirements low, NEVs will be small. They will likely accommodate two or three persons plus storage space, but some may be larger so as to accommodate families with children. We envision that NEVs will range from top-end

vehicles that are intended to travel on arterial streets at speeds of up to 45mph, to bottom-end NEVs, with top speeds of about 25mph.[1] Bottom-end NEVs might have separate right-of-ways, only mixing with other motor vehicles in specialized circumstances, such as streets with stringent vehicle speed and size restrictions. We see little reason for the driving range of NEVs to exceed 40 miles or so, since they will only be driven on sequences of short trips and can be readily recharged each night. We return to this definition after a discussion of NEV markets.

NEV Markets are defined first by places, and second, by people

The theoretical construct we employed to provide a unifying thread to the research presented in this report is the *household activity space*. We explored with households whether they would be able to access the activities that make up their daily lives using a household fleet of vehicles that included a NEV. Within this framework, we conclude that, unlike gasoline vehicles which can be marketed almost independently of where they are intended to travel, markets for NEVs will be defined primarily be characteristics of the environments in which they are intended to be used, and secondarily, by characteristics of persons. That is, the same gasoline car is sold throughout the state, the country and the world. Markets for those cars are differentiated primarily by the characteristics of the people to whom they are sold. NEVs, because they have speed and range limits, cannot be driven everywhere. Therefore, markets for them are defined primarily by characteristics of the places the vehicles are intended to be driven.

Because small, low speed, short range cars are so far outside the experience of consumers, market research methods that engage consumers in reflection on their travel needs and desires are required. We employed a variety of such research techniques. We tested specific hypothesis about the market for NEVs within a framework that incorporates the real behavior of households into their deliberations regarding NEVs. Four of the market segments we examined were residents of resort and retirement communities, environmentalists, EV hobbyists, and multi-vehicle households. We explored the assumptions that led to the initial choices of these hypothetical market segments by also examining some households outside these groups. Within these market segments, we found that advance technical knowledge of EVs and strong environmental convictions have much less to do with responses to NEVs than does a household's ability to visualize a NEV providing practical access to household activities.

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[1] Electric-assist bicycles are considered by some to be NEVs. We do not include them in this discussion since there are few policy, infrastructure or marketing issues that differentiate electric-assisted from non-assisted bicycles In fact, electric-assist bicycles enjoy the advantage, relative to other NEVs, of already being explicitly recognized in vehicle codes.

An example NEV market defined by location: retirement age households

A previous feasibility assessment of NEVs did not find differences in responses to the concept of NEVs across different types of households (Theodore Barry and Associates, 1992). We too find that many types of households are responsive to NEVs. But we also find that differences in responses between and within household types are related primarily to place and location, and secondarily to persons and households. For example, we found wide spread purchase and use of electric golf carts for general transportation amongst retirement age households in golf resort communities, yet in our statewide survey, no retirement age household chose a NEV.

It is the differences between the location the retirment age households in these two samples that explains differences in their response to NEVs. Households in the golf resort communities of Palm Desert and Sun City are already driving NEVs because of supportive local institutions, NEV-amenable roadway infrastructure, and activity and lifestyle choices that favor ownership of a golf cart (a low performance NEV). For the statewide survey, we did not sample form either golf resort towns or other small towns or resort locations that we expected, a priori, to be favorable to NEVs, rather we sampled from the large urban and suburban metropolitan areas of the state. The retirement age households who live in these communities are making different activity and life style choices—different choices driven, in part, by differences in the characteristics of the locations in which these households reside.

Retirement age households in the statewide survey did not chose NEVs for two reasons. First, across all households in the survey, if the next new vehicle the household intends to buy is to be an addition to the household's vehicle holdings, then that household is more likely to choose a NEV than if the next new vehicle is intended to displace an existing vehicle from the household's fleet. Retirement age households were far less likely to be planning to add another vehicle than were any other household types. Second, the single most common reason for the purchase of the next new vehicle among retirement age households was weekend and vacation travel—a use clearly not compatible with the purchase of a NEV.

Through this example, we illustrate the detailed insights into the market for NEVs that can be developed through the application of *activity analysis* and the importance of implementing appropriate market research tools. If we had conducted only the statewide survey, we would have inappropriately concluded that retirement age households are not good candidates for NEV purchase. Instead, we supplement the conclusions of the statewide survey with the results of a study focused on locations amenable to NEVs in which retirement age households reside. We conclude that the activity, life style and vehicle choices of these older households are compatible with NEVs. Outside these NEV-friendly locations, retirement age households

are more likely to be limiting and reducing their vehicle holdings (thus reducing possibilities for vehicle specialization) and buying vehicles whose intended use is not compatible with the speed and range constraints of NEVs.

Answers to the Initial Research Questions

Two questions that we set out to answer about households' responses to NEVs were these:

- "Will households create *NEV activity sub-spaces*?"
- "Is the existence of these *NEV activity sub-spaces* a necessary condition for households to include NEVs in their choice sets for their next vehicle purchase decisions?"

Creating NEV Activity Sub-spaces

The answer to the first question is yes. We found in the week long vehicle trials that households who use several distinct travel modes organize their activities into sub-spaces defined by the travel mode used to access those activities. In households that use both automobiles and bicycles, each mode is used to regularly access distinct sets of activities. In the case studies of Sun City and Palm Desert, we saw that households constructed activity sub-spaces that they accessed by golf cart. These *cart activity spaces* included recreation and social activities located at golf courses and community centers, as well as shopping, banking and other personal business errands located near home. The participants in the EV and NEV ride-and-drive clinics who chose NEVs lived in the downtown area of Sacramento. A NEV provided access to an important sub-set of their activities as so many of their activities were located near their residence and were accessible by suitable streets. Households who participated in the week-long vehicle trials in both Davis and Sacramento could be differentiated into those who could construct sub-sets of their activities accessible by NEVs and those who could not. We believe therefore it is entirely plausible that some households will be able to construct distinct sets of activities that they access by NEVs. These sets of activities are what we call the *NEV activity sub-space*.

NEV Activity Sub-spaces and Vehicle Choice Sets

To answer the second question, we make a distinction here between whether a NEV is included in a household's vehicle choice set and whether it is included in the household's vehicle fleet. Vehicles in the household's choice set are those vehicles it considers for purchase; a household must buy a NEV in order for it to be included in the household fleet. The existence of a viable *NEV activity sub-space* is a necessary pre-condition of whether a household includes NEVs

in its vehicle choice set. The formation of this *NEV space* is a necessary condition for households to consider the purchase of a NEV. Before households will include a NEV in the set of vehicles they will consider buying, they must visualize the possible *activity sub-space* the NEV will access. They must assess whether this sub-space is sufficiently different from that accessed by some other travel mode available to the household, and evaluate whether the *NEV activity sub-space* contains sufficient activities to warrant inclusion of a NEV in the household's fleet of vehicles. We find no evidence that any household was so motivated by environmental goals or fascination with EV technology that they would buy a NEV if it did not provide valued transportation services to the household.

Activity Space and NEV Market Potential

We found that NEV purchase and use is most likely when:

- a high density of the household's activities are located within a compact geographic area around a location at which the NEV would regularly be charged, usually home but possibly also work;
- these household activities are accessible by low speed, or otherwise appropriate, streets;
- the household has few binding authority constraints or binding coupling constraints associated with its routine activities; and
- the household has a high degree of flexibility in assigning travel tools to household members (because of high automobile ownership, use of multiple travel modes, or a compatible structure of links between household members' activities).

Households that rejected the notion of buying a NEV do so for one (or more) of three reasons

- the small size of NEVs (expressed as a response to passenger occupancy, cargo capacity or safety perceptions of small vehicles) ruled them out;
- the speed limitation of the NEVs created a binding capability constraint that precluded travel on some crucial roadway network links to important activities; or
- the *NEV- space* was not clearly differentiated from the activity sub-space of some superior (cleaner, cheaper, safer, bigger, etc.) mode or modes.

Accepting that a household must first be able to define some useful NEV-activity space prior to competently imagining a NEV purchase decision, our work leads us to some conclusions about the possible markets for NEVs.

Compact Activity Space Accessible by Surface Streets

To plan for, and market, vehicles that are not capable of long-distance, high-speed travel, we need to shift our perspective. We need to shift from our stereotypical vision of our sprawling, urban metropolises and begin to look for those households that can reapportion their activity spaces into a local activity space, accessible by a low speed, short range vehicle and an activity space that requires a high speed, long range vehicle. We need to focus on providing affordable, clean transportation options to urban residents who can and will allocate their travel to specialized vehicles. We need to develop demonstration projects and other learning experiences for consumers to foster the reflection and visualization required to assess their ability to adapt to a vehicle specialized for local travel.

Part of this shift requires that we examine household activity space, rather than geographical space itself. The portion of any given urban area that corresponds to any one household's activity space will be much smaller than the urban area itself. Within these smaller spatial units centered around household locations, NEVs may provide a superior transportation option to many multi-car households, allowing them to maintain a high level of accessibility at a lower cost. If we can identifying these households, we can develop markets for NEVs Once we have identified these households, we can construct aggregates of their activity spaces to guide possible infrastructure and land use changes that may be helpful, or required, to allow households to actually buy and use a NEV.

NEVs in Household Vehicle Fleets

A household that combines electric and gasoline vehicles in its stock of vehicles is one example of what we call a *hybrid household.* In contrast to a hybrid vehicle that combines different propulsion systems in one vehicle, a hybrid household chooses two vehicles with different propulsion systems and then must allocate household travel accordingly. A household that chooses to buy a NEV would be a hybrid household and would have to reallocate travel to its vehicles based not only on range, but also on speed, passenger and payload capabilities.

The case studies of golf resort communities, the household vehicle trials and the statewide survey all provide information on how households can and will become hybrid households. Households will change their stocks of vehicles, and change how those vehicles are used, in order to accommodate a NEV. The case studies of Palm Desert, California and Sun City, Arizona indicate the real potential for households to restructure their vehicle holdings so that a small, clean, low speed vehicle displaces the use of a full size gasoline vehicle for some of that vehicle's most polluting trips. Particularly in Sun City, with its long history of golf cart

use for local transportation, we heard evidence in our focus groups and interviews that households displace an automobile with a golf cart. Palm Desert's more recent experience has yet to produce a preponderance of evidence for such shifts in vehicle ownership. However, we found no reason to believe that many of its residents will not give up one gasoline car, becoming hybrid households, as they become familiar with the new roadway infrastructure, accustomed to accessing non-golf activities in their carts, and habituated to seeing golf carts on the streets.

The in-depth interviews conducted after the week-long vehicle trials allowed for discussion of which vehicles could be displaced by a NEV and what adaptive strategies households use. We heard households of limited financial means make cogent argument that a NEV could be their only vehicle. We heard how some households could displace one of their gasoline vehicles with a NEV and we heard households express a desire to add a NEV to their vehicle holdings. We observed households construct hypothetical household fleets that included NEVs.

The process of developing these new hypothetical household fleets indicates NEVs may also represent a superior transportation option to used ICEVs. We saw that many older cars were driven primarily for local travel because of their high cost of operation and perceived unreliability. If NEVs are inexpensive to buy, cheap to operate and reliable, then they may represent a superior transportation option even in households that do not now buy new vehicles. This competition with used ICEVs opens the immediate possibility of NEV ownership to many households who might not otherwise participate in the market for electric vehicles until there are many used, freeway-capable electric vehicles.

These interviews reveal that often speed and range are not the important limits on NEV use. Rather, a NEV's limited passenger and payload capacities will often cause a gasoline vehicle to be used on a given day or for a given trip when a NEV could have otherwise been used. In using their temporary household fleet during the NEV trial week, the coupling constraints imposed by links between the activities of household members (and non-household members) often caused a gasoline vehicle to be used when a NEV could have otherwise made the trip(s).

The results of our statewide survey indicate that, even within the suburban land use patterns of California's cities, some households can displace a gasoline vehicle with a NEV. Some of these households own more vehicles than they have drivers, thus allaying any fears the limited speed and short range might "strand" a household member. Others of these households, with the means and motivation, will add a NEV to their fleet of vehicles. These households made choices of limited range, low speed vehicles that could provide them with practical, affordable

transportation within the context of their own activity space and the fleet of vehicles that they would construct around a NEV.

The ride-and-drive clinics confirmed that common measures of household socio-economic, demographic and attitudinal characteristics are less useful in identifying possible NEV markets than are the activity space concepts used throughout this research. Further, the response of EV hobbyists and environmentalists to NEVs are driven less by specialized knowledge of EVs, environmental attitudes and income than by the location of the household, its activities, and its fleet of vehicles and other available transportation options.

New Vehicle Ownership Arrangements

In adapting a NEV to their use, many households in the vehicle trials speculated about the possible, beneficial effects of new vehicle ownership arrangements. These discussions followed two lines: arrangements in which the household would not have to buy the NEV itself and thus would not have to absorb the risk of this new vehicle type; and, arrangements that would allow the household to own only NEVs, but have easy access to a long-range, high-speed vehicle. Examples of the first type would be NEVs operated as station cars or employer-provided vehicles. Examples of the second include cooperatives that rent ICEVs to their members or expanded, neighborhood level availability of commercial rental ICEVs.

Ownership arrangements in which an employer or other vehicle provider owns the NEVs and rents or leases them to employees are potentially valuable ways to provide consumers with experience with NEVs. Large institutional buyers, who might otherwise be good prospects for NEVs for their own fleet use, could operate NEV demonstration programs for their employees. Potentially, many large industrial, commercial, educational or health-related complexes could use NEVs in their own fleets of vehicles and in demonstration projects for their employees.

Market Niches for NEVs

Our efforts to distinguish hypothetical early market segments for EVs and NEVs met with mixed success. Our efforts to identify NEV buyers by characteristics of the households themselves revealed a complex set of relationships that did little to clarify who would buy NEVs. The concept that consistently identified households amenable to NEV purchases was the *household activity space*. Above we provided a description of household activity spaces that were amenable to NEV use, but because it is multi-dimensional (including not only space and time but also types of activities, household relationships, and available travel tools), virtually no existing surveys of households or travel provide us all the information needed to

identify those households. One useful way to employ the concept is to rephrase the answer to the question of who will by NEVs. Rather than attempting to answer the question using only characteristics of the people who represent particular market segments, we describe some possible NEV market niches below by identifying characteristics of the environments in which the vehicles would be used.

One important niche for NEVs is resort communities and facilities. These are often located on mountains, at seashores, in deserts and in other environmentally fragile areas, where clean and uncongested environments are highly valued. A subset of this market niche is owners of second homes in vacation areas. Another subset of this market niche is areas such as national and state parks where vehicle exhaust is damaging unique natural environments. One plausible strategy for heavily used natural environments is to ban gasoline and diesel vehicles and replace them with electric buses and NEVs. Proposals to severely curtail automobile access to places such as Yosemite Valley have been discussed for years. Even if automobiles were allowed access to the valley, they could be limited to entry and egress only, with all vehicle movements within the valley made by transit or rented NEVs.

A second niche is neighborhoods and towns where speeds are controlled and the communities are receptive to NEVs. Again, a sub-group of these is resort towns. The possible markets in resort towns such as Palm Desert for small, light-weight, electric vehicles are large. Interstate 10 and State Highway 111 in California's Coachella Valley string together a long series of such resort towns. Other golf resort clusters and communities exist throughout California and more are planned. One important feature of resort clusters is that the estimates of their permanent resident population grossly understate the potential market niche for NEVs because resort towns experience large seasonal changes in population. One distinguishing feature of our focus group participants in both Palm Desert and Sun City is that they are permanent residents of those towns. The large influx of non-permanent residents in winter increases the possible market for small, low-speed vehicles. In fact, these migratory households may wish to have a NEV at both their sunny, winter homes and at their summer homes.

Golf resort communities have a large existing population of small, low-speed vehicles. In communities that lack an existing population of golf carts, it may be harder to demonstrate the same latent demand for the use of a cart-like vehicles. A number of non-resort communities around California are currently seeking legislation to allow them to engage in golf cart demonstrations such as Palm Desert's. While they are unnecessarily limiting their focus on a very specialized vehicle, these towns are clearly demonstrating an interest in small, low-speed vehicles. These communities will require either a coordinated effort to simultaneously provide

vehicles and infrastructure or the availability of NEVs that are able to mix with existing traffic on most existing streets.

A third market niche is new residential, mixed use, or industrial developments designed specifically for NEVs. In California alone, neighborhood electric vehicles are being considered as integral elements in some new town developments. Some developers are considering providing a NEV with some or all homes sold in the new towns. The potential market in these new towns is in the hundreds of thousands. Industrial parks are another example of land use patterns that could readily be designed to accommodate NEVs.

Though a fourth market niche is seemingly identified by characteristics of the people who might use NEVs, we can define this niche more generally as "persons who move through a tightly circumscribed activity space." This group of people includes mobility-impaired individuals, estimated to include about 10 million people in the U.S. NEVs are easy to drive partly because they operate at slow speeds and are small and easy to maneuver. This ease of driving can be enhanced by specialized controls, similar to the thousands of motorized wheelchairs and many retrofitted gasoline vehicles. Another enhancement is the use of partially or fully automated controls. Partial controls could be installed on NEVs to aid with steering or braking and to avoid collisions. With the expanding population of elderly people, many of them mobility-impaired, neighborhood cars could become increasingly important as a mode of transportation.

These market niches are just the beginning. Initially, neighborhood electric cars will not be accepted in many locations because of safety problems in mixing NEVs with much larger vehicles and because road infrastructure is not perceived as suited to their use. But as neighborhood cars gain acceptance in various niches, local governments and developers are likely to alter road and parking infrastructure to accommodate and even reward users of these vehicles. At the same time, lobbying groups will emerge to push for changes in liability and traffic control rules that hinder the market penetration of neighborhood EVs.

With varying levels of both NEV performance and commitment by local governments to providing NEV-centric infrastructure improvements, the total potential sales of NEVs will continue to be difficult to estimate. But as the demonstration projects and surveys reported here indicate, households throughout California are receptive to NEVs. This reception is based on an expectation that, within the context of increasingly specialized household vehicle holdings, a can NEV provide a superior transportation alternative if it is inexpensive to buy, cheap to operate, and reliable.

Safe Vehicles or Safe Systems?

Because of the concerns raised by participants in both the ride-and-drive clinics and the vehicle trials, we revisit the issue of safety. Safety may be the most controversial aspect of small cars. Safety regulators in the U.S. are diligent, determined, and effective. Their mission is to increase the survivability of vehicle occupants in an accident. Safety debates are guided by this regulatory mission. But this regulatory approach is narrow; it misses the larger benefits that result from a safer transportation system. The standards promulgated by this approach are neither necessarily consistent nor above reproach: for more than a decade, minivans met only the less stringent safety standards of light trucks, not passenger cars, though minivans are disproportionately bought by families with children. In an expanded approach vision, traveler's safety could be enhanced, for instance, by limiting the mixing of large and small vehicles or by controlling speeds of all vehicles in neighborhoods and on NEV-designated roads, using speed bumps, intelligent vehicle technology and other traffic "calming" techniques. Moreover, local residents along speed-controlled and vehicle-restricted streets benefit by being liberated to bicycle and walk in relative safety. Unfortunately, safety data do not exist for such a transportation system to determine how large and important these safety benefits might be.

The narrowed safety debate will therefore probably focus on the undeniable physical reality that an occupant of a small car is more vulnerable to injury than an occupant of a larger car, all else being equal. But even at this level of argument, it is not evident that occupants of very small cars will be at greater risk, because all else need not be equal. The small car could be made safer through better design and use of safety devices inside the cabin. As an extreme example, race car drivers routinely survive crashes at 150 mph and higher by using ultra-stiff shells with internal restraints. The Horlacher City used in the vehicle ride-and-drives has already passed the slightly less stringent European crash tests using this design philosophy.

Currently there are no safety regulations or laws specific to EVs of any size or type—although several proposed rules regarding recharging, crash avoidance, and crash-worthiness were issued in the early 1990s—and none specifically targeted at small vehicles.

A class of lightweight vehicles was recognized by the National Highway Traffic Safety Administration in the past. In 1967 a broad exemption from the standards was granted for four-wheeled vehicles weighing less than 1000 lbs., because it was believed impossible for such vehicles to meet the general standards; that exemption was subsequently removed in 1973. NHTSA subsequently rebuffed several efforts to re-instate a similar exemption, reflecting its insistence on all vehicles meeting the same standards (Sparrow and Whitford,

1984; Lipman, Kurani and Sperling, 1994). It is uncertain how difficult it would be to obtain an exemption or to create a new category for NEVs.

The safety of NEVs is possibly the most critical issue in determining how and where to introduce NEVs. Unfortunately, little evidence is available to make a reasonable determination, largely because the safety record is sensitive to the design of the vehicle, and how and where it is used. What is needed is bolder thinking. Safety regulators must consider safety in context. The context we suggest here includes two new vehicle definitions: slow and small cars designed specially for neighborhoods or use on specified roadway infrastructure and larger, faster (but still not freeway-capable) vehicles for more general urban use.

NEVs for Household Markets: Two Types of NEVs?

Based on the preceding discussion of markets for NEVs, responses to specific NEV attributes by our research participants, and on the design of possible NEV implementation strategies, we believe it is important to identify different classes of NEVs. Vehicles that can travel on much of our existing urban roadway infrastructure will need higher top speeds and increased safety engineering—yielding a more expensive vehicle—than will vehicles that could safely and practically be used in an environment specifically designed for low-speed vehicles. We saw in the ride-and-drive clinics that the distinctions between freeway capable and non-freeway capable vehicles are important. Even to those people who learn that a large amount of their daily travel can be accomplished in a non-freeway vehicle, the non-freeway limit is an important perceived barrier to purchase.

Thus NEVs are a distinct class of vehicles; but within this class are finer distinctions still. At least two types of NEVs can be distinguished from each other based upon our work: vehicles suitable for use in communities, industrial parks or other facilities designed specifically for, or otherwise amenable to, low speed vehicles and vehicles suitable for immediate use in many urbanized areas. We summarize possible characteristics of these two types of NEVs in Table 6.1. Modifications to the FMVSS for the higher performance vehicles to be used in existing communities may need only require that we specify performance criteria rather than design criteria. For example, it is desirable to specify a level of occupant protection, without requiring that protection be provided (in part) by a crush-zone of some minimum distance. The top speed, acceleration, seating capacity and price targets are taken from a synthesis of responses to the various vehicles reviewed by participants in the focus groups in golf resort communities, the ride-and-drive clinics, the week long vehicle trials and the statewide survey.

Table 6.1: Possible Characteristics of Two Classes of NEVs

Characteristic:	NEVs for use in existing communities	NEVs for use in purpose built environments
Top Speed	40 miles per hour	25 miles per hour
Acceleration	0-40 mph ≤ 8 seconds	0-25 mph ≤ 7 seconds.
Seating Capacity	Available in 2 to 4 seat configurations.	Available in 2 to 4 seat configurations.
Safety Standards	Meets slightly modified FMVSS[1].	Meets highly modified FMVSS or exempt.
Price Targets[2]	$5,000 to $10,000	$3,000 to $5,000

1. Federal Motor Vehicle Safety Standards

2. These are price targets, not cost targets We believe existing consumer incentives for electric vehicles should be available for buyers of NEVs too Precise prices will depend on the level of purchase incentive and consumer choices of options and trim levels

NEV Driving Range

We have previously described NEVs as having driving ranges of 40 miles, but we did not specify a lower bound on range for the NEVs in Table 6.1. Few households in the NEV trials experienced any problems with the 20 to 30 mile range capabilities of the vehicles in the trials. Continued experience with the vehicles might lead some households to explore further afield and thus to desire more range. The range requirements for NEVs are likely to be a function of where they lie on the spectrum from electric-assist cycles to short-hop freeway vehicles. The lower the vehicle's top speed capability, the more likely it is that time, not distance, will be the important constraint on a NEV-activity space. People traveling slower will not choose to travel as far because the time it takes to get to an activity becomes prohibitively long.

NEVs and the ZEV Mandate

Most instrumental of all in aiding the introduction of neighborhood cars will likely be the zero emission vehicle (ZEV) mandate. As major auto makers confront the high cost of meeting the ZEV mandate with EVs that attempt to mimic (or even approach) the driving range of full-size gasoline cars, they may become increasingly receptive to new means. Recognizing the poor energy storage characteristics of batteries, they may conclude, for reasons listed below, that

NEVs are economically and environmentally superior and technically more sensible than larger, freeway-capable EVs.

NEVs are arguably the most compelling application of battery-powered electric propulsion. NEVs do not suffer from the shortcomings of batteries as do larger EVs, simply because they require relatively little energy and power. Their low energy needs are due to low weight, low top speed, and short driving range. In addition, the low weight of the battery pack allows for a lighter structural design, and therefore still greater weight and energy reductions. Though based on simple designs and relatively unsophisticated engineering, the City-Com City-El used in this study carries only 240 lbs. of conventional lead-acid batteries, costing $250. The Kewet El-Jet carries 600 lbs. of batteries, and another prototype NEV, the Trans2, carries less than 300 lbs. of batteries. In contrast, a typical subcompact EV would need perhaps 1,000 lbs. of lead-acid batteries (GM's very energy-efficient Impact prototype currently carries 900 lbs. of batteries).

NEVs, under mass-production, should be much cheaper to buy, own and operate than full-size gasoline or electric cars. As major auto makers begin to recognize the relative ease of building a cost-competitive NEV, they may reconsider their historic disinterest in small vehicles.

Closing

The key question is this: will there be a market for what is easiest and cheapest to build? This research leads us to believe the answer to this question is yes. Through all the research tasks reported here, households living in many different towns and cities, faced with a variety of real or hypothetical NEVs, made real or hypothetical choices of NEVs. They constructed both meaningful sets of their activities to which a NEV affords them access and household vehicle holdings that included a NEV.

NEVs are not a panacea for near term problems, but they are energy efficient, low-polluting, and scaled for neighborhood use. NEVs would use less space than conventional vehicles, provide the premise for lowering vehicle speeds in neighborhoods, and help create a more pedestrian-friendly setting, while still providing high levels of accessibility. They also would be economical, in part because they are an ideal application of battery-powered electric propulsion. Indeed, it is a fortunate coincidence that the market applications in which electric vehicles are best suited—short trips—are also the applications in which NEVs provide the largest environmental benefits. NEVs clearly are an attractive option. They fit well into any vision of a sustainable transportation-energy future.

But will this good idea ever be realized? NEVs confront large perceptual, physical and regulatory barriers. There is a uniformity of expectations by consumers, government regulators, and highway suppliers that results in all vehicles being expected to satisfy all purposes, all roads serving all vehicles, and all rules being designed for the standard vehicle of the past. The result is a strong inertia that discourages innovation and change by vehicle suppliers and users. The success of NEVs will depend on an openness by regulators and highway suppliers to new types of vehicles, and entrepreneurial initiative by vehicle manufacturers.

Research into the size of the potential market for NEVs remains speculative in its conclusions. The statewide survey was not intended to measure all, nor even the most likely, NEV markets. If we take the results of that survey as a starting point though, the annual market for our higher performance NEVs (as specified in Table 6.1) is just under 1 percent of the new light-duty vehicle market in California. The households we sampled owned multiple vehicles, buy new cars, and own at least one vehicle that is not a full-size body style. The sample was not designed to reflect the attractiveness of NEVs in particular operating environments. It does not count sales to the market segments we discussed earlier in this section— resort towns, other towns that choose to control vehicle speeds and are receptive to NEVs, environmentally sensitive areas, new residential, commercial, industrial or mixed use developments designed for low speed vehicles, and individuals who either through disability or choice move through tightly constrained activity spaces. Sales to these market segments could easily dwarf sales to those households who are located throughout our existing suburban landscape.

While it appears that the long term market for NEVs could be millions per year in the U.S., in the short term, with little change in consumer expectations and various government rules, the market might still be sizable. However, this "no change" scenario requires NEV manufacturers to build vehicles to meet existing vehicle definitions, including golf carts, motorcycles, and motor-driven bicycles. The existing markets for such vehicles are so specialized as to make them a poor basis for predicting future markets for NEVs developed under new conditions. Market penetration of a new class of NEVs will depend on a large number of factors related to the ZEV mandate, vehicle safety rule making, local initiatives to accommodate and encourage NEVs, liability rulings, developments in traffic control, and the entrepreneurial initiative of manufacturers. Consumers, for their part, may require education and incentive to reflect on their travel needs and desires. Given that reflection, NEVs are chosen by some as a practical, desirable travel tool. These thoughts lead us to the following recommendations.

Recommendations

Demonstration projects

To develop these markets, there is no more important task than continued demonstrations of a variety of NEVs. As a distinct class of vehicles that embodies performance characteristics well outside the bounds consumers usually experience, markets for NEVs will depend on education, reflection and increased familiarity. We have demonstrated that the ability of a household to conceptualize a distinct and valued set of activities to which a NEV provides access is central to purchase consideration. Households will have to examine, and possibly reconsider mode choices, route choices, activity choices and a variety of other travel and life style choices that simply are not as relevant to the vehicle purchase decisions they now make. In some communities, such as golf resorts, this process is already underway. If many households are driving about in golf carts, it is much easier for others to imagine they can too. In other communities, greater effort will be required to provide examples and images for households to use in constructing their own *NEV spaces.*

Demonstration projects must be designed with clear goals and objectives. The distinction we make between types of NEVs in Table 6.1 highlights that there are alternate pathways to introduce NEVs. Whether households choose to buy NEVs depends on whether they can use NEVs to access some substantial subset of activities. This *NEV space* is constrained, in part, by the interaction between the capability constraints imposed by the NEV and the objective spatial structures (primarily transportation infrastructure) of the city or town in which the household lives. Matching vehicle capabilities to intended use environments will increase the effectiveness of NEV demonstrations. Vehicles with capability constraints that are too limiting may lead to peremptory rejection of NEVs by consumers. Vehicles that are of greater performance capabilities than required will unnecessarily drive up the cost of NEVs. Either error will lead to misguided investments in supporting infrastructures, including roadway, recharging, and vehicle sales and service.

Coalition building

Coalitions of NEV proponents will likely be required to overcome several key problems. These problems include the currently limited variety and limited production of NEVs and barriers to the acceptance of NEVs by safety regulators. These issues are important to consumer acceptance because they represent barriers to consumers ever having the opportunity to evaluate NEVs. While legislative approval of specific demonstration projects (such as that in Palm Desert) can be time-consuming, such approval for large-scale demonstrations might

generate sufficient demand for production of NEVs. Though they have chosen to initially invest in freeway capable EVs, the National Station Car Consortium is one model for a coalition that is trying to call forth EV production. In order to address safety problems within the existing institutional structures for transportation safety, coalitions of NEV manufacturers, NEV users, and communities and policy makers interested in promoting NEVs should lobby for changes in existing vehicle definitions to legitimize NEVs in the codes and regulations governing the design, sale, and registration of vehicles and the design of roadway infrastructure.

Quantitative market estimates

While the intent of the market research reported here was to understand the dynamics of markets for NEVs, it will be beneficial to develop quantitative estimates of the NEV market niches. Such estimates could also build momentum and legitimacy for continued development of NEVs. We would caution against analyses based on such simplistic measures as counts of golf carts, even within golf resort communities. We observe that the introduction of a variety of NEVs creates fundamentally new dynamics into the market for household vehicles. A more appropriate starting point is to examine the activity spaces of households living within the types of vehicle use environments identified as NEV market niches in this report.

REFERENCES

Buist, D.R. (1993) "An Automotive Manufacturer's Alternative Fuels Perspective." *Proceedings of the First Annual World Car 2001 Conference* . University of California, Riverside: The Center for Environmental Research and Technology, pp. 51-55

Chapin, F.S. (1974) Human Activity Patterns in the City: Things People do in Time and Space. London: John Wiley and Sons.

Daniels, P.W. and A.M. Warnes (1980). Movement in Cities: Spatial Perspectives on Urban Transport and Travel. London: Methuen.

Dettelbach, Cynthia Golomb. In the Driver's Seat: A Study of the Automobile in American Literature and Popular Culture. Dissertation. Case Western Reserve University: Department of English. 1974.

EPA. Report #420-R-93-007, 1993, cited in E.W. Johnson. "Taming the Car and Its User: Should We Do Both?" Bulletin, The American Academy of Arts and Sciences. Vol 46, No. 2, November, 1992, pp. 13-29.

Fried M., J. Havens and M. Thall (1977) Travel Behaviour—A Synthesised Theory. Final Report to the National Cooperative Highway Research Program. Washington D.C.

Garrison, W.L. and J.F. Clarke, Jr. (1977) Studies of the Neighborhood Car Concept. University of California, Berkeley: College of Engingeering Report 78-4.

Hägerstrand, T. (1970) "What about People in Regional Science?" Papers of the Regional Science Association, v. 24 pp. 7-21.

Horton, F.E. and D.R. Reynolds (1971) "Effects of Urban Spatial Structure on Individual Behavior." Economic Geography. 47:1 pp. 36-48.

Jones, P.M., M.C. Dix, M.I. Clarke and I.G. Heggie (1983) Understanding Travel Behaviour. Aldershot, U.K.: Gower.

Jones, P., F. Koppelman and J.P. Orfueil (1990) "Activity Analysis: State-of-the-Art and Future Directions." in P. Jones (ed.) Developments in Dynamic and Activity-Based Approaches to Travel Analysis. Aldershot, U.K.:Gower.

Kitamura, R., K. Nishi and K. Goulias (1990) "Trip Chaining Behavior by Central City Commuters: A Causal Analysis of Time-Space Constraints." in Jones, P. (ed.) Developments in Dynamic and Activity-Based Approaches to Travel Analysis. Aldereshot, U.K.: Gower.

Kurani, K.S and T. Turrentine (1993) "Electric Vehicle Owners: Tests of Assumptions and Lessons on Future Behavior from 100 Electric Vehicle Owners in California." University of California, Davis: Institute of Transportation Studies.

Kurani, K.S, T. Turrentine and D. Sperling (1994) "Demand for Electric Vehicles in Hybrid Households: An Exploratory Analysis." Transport Policy. v.1. n.4 .

Lipman, T.E., K.S Kurani and D. Sperling (1994a) Regulatory Policy Development for Neighborhood Electric Vehicles. Report prepared for the CALSTART Program on Neighborhood Electric Vehicles. University of California, Davis: ITS-Davis. UCD-ITS-RR-94-21. November 1.

Lipman, T.E., K.S Kurani and D. Sperling (1994b) Incentive Polices for Neighborhood Electric Vehicles. Report prepared for the CALSTART Program on Neighborhood Electric Vehilces. University of California, Davis: ITS-Davis. UCD-ITS-RR-94-20. November 1.

Rogers, E.M. (1983) Diffusion of Innovations, 3rd edition. New York: The Free Press.

Sparrow, F.T. and R.K. Whitford (1984). "The Coming Mini/Micro Car Crisis: Do We Need a New Definition?" Transportation Research. Vol.18A. pp. 289- 303.

Sperling, D. (1994). Future Drive: Electric Vehicles and Sustainable Transportation. Washington, D.C.: Island Press.

Soules, G., M.W. Brannan and A.G. Letzkus (1993) Golf Cart-Vehicle Accident Analysis. Phoenix, AZ: Maricopa County Department of Transportation, Traffic Engineering Division. June 23.

Stein, A., K.S Kurani and D. Sperling (1994) Infrastructure Planning and Development for Neighborhood Electric Vehicles. Report prepared for the CALSTART Program on Neighborhood Electric Vehicles. University of California, Davis: ITS-Davis. Report UCD-ITS-RR-94-22. November 1.

Theodore Barry and Associates (1992) Neighborhood Electric Vehicle Concept Feasibilty Study. Report prepared for Southern California Edison, the South Coast Air Quality Management District and Caltrans.

Turrentine, T. and K.S Kurani (1995) The Household Market for Electric Vehicles: Testing the Hybrid Household Hypothesis. A Reflexively Designed Survey of New-Car-Buying, Multi-Vehicle California Households. Report to the California Air Resources Board. University of California, Davis: ITS-Davis.

Turrentine, T. (1995) Lifestyles and life politics: Towards a green car market. Ph.D. dissertation. Available as research report from University of California: ITS-Davis.

Turrentine, T. and K.S Kurani (1994) "Segmentation and Size of the Market for Battery Powered and Hybrid Electric Vehicles in California: A Diary Based Survey of New Car Buyers in California." *Proceedings*. The 12th International Electric Vehicle Symposium (EVS-12) and Electric Vehicle Exposition. Anaheim, CA. December 5-7.

Turrentine, T. and D. Sperling (1992) Theories of New Technology and Social Choice Decision Strategies: The Case of Alternative Fueled Vehicles. Berkely, CA: The Univerity of California Transportation Center Working Paper No. 129.

Turrentine, .T., D. Sperling and K.S Kurani (1992) Market Potential of Electric and Natural Gas Vehicles. Davis, California: Institute of Transportation Studies, University of California. UCD-ITS-RR-92-8.

Turrentine, T., M. Lee-Gosellin, D. Sperling and K.S Kurani (1991) A Study of Adaptive and Optimizing Behavior for Electric Vehicles based on Interactive Simulations Games and Revealed Behavior of Electric Vehicle Owners. Available from University of California, Davis: ITS-Davis RP-24-92.

U.S. Federal Highway Administration. Summary of Trends. Washington, D.C., 1990. p. 14.

Wachs, M. and M. Crawford (eds.) (1991) The Car and the City: The Automobile, the Built Environment, and Daily Urban Life. Ann Arbor, MI: The University of Michigan Press.

APPENDIX A: PALM DESERT, CALIFORNIA GOLF CART LANE DESIGN CRITERIA

The information provided here is contained in Exhibit "A" of City of Palm Desert Resolution No. 93-2, City of Palm Desert Golf Cart Lane Plan/Transportation Pilot Program.

Golf Cart Lane Design Criteria

(a) Minimum General Design Criteria for Class I Golf Cart Lanes—Class I golf cart lanes shall be a minimum of six (6) feet in width in each direction, have a minimum clearance of seven (7) feet, improved hardened surface capable of weights of up to 2,300 pounds, totally separated from vehicle traffic or separated by a minimum six-inch vertical and six-inch horizontal curbing, designed with a maximum grade of 10%, radius of curvature may not be less than fifteen (15) feet, shall be designed for golf carts to be safely operated at speeds of 15 miles per hour unless posted with speeds of less than 15 miles per hour, and clearly designating all transitions to other golf cart routes.

(b) Minimum General Design Criteria for Class II Golf Cart Lanes—Class II golf cart lanes shall be a minimum of six feet in width, have a minimum clearance of seven (7) vertical feet, have consistent street surface, have separation from vehicle traffic designated by a sold white line and either a street symbol stenciled onto street pavement or golf cart lane symbol or sign posted along route designed with safe and clearly marked street transitions, and shall be parallel to only local highways that meet critical California Traffic Manual design criteria.

(c) Minimum General Design Criteria for Class III golf Cart Lanes—Class III golf cart lanes shall be designated golf cart routes parallel to local highways with a minimum posted speed limit of 25 miles per hour. All golf cart route transitions shall be clearly marked. It is the intent of Class III golf cart routes to be shared with pedestrians, bicycles, and motorists.

(d) Symbol Design—The City shall design a golf cart route symbol and provide said symbol to National Traffic Control Devices Committee and State of California Traffic Control Devices Committee for review, comment, and approval. Until said symbol is approved, City may utilize an existing symbol for purposes of marking golf cart routes. After approval, if different from State and National design, City shall modify existing symbols.

(e) Symbol and Marking Placement—The City shall clearly mark all Class I and Class II golf cart routes with signs and by symbols a minimum of every 300 feet in each direction. The City shall mark all dangerous conditions, obstacles, and hazards along all golf cart routes as required. The City shall mark all golf cart route transitions and shared facilities with bicycles and pedestrians.

APPENDIX B: PALM DESERT, CA and SUN CITY, AZ FOCUS GROUP OUTLINES

Palm Desert, California

I. Introduction

Who we are -- UC Davis. ITS-Davis

Why we are here -- To discuss golf cart use for local travel Small electric vehicles designed for local, neighborhood travel

How we are funded -- Calstart: a consortium of private industry, utilities, State and Federal agencies

Anonymous participation

II. Describe your Community

In general terms, tell me about your community. Why do you choose to live here?

III. Describe vehicles, recharging, use

Vehicles

Size

How large are they? How many seats for people? How much cargo space is there? Golf bags, grocery bags, etc.

Speed and acceleration

What is your vehicles top speed? Is the acceleration adequate?

Brakes

How good are the brakes? Do you always feel you can come to a controlled stop?

Comfort and amenities -- seats, enclosure

Range

What is the longest distance the vehicle will travel before it needs to be recharged?

Maintenance and repair

What types of maintenance do the vehicles require? Have any of your vehicles required repairs other than routine maintenance? Where is the maintenance and repair work done?

III. Describe vehicles, recharging, use (continued)

Licensing

Cart: How are the vehicles licensed?

Driver: Is driver's license required?

Restrictions

Do restrictions apply to either license? Where the vehicle can be used? Are drivers' licenses restricted specifically to carts available?

Insurance

Insured by auto or homeowners policy? Amount of Liability, collision, injury insurance required—is it the same as for your autos? What is the cost of the insurance on your cart relative to your auto insurance?

Recharging

Home

Where do you recharge the cart at home? How do you recharge at home? When do you recharge? After every trip? Only in the evening?

Is home recharging a convenience?

Away-from-home

Are there any locations away from home where you can recharge? golf courses, shopping locations, friends homes, etc.

When do you recharge away from home?

Cart Use

For what types of trips, in addition to trips to the golf course, do you use your cart?

Do you link together errands to different places, or make trips to only one place? How far are these trips? What types of streets and roads? Time of year? Time of day? What proportion of all your local travel?

IV. Safety

Intersections

Where are specific intersections at which you feel *unsafe*? Where are specific intersections at which you feel *safe*?

Special lanes and signs

Do you feel more or less safe in these lanes?

IV. Safety (continued)

Vehicles

How safe do you feel in your cart when you are in traffic with full size motor vehicles? What about your cart makes you feel safe or unsafe?

V. Changes to make golf carts a better transportation option

Vehicles

Top Speed, Range, Vehicle size. Specific safety features: Passenger enclosures, Seat Belts

Infrastructure

Streets, Roads, Lanes: cite specific locations. Signs

Policy

Licensing. Registration. Insurance. Permitted uses of cart.

Sun City, Arizona

I. Introduction

Who we are -- UC Davis, ITS

Why we are here -- To discuss golf cart use for travel other than to play golf

Small electric vehicles are being designed for local, neighborhood travel

How we are funded -- Consortium of businesses, State and Federal Agencies

Anonymity

II. Describe your Community

In general terms, tell me about your community. Why do you choose t o live here?

III. Describe vehicles, recharging, use

Vehicles

Are your carts Electric or Gas? Why did you choose an electric or a gas-powered cart?

Size

How large are they? How many seats for people? How much cargo space is there? Golf bags, grocery bags, etc.

Speed and acceleration

What is your vehicles top speed? Is the acceleration adequate?

Brakes

How good are the brakes? Do you always feel you can come to a controlled stop.?

What are the various safety features -- Lights, seat belts, horns rear veiw mirrors, etc.

Comfort and amenities—seats, enclosure

Range

What is the longest distance the vehicle will travel before it needs to be recharged or refueled?

III. Describe vehicles, recharging, use (continued)

Maintenance and repair

What types of maintenance do the vehicles require? Where is the maintenance and repair work done?

Licensing

Cart: How are the vehicles licensed? Do they have special license plates, regular Arizona motor vehicle plates, no plates?

Driver: Is drivers license required?

Restrictions

Do restrictions apply to either license? Where the vehicle can be used? When it can be driven? Are drivers' licenses restricted specifically to carts available?

Insurance

Insured by auto or homeowners policy? Amount of Liability, collision, injury insurance required—same as for your autos?

Recharging (Electric Only)

Home

Where do you recharge the cart at your residence? How do you recharge at home? When do you recharge? After every trip? Only in the evening? Is there a special recharging appliance in your home, or do you simply plug into an outlet? 110 Volt? Is home recharging a convenience?

Away-from-home

Are there any locations away from home where you can recharge? golf courses, shopping locations, friends homes, etc. When do you recharge away from home?

Refueling (Gasoline Only)

Where do you refuel your gasoline cart? Is there one "usual" station? Is this a station where you often refuel your car? Why do you refuel at this(theses) station(s)?

Cart Use

For what types of trips, in addition to trips to the golf course, do you use your cart? Do you link together errands to different places, or tend to make trips to only one place? How far are these trips? What types of streets and roads? Time of year? Time of day? What proportion of all your local travel?

IV. Safety

How much of your driving is on public streets and roads as opposed to golf cart paths?

Intersections

Where are specific intersections at which you feel *unsafe*? Where are specific intersections at which you feel *safe*?

Special lanes

Are there places where there are special lanes for golf carts, other than on golf courses? Describe these lanes. Where are they? Are they striped on regular roads or are they separate right-of-ways? Do you feel more or less safe in these lanes?

Signs

Are there special signs to indicate golf cart right-of-ways? What do these signs look like? Left turn, right turn, yield, stop, lane indicators, parking?

Vehicles

How safe do you feel in your cart when you are in traffic with full size motor vehicles? What about your cart makes you feel safe or unsafe?

V. Desired Changes to make golf carts a better transportation option

Vehicles

Would an increase in your carts performance (top speed and acceleration) make you feel safer? An increase in size? Enclosures?

Aside from safety, what other changes in your cart would make it possible for you to use it for most of your local travel local travel?

Infrastructure

What changes in Streets, Roads, Lanes or Signs would you like to see before you would use your cart for most of your local travel?

Policy

Licensing, Registration, Insurance, other.

APPENDIX C: PERCEIVED UNCERTAIN or HAZARDOUS ROUTES and INTERSECTIONS in the PALM DESERT GOLF CART NETWORK

Routes which focus group discussants generally felt were "unsafe" or "uncomfortable" to drive along in electric golf carts:

El Paseo from State Highway 111 to Portola;

Fred Waring Drive;

Portola (near Grapevine);

Portola (near Post Office at El Paseo).

Intersections which discussants felt were "unsafe" or "uncomfortable" or created uncertainty as to which were permitted movements:

State Highway 111 at both ends of El Paseo;

State Highway 111 at San Pablo;

State Highway 111 at Deep Canyon; *

State Highway 74 at Grapevine; *

State Highway 74 at Haystack; *

State Highway 74 at Sommerset; *

Portola at Haystack;

Portola at Marrakesh;

Portola between Larrea and El Paseo;

Portola at Rutledge;

Fred Waring at Deep Canyon.

* Not a legal crossing under Phase I Pilot Program infrastructure in place at time of site visit.

Green Market Part A

1. Below are combinations of words joined by lines. Put a vertical mark through each line at the point which indicates how your image of EVs compares to your image of the gasoline-powered cars and trucks you actually buy. The middle point of the line indicates you imagine there is no difference between EVs and the gasoline cars you buy. Try to recall your image of EVs prior to seeing the City-El at the Whole Earth Festival.

Compared to the gasoline cars and trucks I usually buy, EVs are:

small	----------|----------	large
slow	----------|----------	fast
unsafe	----------|----------	safe
non-polluting	----------|----------	polluting
inconvenient	----------|----------	convenient
cheap to run	----------|----------	expensive to run
cheap to buy	----------|----------	expensive to buy
impractical	----------|----------	practical
unstylish	----------|----------	stylish
old fashioned	----------|----------	futuristic

2. According to what you know about EVs, do you agree or disagree that EVs are the key to solving air pollution in the Davis-Sacramento area? Circle one.

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

3. Electric vehicles are not yet practical to replace gasoline fueled vehicles. (Circle one.)

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

4. What are the sources of information upon which you base your images of EVs? Please list the three most influential sources of information in forming your image of EVs.

_____

_____

_____

APPENDIX D: RIDE-AND-DRIVE CLINIC SURVEYS and FOCUS GROUP OUTLINES

Surveys

During the ride-and-drive clinic itself participants completed three survey forms. One survey (Part A) was completed prior to their review of the vehicles. An interviewer accompanied them through their review of the vehicles, recording their answers to Part B. Lastly, the participants completed a third section (Part C)after they had reviewed the vehicles. Two different versions of Parts A and C were administered; one to the "innovators" the other to the "environmentalists". This was done to allow for differences in information we already possessed on the two groups and to allow EV owners in the "innovators" group to respond to some questions based on their experience with their own vehicles. Page layouts have been changed to fit the format of this appendix.

5. Look over the list below. If this list reminds you of any important information sources which you did not list in your answer to the last question, please write them here.

_____

_____

_____

Electric Utility (SMUD or PG&E)

Television or Radio news

Newspapers

Television shows or specials

Automotive magazines

Technology and science magazines

Environmental organizations

Seeing EVs on the road

Word of mouth

Automobile manufacturers

Science Fiction

Electric Vehicle Clubs

Other (specify)_____

6. If EVs were widely available at auto dealers and you were in the market for a new car, which of the following most closely describes what you would you do? (Mark one.)

1 ( ) I would not consider an EV until they had been on the market for several years.

2 ( ) I would consider an EV, but would investigate carefully the costs and usefulness of each vehicle type before making a commitment.

3 ( ) I would buy an EV immediately in spite the uncertainty.

Innovators Part A

I. We would like to start with some information about the EV(s) you now own. If you do not currently own an EV, please skip to the third page of this questionnaire.

1. How many total vehicles does your household own? _____

   How many of these are EVs? _____

   How many of these EVs are currently operating? _____

The rest of the questions in this section will refer only to the EV that is driven most often.

2. What is the total system voltage? _____

3. Is this vehicle a:

   1 ( ) manufactured car (Name:_____)

   2 ( ) kit car (Name:_____)

   3 ( ) steel frame conversion (Name of body:_____)

   4 ( ) other (specify:_____)

4. Which of the following body styles best describes this EV?

   _____subcompact _____compact _____mid-size _____full size

   _____light truck _____van _____sports car _____other

5. How long have you owned this vehicle? _____years _____months

6. What is the (continuous) horsepower rating of this vehicle's motor? _____

7. Is it a single or multi-speed vehicle? _____

8. How many seats does this vehicle have? _____

9. Do you have as much luggage space as you want in this vehicle? _____yes
_____no

10. What is the top speed of this vehicle? _____

If the top speed is high enough for freeway travel, is the acceleration adequate for freeway on-ramps?

_____yes _____no

11. Do you ever use this vehicle on freeways? _____yes _____no

12. What do you consider to be the driving range of your EV when it is fully charged?
_____miles

13. Are the batteries in your vehicle:

_____lead-acid _____other(specify_____)

Are they: _____6 volt _____12 volt

What is the amp-hour rating of each battery:_____amp-hours

14. Do you carry your recharger on-board your vehicle? _____yes _____no

15. Do you try to recharge your batteries after every use? _____yes _____no

If yes, why? (choose one) _____to always have maximum range

_____good for batteries

_____other (specify:_____)

16. Do you recharge at: _____110 volts _____220 volts _____switchable

_____other (specify:_____)

17. Does your charger have an automatic shut-off? _____yes _____no

18. Did you have to modify the wiring in your house to accommodate recharging?

_____yes _____no

19. What characteristic of your vehicle do you consider to be the single most important barrier to your being able to use your EV for more of your driving?

_____driving range _____top speed _____acceleration _____body style

_____other (specify_____)

20. Below are combinations of words joined by lines. Put a vertical mark through each line at the point which indicates how your image of EVs compares to your image of the gasoline-powered cars and trucks you actually buy. The middle point of the line indicates you see no difference.

Compared to the gasoline cars and trucks I usually buy, EVs are:

small	----------|----------	large
slow	----------|----------	fast
unsafe	----------|----------	safe
non-polluting	----------|----------	polluting
inconvenient	----------|----------	convenient
cheap to run	----------|----------	expensive to run
cheap to buy	----------|----------	expensive to buy
impractical	----------|----------	practical
unstylish	----------|----------	stylish
old fashioned	----------|----------	futurisitic

21. According to what you know about EVs, do you agree or disagree that EVs are the key to solving air pollution in the Davis-Sacramento area? (Circle one.)

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

22. Electric vehicles are not yet practical to replace gasoline fueled vehicles. (Circle one.)

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

23. Please indicate the degree to which you agree or disagree with the following statements.

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

_____ Air quality is an important problem in my community.

_____ Reducing petroleum consumption will benefit the environment.

_____ Compared to other sources, motor vehicles are a minor source of air pollution.

_____ I buy environmentally "friendly" products whenever I can.

_____ I do not support a gas tax to improve air quality.

_____ Actions taken by individuals can affect air quality.

_____ My household could use a vehicle with a 50 mile per day driving range.

24. What are the sources of information upon which you base your images of EVs? Please list the three most influential sources of information in forming your image of EVs.

_____

_____

_____

Electric Utility (SMUD or PG&E)

Television or Radio news

Newspapers

Television shows or specials

Automotive magazines

Technology and science magazines

Environmental organizations

Seeing EVs on the road

Word of mouth

Automobile manufacturers

Science Fiction

Electric Vehicle Clubs

Other (specify)

25. If EVs were widely available at auto dealers and you were in the market for a new car, which of t[illegible]ollowing most closely describes what you would you do? (Mark one.)

1 ( ) I w[illegible]d not consider an EV until they had been on the market for several years.

2 ( ) I would consider an EV, but would investigate carefully the costs and usefulness of each vehicle type before making a commitment.

3 ( ) I would buy an EV immediately in spite the uncertainty.

Green Market and Innovator Part B:

Test Drive Phase (Repeat for Each Vehicle)

Indicate which Vehicle:	1 ( )	City-El	4 ( )	Horlacher City	7 ( )	Kewet
	2 ( )	Geo Storm	5 ( )	Horlacher Sport		
	3 ( )	Geo Prism	6 ( )	Esoro		

On-sight Impressions:

How close is this body style to your tastes and needs in vehicles?

1 ( ) Very different 2 ( ) Different 3 ( ) Similar 4 ( ) Very Similar

Show Features and briefly describe attributes: Recharging point. Battery and motor. Safety features and differences

What are your first impressions of the vehicle and motor?

Probes: Instrument location, Motor, Batteries, Entry/Egress, Seating Position, Controls

How does starting and driving feel?

Probes: Starting,Sound

Acceleration, Speed

Steering, Stability

Braking

Safety, including visibility -- both how easy is it to see and be seen

This car performs

1 ( ) Worse than I expected

2 ( ) About as well as I expected

3 ( ) Better than I expected

Is there anything else about this vehicle which you believe deserves comment?

Green Market Part C: Post-Test Drive

Now that you have had an opportunity to drive a few examples of small EVs, please answer the following questions.

1. Electric vehicles are not yet practical to replace gasoline fueled vehicles. (Circle one.)

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

2. Can you imagine replacing one of your gasoline vehicles with one of these EVs?

_____yes _____no

If yes, which one of these EVs would you most be interested in acquiring?

1 ( ) City-El 2 ( ) Nordskog 3 ( ) Kewet El-Jet

4 ( ) Horlacher City 5 ( ) Horlacher Sport 6 ( ) Esoro

If no, would you consider adding one of these EVs to your current set of vehicles?

_____no _____yes (Which one? _____)

3. How often do you drive more than 10 miles from home?

1( ) Daily 2( ) Weekly 3( ) Monthly 4( ) Less than monthly 5( ) Almost never

More than 30 miles?

1( ) Daily 2( ) Weekly 3( ) Monthly 4( ) Less than monthly 5( ) Almost never

4. Are any of the cars in your household consistently driven less than **20** miles per day?

_____yes _____no

If yes, please describe the use of that vehicle.

_____Primarily used for commuting to work

_____Primarily used for commuting to school

_____Primarily used for local errands

_____Used for many purposes, just not driven very far

_____Used only infrequently

_____Other _____

Is this the vehicle you are most likely to replace with an EV?_____yes _____no

5. Other than the vehicle you just described, are any of the cars in your household consistently driven less than **50** miles per day?

_____yes _____no

If yes, please describe the use of that vehicle.

_____Primarily used for commuting to work

_____Primarily used for commuting to school

_____Primarily used for local errands

_____Used for many purposes, just not driven very far

_____Used only infrequently

_____Other _____

Is this the vehicle you are most likely to replace with an EV?_____yes _____no

6. You have driven a variety of EVs with driving ranges of 20 to 70 miles between charges and top speeds ranging from 35 to 70 miles per hour. Which of these characteristics, driving range or top speed, seems like the more important barrier to your using an EV?

_____Driving Range _____Top Speed _____Body Styles

7. Electric vehicles can be recharged at your home over a few hours. What do you think of this idea?

1 ( ) I don't like the idea

2 ( ) I like the idea

3 ( ) I would have no place at my residence to recharge

If you answered "1", please answer this: I don't like the idea because (choose one)

a ( ) it sounds dangerous

b ( ) my driving habits are so varied I would not always be home to recharge

c ( ) having to plug and unplug the recharger all the time would be inconvenient

d ( ) other (please specify)_____

If you answered "2", please answer this: I like the idea because (choose one):

a ( ) I won't have to go to gasoline stations

b ( ) I like the idea of a monthly utility bill rather than paying a gasoline station

c ( ) it seems like it might be cheaper

d ( ) I like the idea of a "full tank" each morning

e ( ) other (please specify)_____

8. Some of the vehicles you drove or rode in today are intended to meet all US Department of Transportation passenger vehicle safety standards and some are not. Considering also how you might use one of these vehicles, which of the following statements most nearly matches your feeling regarding the safety of these vehicles.

_____I would not consider buying any vehicle which is not fully safety certified as a passenger vehicle.

_____I would consider buying a vehicle which meets some, but not all, safety standards as long as I was informed about which standards were met and which were not.

_____I would consider buying a vehicle even if it were registered as a motorcycle and thus was not required to meet passenger vehicle safety standards and this meant I had to wear a helmet.

9. If you were buying a new car and believed EVs could improve air quality, but EVs were only offered in the small body styles you have seen today, which of the following statements do you believe most nearly describes how you would act? (Choose only one.)

_____I would consider buying a small EV.

_____I would not consider buying a small EV because the driving range between charges is too short.

_____I would not consider buying a small EV because the top speed is too slow.

_____I would not consider buying a small EV because I don't believe they would be safe.

_____I would not consider buying a small EV because (specify) _____
_____

10. If you were to choose one way you could improve air quality in this region, which would you choose:

_____carpool to work

_____bicycle or walk instead of driving

_____buy an EV

_____use transit instead of my car

_____other _____

11. Are you proficient or handy in a way which you believe makes you more adaptable to owning and using EVs? _____yes _____no

12. Are you (check one): _____Employed outside my home _____Student

_____Work in my home _____Retired

_____Temporarily not working

If you are currently employed outside your home, what is the approximate location of your workplace?

_____UCD

_____Elsewhere in Davis

_____Woodland

_____West Sacramento

_____Sacramento

_____Other

13. How many people in your household have valid drivers' licences? _____

14. How many motor vehicles are available to your household members on a daily basis? Please include vehicles your household owns or leases and vehicles which are "company cars" but are available for personal use.

_____

15. Please describe these vehicles. If you have more than four, please provide this information on the four vehicles which are most used in a typical week.

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
Make				
Model				
Model year				
Acquired New or Used				
Total Miles on this Vehicle				

16. Do you and other drivers in your household regularly swap vehicles? _____yes
_____no

17. How long have you lived at your current residence? _____years _____months

18. How long have you lived in the Yolo/Solano/Sacramento area? _____years
_____months

19. Do you plan on remaining in this area? _____yes _____no

20. When do you plan to purchase or lease your next new or used motor vehicle (choose one):

_____in the next 6 months

_____in the next 1 year

_____in the next 2 years

_____in the next 5 years

_____after 5 years or possibly never

This vehicle most likely will be acquired: _____new _____used

This vehicle most likely will be a: _____subcompact sedan with a trunk

_____subcompact hatchback

_____compact sedan with a trunk

_____compact hatchback

_____compact stationwagon

_____mid-size sedan

_____mid-size stationwagon

_____full size sedan

_____full size stationwagon

_____mini-van or full size van

_____pickup truck

_____sport utility vehicle

_____sports car

21. Including yourself, how many people in your household are in these age categories:

_____under 6 years _____6 to 15 years

_____16 to 24 years _____25 to 64 years

_____65 years or older

12. Do you belong to the Sierra Club, Friends of the Earth, Clean Air Coalition or any other environmental organization?

_____yes _____no

13. In the past 12 months have you actively worked, either as a volunteer or a paid employee, for an environmental organization

_____yes _____no

14. Is your residence a:

_____single family residence

_____multi-family residence (apartment, townhouse, multi-plex)

_____dormitory

_____other _____

15. What was your households, total pre-tax income for this past tax year?

_____less than 25,000

_____25,000 to 40,000

_____40,000 to 60,000

_____60,000 to 80,000

_____80,000 to 100,000

_____more than 100,000

Thank you for your time, we hope you have enjoyed the ride/drive clinic. Please remember to attend your group discussion on Wednesday night. Please use the space below to add any comments.

Innovators Part C: Post-Test Drive

Now that you have had an opportunity to drive a few examples of small EVs, please answer the following questions.

1. Electric vehicles are not yet practical to replace gasoline fueled vehicles. (Circle one.)

1 = strongly agree 2 = agree 3 = indifferent 4 = disagree 5 = strongly disagree

2A. If you own an EV, do any of the vehicles you rode in or drove during this clinic seem to be improvements over your own EV? _____yes _____no

If yes, which ones: _____

_____

_____

2B. If you do not now own an EV, can you imagine replacing one of your gasoline vehicles with one of these EVs?

_____yes _____no

If yes, which one of these EVs would you most be interested in acquiring?

1 ( ) City-El 4 ( ) Horlacher City

2 ( ) Nordskog 5 ( ) Horlacher Sport

3 ( ) Kewet El-Jet 6 ( ) Esoro

If no, would you consider adding one of these EVs to your current set of vehicles?

_____yes Which one? _____

_____no

3. What characteristics of these vehicles are better than your EV?

_____

_____

4. What characteristics of these vehicles are worse than your EV?

_____

_____

5. Independent of price, would you consider buying any of the vehicles in the drive clinic?

_____yes Which ones: _____

_____no _____

6. How often do you drive more than 10 miles from home?

1( ) Daily 2( ) Weekly 3( ) Monthly 4( ) Less than monthly 5( ) Almost never

More than 30 miles?

1( ) Daily 2( ) Weekly 3( ) Monthly 4( ) Less than monthly 5( ) Almost never

7. Are any of the cars in your household, including your EVs, consistently driven less than **20** miles per day?

_____yes _____no

If yes, please describe the use of that vehicle.

_____Primarily used for commuting to work

_____Primarily used for commuting to school

_____Primarily used for local errands

_____Used for many purposes, just not driven very far

_____Used only infrequently

_____Other _____

8. Other than the vehicle you just described, are any of the cars in your household consistently driven less than **50** miles per day?

_____yes _____no

If yes, please describe the use of that vehicle.

_____Primarily used for commuting to work

_____Primarily used for commuting to school

_____Primarily used for local errands

_____Used for many purposes, just not driven very far

_____Used only infrequently

_____Other _____

9. Some of the vehicles you drove or rode in today are intended to meet all US Department of Transportation passenger vehicle safety standards and some are not. Considering also how you might use one of these vehicles, which of the following statements most nearly matches your feeling regarding the safety of these vehicles.

_____I would not consider buying any vehicle which is not fully safety certified as a passenger vehicle.

_____I would consider buying a vehicle which meets some, but not all, safety standards as long as I was informed about which standards were met and which were not.

_____I would consider buying a vehicle even if it were registered as a motorcycle and thus was not required to meet passenger vehicle safety standards and this meant I had to wear a helmet.

10. If you were buying a new car and believed EVs could improve air quality, but new EVs were only offered in the small body styles you have seen today, which of the following statements do you believe most nearly describes how you would act? (Choose only one)

_____I would consider buying a small EV.

_____I would not consider buying a small EV because the driving range between charges is too short.

_____I would not consider buying a small EV because the top speed is too slow.

_____I would not consider buying a small EV because I don't believe they would be safe.

11. If you were to choose one way you could improve air quality in this region, which would you choose:

_____carpool to work

_____bicycle or walk instead of driving

_____buy an EV

_____use transit instead of my car

_____other _____

Demographic, Household Vehicle Information

1. Are you proficient or handy in a way which you believe makes you more adaptable to owning and using EVs? _____yes _____no

2. Are you (check one): _____Employed outside my home _____Retired

_____Working in my home _____Student

_____Temporarily not working

If you are currently employed outside your home, what is the approximate location of your workplace?

_____Davis _____any of the communities east of Sacramento, for

_____Downtown Sacramento example, Citrus Heights, Orangevale, Roseville

_____North Sacramento _____West Sacramento

_____South Sacramento _____Other (_____)

3. How many people in your household have valid drivers' licences? _____

4. How many motor vehicles are available to your household members on a daily basis? Please include vehicles your household owns or leases and vehicles which are "company cars" but are available for personal use.

_____

5. Please describe these vehicles. If you have more than four, please provide this information for the four vehicles which are most used in a typical week. If you live in a household of non-related adults who do not share cars, describe your vehicles(s).

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
Make				
Model				
Model year				
Acquired New or Used				
Total Miles on this Vehicle				

6. Do you and other drivers in your household regularly swap vehicles?

_____yes _____no

7. Do you own or rent your residence? _____own _____rent

8. How long have you lived at your current residence? _____years _____months

9. How long have you lived in the Yolo/Sacramento area? _____years _____months

10. Do you plan on remaining in this area? _____yes _____no

11. Including yourself, how many people in your household are in these age categories:

_____under 6 years _____6 to 15 years

_____16 to 24 years _____25 to 64 years

_____65 years or older

12. Do you have a reserved or dedicated place to park at least one of your motor vehicles?

yes _____ no _____

13. Is your residence a: _____single family residence

_____multi-family residence (apartment, townhouse, multi-plex)

_____dormitory

_____other (_____)

14. When do you plan to purchase or lease your next new or used motor vehicle (choose one):

_____in the next 6 months

_____in the next 1 year

_____in the next 2 years

_____in the next 5 years

_____after 5 years or possibly never

This vehicle most likely will be acquired: _____new _____used

This vehicle most likely will be a:

_____subcompact sedan with a trunk

_____subcompact hatchback

_____compact sedan with a trunk

_____compact hatchback

_____compact stationwagon

_____mid-size sedan

_____mid-size stationwagon

_____full size sedan

_____full size stationwagon

_____mini-van or full size van

_____pickup truck

_____sport utility vehicle

_____sports car

15. Do you belong to the Sierra Club, Friends of the Earth, Clean Air Coalition or any other environmental organization?

_____yes _____no

16. In the past 12 months have you actively worked, either as a volunteer or a paid employee, for an environmental organization

_____yes _____no

17. What was your households, pre-tax income for this past tax year?

_____less than 25,000

_____25,000 to 40,000

_____40,000 to 60,000

_____60,000 to 80,000

_____80,000 to 100,000

_____more than 100,000

Thank you for your time, we hope you have enjoyed the clinic. Please remember to attend your group discussion on Tuesday night. Please use the back of this page to add any comments you would like.

FOCUS GROUP OUTLINE

I. Introduction

A. ITS Davis

B. Discuss in greater detail the vehicles you saw on Saturday

C. Comments serve to:

1. inform manufacturers, vendors
2. inform SMUD
3. inform ITS EV marketing studies
4. inform you of the variety of opinions

D. Anonymous -- tape recorded and notes taken

E. Rules

- One at a time
- Every one needs to be heard from
- Specific outline of questions to be considered, comments at the end

F. Roundtable Introduction

- Name
- How long a member of the Electric Automobile Club
- Do you own an EV?

II. Vehicle Use

A. Recalling the attributes of each vehicle, for what purposes can you imagine using them? Be very personal -- can <u>you</u> drive to work in a City-El? Why or why not? Can another member of your household make these trips in these vehicles?

1. City - El
2. Kewet
3. Geo Metro
4. Horlachers, Esoro

B. Prompts

1. Travel to work or school
2. Travel to grocery store
3. Travel to doctor or dentist
4. Out to dinner
5. Emergency trips

II. Vehicle Use (continued)

C. What is the important characteristic of the vehicle which prevents you from using one of these vehicles for a specific purpose?

1. Range
2. Top Speed
3. Accleration
4. Body Style
5. Safety
6. Other

D. Why does vehicle attribue apply?

1. Distances too far
2. Have to travel on freeway or other high speed route
3. Have to haul cargo or passengers
4. Vehicle not safe
5. Have to wear helmet
6. Other

E. How many of your activities can you travel to in this vehicle?

III. Vehicle Comparisons -- Based on your years of experience and learning, the test drives and the discussion we just had about using these vehicles:

A. Compare the cars you saw Saturday to the EVs you now drive (for those that do now drive EVs)

1. What trips can you make in the test drive vehicles that you can't make in your own?
2. What trips can you make in your vehicle that you would not make in one of the test vehicles?

B. Compare the test vehicles to each other.

1. Independent of price, which vehicle would you most like to own? next? Least like to own?
   a. why?
   b. follow-up on vehicles between most and least favorite?

IV. What is the value of special features of EVs? (Tell air bag story.)

A. Elicit list of special EV features, prompts (if necessary)

Home recharging. Emissions. Cost to run. Quiet. Other

B. How do you value these features?

Is home recharging really a convenience?

V. Do you compare EVs to gasoline cars? Is your choice to own an EV driven by a comparison to gasoline cars and trucks?

A. Is your ranking of the test vehicles based on comparisons to gasoline cars, or just to the EVs?

B. What other standard might you use?

1. Transit or other modes of travel?

2. Changes in lifestyle?

VI. Purchase and Price

A. Do any of you see yourselves buying one of the test vehicles or a vehicle similar to any of them?

1. Is your interest to own the best possible EV you can buy, or is the process of building and converting your own vehicles the central interest you have in EVs?

B. We have talked about vehicle use, you have your own experiences with EVs, you have told me which vehicles you prefer independent of price. Now let us imagine that the following prices apply to each of the vehicles (not counting tax incentives)*:

City-El	$5,000
Kewet	$10,000
Geo	$15,000
Horlacher City	$17,500
Esoro	$20,000
Horlacher Sport	$22,500

Would you buy any of these vehicles? Which? Why?

(Play with prices if necessary to cause initial purchase.

Adjust prices to cause switch to next lower and higher vehicle.)

*This is only an example of the sets of prices offered. Prices were changed from group to group to observe the effects of changes in prices on choices. The rank order of the prices of the vehicles was preserved from group to group.

APPENDIX E: HOUSEHOLD VEHICLE TRIALS INTERVIEW FORM

NEV Household Interview Log

version: 2.03

Household #: _____

Town/City: _____

Diary Week: _____

Interview Date: _____

If found, please return to:

Ken Kurani

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

INTRODUCTION

Neighborhood Electric Vehicle Demonstration and Marketing Study

ITS-Davis, Calstart, PG&E, SMUD

Background Information

Household Information (pre-record available info.) All regular household members and guests staying with household during the diary week.

First Name	Relation	Age	Occup.	Drivers License
	Female Household Head Male Household Head Child 1 Child 2 Child 3 Other			

Housing Type: _____

Typical Week

Are there any trips you often make which you just happened to have not made during the week you kept your diaries? (prompt for: non-car trips; personal business, errands -- banks, hair cuts; work errands; chauffeur trips. Locate these activities on the map.)

Destination	Mode	Distance	How often?

Unusual Trips in the diary

Other than trips you made just to play wi: the EV, are there any trips in the diary which are extremely unusal? (prompt of non-car trips)

Destination/Day	Mode	Distance	How often?

The next few questions deal with trips you make by some mode other than one of your households cars.

Regular travel in vehicles not belonging to the household

Car pooling, van pooling, regular sharing of rides for non-work purposes.

Destination	Mode	Distance	How often?

Transit Use

Does household use transit? Yes / No

How many minutes walk to nearest transit stop? _____

Which transit service is available at that stop? _____

Do you believe there are places it is easy to reach by transit from your home? Yes / No

If yes, name a few _____

_____

Walking and Cycling

Other than for recreation, does anyone in your household walk or bicycle regulary?

Destination	Mode	Distance	How often?

Weekend Travel

What kinds of trips do you often make on weekends? (out-of-town trips, hauling loads or people, etc.)

Destination	Mode	Distance	How often?

Seasonal/Vacation/Holiday Travel

Special trips for vacation or holidays? Major seasonal trips - eg. ski trips?

Destination	Mode	Distance	How often?

Car Rental

Do you ever rent cars for local travel? (prompts: family, friends visiting; car in the shop, other)

Where is your:

Usual Grocery Store	
Doctor	
Dentist	
Emergency Medical Services	
Local family or friends you regularly visit	
Bank	
Favorite coffee shop, cafe, restaurant	
Recreation spot (park, sports venue, gym)	
Other ( )	

Refueling Behavior

When do each of you refuel? (prompts: gauge level; odometer miles, schedule)

Also, context: when leaving town, on way home from work, etc.

How far do they think they can still drive when they typicaly refuel?

Where do you buy gasoline? (prompts: regular station, typical locations)

Car Purchase Story

Describe vehicles household owns:

Make	Model	Year	Bought new or used

Which car was most recently purchased? Why did you buy this specific car? (How does this vehicle reflect lifestyle choices?)

Tell us about Driving the NEV

(Briefly, we will cover details in later questions.)

NEV TOPICS

Range

Limit vehicle use?

Did the range of the vehicle ever limit your use of it? Did you ever run out of charge?

Recharging

How did you feel about the state-of-charge gauge? Was it useful? stressful?

Did you use it to decide when to recharge, or did you recharge on a schedule?

Recharging locations

Home: Tell us about recharging at home

Where?

When?

Time of Day/Depth of Discharge

Convenience/Inconvenience of recharging

Away-from-Home: Did you ever recharge away from home?

Where?

When?

Time of Day/Depth of Discharge

Convenience/Inconvenience

Safety

Were there any occassions when you felt uneasy about your safety when driving this vehicle? Describe those occassions Why? Where? When? Was discomfort caused by vehicle size, speed, both, other?

Speed

Minimum acceptable speed? Desired top speed? Describe those specific situations (location, speed, trip, traffic) in which speed was felt to be inadequate. Are they different from those situations in which they felt unsafe? Where specifically were they? Single lane or two lanes of traffic? Was traffic light or heavy? Even if they never felt speed was too slow, would they still want higher top speed?

Traffic

Did you feel safe in the vehicle when in traffic?

Routes

Did you change your usual routes to destinations based on speed, safety perceptions?

Vehicle Size

Visibility

Being Seen, Heard

Did you feel the vehicle could be seen by other drivers, cyclists, pededstrians?

Did you ever feel you had "snuck up on" a pedestrian or cyclist who hadn't heard you coming?

Parking

Describe parking the vehicle. Easy/hard. Convenient/Inconvenient. Being seen backing out?

Occupancy/Cargo capacity

Did you ever make a trip in a larger vehicle simply because the NEV did not have enough seats? cargo space? How much more space would you have needed in the NEV?

ACTIVITY SPACE

Is it usual for your trips out of town (prompt: off the map)to be planned well in advance? When was the last time you made a last minute (prompt: did not know it the night before) out-of-town trip?

ACTIVITY SPACE DESCRIPTION

What are the modes you use to access various activities? (make list)

What are the things you do within the range of walking, cycling and the NEV? (prompts: socialize, recreation, go to school, shop, work)

Where are these activities located on the map? (Record locations on map too.)

Draw boundaries around "Mode Spaces" -- walk space, bike space, small EV space, car space

How flexible are these boundaries? What changes them -- weather, who is taking trip, etc.?

GAMING

Space Games

The household now owns a small EV. It replaces an existing car in the household fleet.

Which vehicle is replaced? _____

Reconstruct travel days using the new household fleet.

Household can change characteristics of their activity space, but not of the vehicle in order to accomplish its travel. Prompt with positive and negative attributes of proximity -- shorter travel time vs increased noise and traffic, ability to walk vs attraction of others in autos, etc.

(Find one diary day which creates problems in vehicle use. Be able to trace all travel for that day. Make table which summarizes travel for household.)

Who takes which vehicles where and when?

Day/Trip	Driver	Actual Mode	Destination	New Mode	Notes

How are these decisions made?

Would the household prefer to contract or expand their activity space given theNEV? For what mode does the NEV substitute?

Car Games:

If unable to replace one of the household vehicles, would you add this NEV to your household stock? Yes / No

(Describe the replacement/addition choice. How was it made? Who made it? Who is most affected by choice? Is there a primary driver of the NEV? To what activities is it assigned? What affected the choice -- vehicle characteristics, travel characteristics, location of activities?

DEBRIEFING

Anything we have not discussed which would make it easier for you to use such a vehicle?

Would a small electric vehicle like the one you drove handle all of your in-town travel needs (include walk and bike trips)? Yes / No

Would it increase your households local travel?

Considering your experience with the vehicle and all we have discussed, this evening, what would you need in order to decide to buy such a vehicle? (What other information? What new or enhanced or improved attribute? What other vehicle is the point of reference for the NEV -- a car, or a bicycle?)

Anectodes/Observations

What do cars mean to this household? Image vs. function. Lifetyle choice.

How stable are the lifestyle choices of this household likely to be over the next few years? Presence or absence of children? Housing choices? Job choices?

APPENDIX F: VEHICLE DESCRIPTIONS in the STATEWIDE SURVEY

The appendix contains the vehicle descriptions supplied to the statewide mail survey respondents in Part 4 of the questionnaire.

Neighborhood electric vehicle

Neighborhood electric vehicle is designed for around the town driving. Easy parking, handling and use.

Comes as two passenger version or small rear seat for two additional passengers. Cargo room for four bags of groceries.

Vehicle overall length is 11 feet, width is 5 feet. Can park in small places Turning radius 15 ft.

Top speed is 40 mph.

Accelerates 0-40 in 15 seconds.

The range before recharging is 40 miles.

The overall weight of the vehicle is 1200 lbs.

Composite structure is fully crash tested and passes all federal crash safety.

Optional airbags.

The neighborhood electric is not intended for freeway and highway driving.

Costs less than a penny per mile for electricity.

Plugs into any 110 volt plug.

Recharges in one to two hours depending on the charge level of the battery.

Replacement cost of battery back is just $500

Optional solar panels. Offers 7 miles extra of range on sunny day.

Batteries are guaranteed for 20,000 miles.

Drive train and motor is warranteed for ten years or 60,000 miles.

Service is minimal.

Meets California Zero Emissions vehicle standards for small vehicles. Qualifies for some tax credits.

Community electric vehicle

Do all of your refueling at home; no gasoline on your hands or fumes. Costs less than 2 cents per mile to drive, when charged at night, 6 cents per mile for daytime charging.

Simply plug into any 110 volt wall socket for a slow charge (slow charge takes 8 - 10 hours if batteries fully discharged), or

Install a special 220 volt *quick charge* circuit and outlet in your garage, carport or driveway of your home, condominium or apartment* (quick charge takes 2-4 hours if batteries fully discharged)

*(Utility rebates available for installing new circuit)

Community electric does not have fast charging capabilities

Features two battery ranges

60 miles per charge, lead acid gel cells Warranteed to 25, 000 miles (*replacement cost $800*).

80 miles per charge, lead acid gel cells. Warranteed to 25, 000 miles (*replacement cost $1200*).

New range instrumentation : Tells precisely how many miles are left on the vehicle. (smart instruments estimate range based on how your drive).

Drive train: 60 horsepower, three phase, alternating current motor.

Top speed 75 mph (speed is governed to reduce drain to batteries)

Accelerates 0-60 in 13 seconds (some sports models faster).

HEATING AND AIR CONDITIONING

Standard Interior of vehicle pre-air conditioned or heated while recharging.

Options A. Heated and cooled seats.

B. Advanced heat-pump style air conditioning. Minimal energy use.

Optional Solar panels for roof and hood. Provides 10 extra miles on sunny days or can extend range by offsetting air-conditioning load.

Maintenance: 10 minute battery and check up service each 10,000 miles.

Warranty: 2 years or 24, 000 miles warranty on electronics, 8 year or 100,000 mile warranty on motor and drive train, 25,000 mile warranty on batteries.

Regional electric vehicle

Do all of your refueling at home; no gasoline on your hands or fumes. Costs less than 2 cents per mile to drive, when charged at night, 6 cents per mile for daytime charging.

Simply plug into any 110 volt wall socket for a slow charge (slow charge takes 8 - 10 hours if batteries fully discharged), or

Install a special 220 volt *quick charge* circuit and outlet in your garage, carport or driveway of your home, condominium or apartment* (quick charge takes 2-4 hours if batteries fully discharged)

*(Utility rebates available for installing new circuit)

Fast charging capabilities are standard equipment, recharge up to 80% of your battery in around 20 minutes at special fast charge stations.

Features two battery ranges

100 miles per charge, woven lead acid "sandwich" cells. Warranteed to 25, 000 miles (*replacement cost $2000*)

130 miles per charge, nickel metal hydride. Warranteed to 50,000 miles (*replacement cost $5000).*

New range instrumentation : Tells precisely how many miles are left on the vehicle. (smart instruments estimate range based on how your drive).

Drive train: 140 horsepower, three phase, alternating current motor.

Top speed 85 mph (speed is governed to reduce drain to batteries)

Accelerates 0-60 in 8-9 seconds (some sports models faster).

HEATING AND AIR CONDITIONING

Standard Interior of vehicle pre-air conditioned or heated while recharging.

Options A. Heated and cooled seats (Japanese style heating and air)

B. Advanced heat-pump style air conditioning. Minimal energy use.

Optional Solar panels for roof and hood. Provides 10 extra miles on sunny days or can extend range by offsetting air-conditioning load.

Maintenance: 10 minute battery and check up service each 10,000 miles

Warranty: 2 years or 24, 000 miles warranty on electronics, 8 year or 100,000 mile warranty on motor and drive train, 25,000 mile warranty on lead acid, 50,000 miles on nickel metal hydride batteries.

Hybrid electric vehicle

Hybrid vehicle extends range of battery powered electric, has on small sized on-board reformulated gasoline engine to provide extra miles and gasoline refueling for long trips. Gasoline ragne extender automatically fires when batteris reach minimum level. One hundred and forty miles of range, depending on body types.

Two setups.

Type one: Minimal battery setup. 40 miles of advanced lead acid battery range, automated switch to 40 horsepower range extender for 100 additional miles on gasoline. Type two battery pack replacement = $1000. Recharge time on 220 volt is 1-3 hours depending on level of battery charge.

Type two: Maximum battery setup. 80 miles of advanced lead acid batteries range, automated switch to 40 hsp gasoline fired range extender 60 additional miles on gasoline. Battery repalcement for type one =$1700. Recharge time on 220 volt recharge circuit is 2-4 hours depending on level of battery charge.

Fast Charging available on Type 2 maximum vehicle only.

Standard pre-heating and cooling while charging.

Optional heat pump air-conditioning.

Meets California Ultra-Low Emissions Vehicle requirements.(Does not qualify for Zero Emissions vehicle standards because of emissions when range extender operating as well as vapor emissions from gasoline refueling).

Economy models come with AM FM radio, and manual transmission (*air conditioning is optional*)

Standard models come with AM/FM and Cassette, manual or auto transmission (electrics do not have transmissions) anti-lock brakes, drivers air-bag, power windows and cruise control (*air conditioning is optional*)

Luxury models come also with CD Stereo sytem, automatic climate control, dual airbags, all power accessories, leather seats and sunroof, keyless entry

Maintenance: Oil change each 7,500 miles, Lube, safety check, belts, exhaust , minor tune-up and safety check, every 25,000 miles, major service at 75,000 miles, replace belts, coolants, catalytic converter on range extender.

Warranty : Four year or 50,000 mile on emissions system. Three year or 36,000 mile power train warranty, two year or 24, 000 on rest of vehicle. 25,000 mile warranty on the batteries.

Compressed natural gas vehicle

Natural gas: The same clean and safe fuel used for heating and cooking at your home. Natural gas has been used for decades in New Zealand, Canada and other nations in place of gasoline to power vehicles. Available in all sizes of vehicles through full sized vehicles. Clean fuel and low engine wear. Impact resistant compression tanks, made of spun aluminum and wrapped with fiberglass.

Refueled: at quick-fill stations in about ten minutes.

Optional Home Refueling Appliance: can be slow filled overnight, 6-8 hours when empty.

Driving Range: Single cylinder (80 miles range)
Double cylinder (120 miles range)

Fuel price: the equivalent of paying 70 cents per gallon for gasoline

Dedicated: natural gas only vehicle -- not a dual-fueled conversion-- optimized for high octane natural gas, same high performance as gasoline.

Powered: by 4, 6 or 8 cylinder fuel injected combustion engines

Meets California Ultra-Low Emissions Vehicles standards ($1000 tax credits).

Annual smog check required

Maintenance: Fuel cylinder safety test required every five years. Oil change each 7,500 miles, lube, safety check, belts, exhaust , minor tune-up and safety check, every 25,000 miles, major service at 75,000 miles, replace belts, catalytic converter.

Warranty: Lifetime warranty on cylinders Four year or 50,000 mile on emissions system. Three year or 36,000 mile power train warranty, two year or 24,000 mile warranty on rest of vehicle (same as reformulated gasoline)

Economy: models come with AM/FM radio, and manual transmission (air conditioning is optional).

Standard: models come with AM/FM and cassette, manual or auto transmission, anti-lock brakes, drivers air-bag, power windows and cruise control (air conditioning is optional).

Luxury: models come also with CD Stereo system, automatic climate control, dual airbags, all power accessories, leather seats and sunroof, keyless entry.

Reformulated Gasoline Vehicle

Fuel and mileage This vehicle runs on reformulated gasoline, which is a less polluting type of gasoline, is not different in any other ways from previous gasoline vehicles, gets between 18 and 38 miles to the gallon depending on the model. Available in all sizes and models.

Powered: by 4,6, and 8 cylinder fuel injected combustion engines.

Options: Four wheel drive, air conditioning (standard on luxury models) and automatic transmission.

Meets Low Emissions Vehicle requirements for State of California (no tax credit)

Annual smog check required

Maintenance: Oil change each 7,500 miles, Lube, safety check, belts, exhaust , minor tune up and safety check every 25,000 miles, major service at 75,000

Warranty: Four year or 50,000 miles on emissions system. Three year or 36,000 mile power train (engine and transmission) warranty, two year or 24,000 miles on rest of vehicle.

Economy: models come with AM/FM radio, and manual transmission (air conditioning is optional)

Standard: models come with AM/FM and cassette, manual or auto transmission, anti-lock brakes, drivers air-bag, power windows and cruise control (air conditioning is optional)

Luxury: models come also with CD Stereo system, automatic climate control, dual airbags, all power accessories, leather seats and sunroof, keyless entry