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A STUDY OF ADAPTIVE AND OPTIMIZING BEHAVIOR FOR ELECTRIC VEHICLES BASED ON INTERACTIVE SIMULATION GAMES AND REVEALED BEHAVIOR OF ELECTRIC VEHICLE OWNERS

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ABSTRACT

Electric vehicles (EVs) promise major improvements in air-quality. But the limited range and long recharge times of EVs have created great uncertainty about consumer demand. Technical constraint studies find good news, that 20-60 % of all households in the United States could substitute an EV with 162 KM range for one of their current vehicles. In startling contrast, choice studies - based on the responses of consumers to hypothetical choice sets - find that limited range and long recharge are extremely expensive drawbacks and forecast sales of a few percent or less of the yearly new auto market. These studies have relied on meager data and not investigated the potential revolutionary effect on the automobile market of the introduction of alternative fueled vehicles.

To explore potential dynamics, we have conducted three linked studies: 1) a test drive of EVs, natural gas, and methanol vehicles by 236 citizens in Los Angeles (with 11 post-drive focus group interviews); 2) purchase intention and range simulation games (PIREG) and 3) interviews with over 100 owners of EVs. In this paper, we focus upon the methods and results of PIREG, an interview gaming technique derived from the CUPIG (Car Use Patterns Interview-Game) developed by Martin Lee-Gosselin to study future automobile use. The interview uses one week diaries of households and detailed descriptions of a recent vehicle purchase decision to create a realistic simulation context for examining the potential substitution of several new electric vehicle technologies.

The results demonstrate several dynamics. First, increased information and learning experience will reduce uncertainty in the EV market, affecting stated preferences. In the test drive, 76% of participants said their opinion of EVs improved after a test drive. Participants were surprised at how normal the EVs looked and performed. Second, households will consider adaptive responses to limited range vehicles, given the social benefits of clean air. Most PIREG participants were surprised at how easily electrics fit their travel needs; most were highly receptive to EVs if the price were equal to that of a gas car. Using detail diaries of their own car use, participants proposed simple ways of adapting to limited range including swapping vehicles for longer days, opportunity charging at work and in some households increasing the vehicle stock. In most cases, households preferred occasional adaptations to more expensive, long range vehicles. Finally, PIREG interviews and electric vehicle owner interviews suggest that a multi-fueled household (gasoline and electric) will optimize the EV use with significant fuel cost differences. In some cases, the ability of households to shift vehicle use to the EV was so significant, that it may offset the higher initial cost of EVs.

Information development, experience, adaptive response and optimization are central processes underlying the development of the electric vehicle market. PIREG interviews offer the most detailed understanding of these processes and the purchase intentions that will result. While the market is uncertain for EVs, PIREG games and current practices of EV owners suggest that with the right price incentives, EVs could become the primary vehicles in households, used for a higher percentage of household trips and VMTs than a gasoline counter part in the household.

THE PROBLEM

Electric vehicles (EVs) hold great promise to reduce urban air pollution, greenhouse emissions and diversify the fuels used in transportation. However, the short refueling range and long recharge times of current EVs have discouraged any auto-makers from investments until there are major innovations in battery technology. But there are no guarantees that a miracle battery will come in the near future and investment money will only begin to flow into development with an initial market. A decision has been made in California to proceed with developing an initial market to encourage investment and competition.

Faced with no sales data on electrics, there is tremendous uncertainty about the size of the market for EVs. Consumers are experienced with long range vehicles which refuel easily. Current gasoline vehicles offer refueling ranges of 200 to 350 miles range and refuel in about 6 minutes. A few consumers have experience with diesel vehicles which offer even greater ranges. A few drivers in Canada, Italy and New Zealand have experience with compressed natural gas vehicles (CNG) having ranges of 50 to 200 miles. A few hundred CNG owners are experienced with slow refills of five to seven hours at their residence. Electric vehicles are a sharp contrast, offering ranges of 50 to 110 miles, and recharging at stations in 30 minutes or more and slow charges of 3-8 hours at home.

Only a few thousand electric vehicle enthusiasts throughout the world have experience with short ranges and long recharges, and allocating trips to either a gas or electric vehicle. Enthusiasts have claimed these ranges are sufficient for most driving, but their opinions and experiences have been largely overlooked as those of a few zealots.

Most manufacturers believe these limitations eliminate EVs from the market. In fact, they often note that EVs were a significant part of the market early in the century, but lost appeal once gasoline cars gained starter motors. This history is worth noting, but it must also be recognized that much has changed in the interim. Households often have two, three and four vehicles, specialized vehicles for recreation, commuting and cargo, more drivers per household, increasingly complex travel behavior as well as a growing concern for controlling pollution.

The long range and quick refill of gasoline vehicles is a convenient attribute which manufacturers can offer on all vehicles regardless of the intended use; therefore tank size is seldom an option. But the value of long range in tradeoffs with new attributes of EVs is still unknown, especially given that consumers have not had an opportunity to pick and choose for themselves from different ranges, refill speeds, and home recharging. Latent market segments may exist for EVs in which the mix of attributes are valued more than gasoline. The problem for those wishing to predict the market is that consumers themselves cannot usually tell us with any certainty what they need themselves, seeing they have even less experience than do we with electrics to assess needs and wants.

PREVIOUS STUDIES

Several studies in the United States, and one in Germany have looked at how the limited range and long recharge will shape the EV market (earlier studies included the impact of expected diminished performance of EVs but improved performance of current electric vehicles diminishes the importance of that constraint). In the more distant future, longer ranges and quicker recharge times will perhaps be available, but for the coming decade vehicles will have ranges of about 162 km and slow recharge times of several hours and fast recharges of at least 30 minutes.

As a result of the limited range and long recharges, all studies have assumed EVS fit only a two car household with travel habits for one vehicle less than the estimated range of current lead acid battery EVs. Kiselwich and Hamilton (1982) estimate that 57% of households in the United States could accommodate a vehicle with eighty miles of range, Deshpande (1984) estimates that 60% of households drive less than 96 miles 348 days per year. Greene (1985) estimates that 20-50 percent of vehicles are driven under 100 miles per day. These figures suggest a sizable potential market for limited range EVs in the United States.

In the United States, technical constraint studies find that range is so minimal a constraint, that recent studies (Nesbitt et al 1992) are focused more upon the constraints of recharging requirements, such as house ownership and having a logical place to recharge. Nesbitt et al estimate 28% of households in the United States could meet these constraints. Fewer households in Europe have two vehicles. A constraint study by Hautzinger et al (1992) finds a market for 5 million EVs (approximately 15% of households) in former West Germany. But car ownership trends indicate that per capita car ownership is heading in the direction of the United States (Shipper et al 1992).

The complaint about technical constraint studies is that the real constraint on EV sales will not be the physical constraints of household travel and infrastructure, but rather the preferences of car buyers; that consumers will not give up unlimited range or quick refueling. Stated preferences surveys have supported this idea quite forcefully, and estimate very low percentages of vehicles sold per year.

In the absence of sales data on EVs, market researchers have used: 1) focus group studies to explore potential preferences, 2) quantitative studies which estimate market shares of EVs from purchase data in the gasoline market and 3) stated preference studies in which survey participants make hypothetical choices from sets of car descriptions. Focus groups offer insights but no numbers and studies of the gas market use irrelevant data. The stated preference work is most influential.

Stated preferences studies report very high disutilities for limited range. Two influential studies were done in the late seventies. If adjusted for 1991 prices, for a range of 50 miles in contrast to 200 miles, Morton et al (1978) found a disutility of $ 10,000 ; Beggs et al (1981) found a disutility of $ 16,250. In a very recent study, Bunch et al (1992) found a high aggregated disutility of $ 15,000 for similar differences in range. In a slightly different study, in which individual utilities were calculated for each participant, Calfee et al (1986) found a wide range of disutilities but many in the range above, even for consumers who said they wanted an EV anyway. These disutilities project very low probabilities for purchase.

The assumptions of these methods must be questioned; for radical new products, stated preference studies probably measure consumer uncertainty more than preferences. In this case, they measure uncertainty about electrics, exaggerated against the long term experience consumers have with gasoline vehicles. Just on the issue of range preferences, the participant has no idea how to evaluate limited range because range is not a normal attribute for consideration. Many participants in our studies don't know the range of their current vehicle. Consumers are uncertain about the reliability of new technology and the stability of public policy and support for electric vehicles. Under these conditions, stated preference studies are subject to large potential data errors; they inappropriately calculate utility values from uncertain and volatile opinions.

Stated preference studies can measure public opinion, identify widespread beliefs about AFVs, and may help to identify potential hot-spots in sales for planning purposes, but consumer tastes, knowledge and understanding of EVs are as yet undeveloped. There is a greater need to pursue the constraint approach with an eye on the processes which will lead to diffusion of AFVs. The emphasis should be upon identifying potential market segments which can be targeted by government policy. Identifying these markets requires innovative research to simulate household decisions in a yet undeveloped context.

RESEARCH APPROACH

Diffusion studies have demonstrated that learning processes are a critical dynamic in the spread of new technologies. We propose that these learning processes can be further identified as information acquisition, adaptive response, and optimization. While diffusion studies have focused upon the bundled properties of a single innovation, economic studies have moved to analysis of particular attributes of products. We adopt this attributional perspective and combine it with diffusion studies to investigate how consumers will learn about and evaluate EV attributes for purchase, adapt to limitations and optimize benefits. EVs also have social benefits, which will make vehicle purchases an increasingly political and cultural decision, nevertheless constrained by the transportation needs and budget of a household.

Nesbitt et al (1992) assumed that a major constraint on the near term market for EVs would be the infrastructure needs of households. They assume that only homeowners with a safe recharging location would be likely to purchase EVs in the early market. Given this new constraint, they found about 28 million households in the US and (approximately 1.4 million households in Los Angeles) could practically substitute an EV for one of the vehicles in their household. These households are homeowners, with a reliable place to recharge, and have 2 or more cars, and don't drive both cars more than seventy miles per day.

We recruited 236 households in the Pasadena area of Los Angeles who met the criteria of Nesbitt et al and a earned a household income of at least 50,000 U.S.dollars, (this income level is average for households who purchase new cars). These participants test-drove electrics, methanol and compressed natural gas vehicles. Participants answered questions before, during and after inspecting and driving vehicles. We also held 11 focus group interviews one week afterwards for in-depth responses to test-drive experiences and public policy questions.

While the test drive allowed us to improve our understanding of consumer responses to the driving characteristics of EVs, we also devised a Purchase Intention and Range Evaluation Game (PIREG) to investigate in a more detailed way the responses of households to EVs of various ranges and recharging possibilities. PIREG was derived from CUPIG (Car Use Patterns Interview-Game), an interactive interview gaming technique developed by Martin Le-Gosselin to investigate future car use patterns.

Households were chosen which have a minimum of $ 50,000 annual income, own their own house, have two (36 % of US households in 1988) or three vehicles (21 % of U.S. households in 1988), two or three drivers, all vehicles of 1985+ vintage, and have purchased a new compact car or mini-van in the previous year. Each household kept one week diaries of all vehicle use, which we converted into a single time-line chart for easy visual reference during the interview. Households also describe in some detail how an why they purchased their new vehicle.

The households were then interviewed at their residence, with all drivers participating. A chart of their previous week of driving and a game board are used to simulate the substitution of EVs with various ranges, recharging schedules and opportunities into their previous week. Participants were presented sequentially with two different ranges (120 km; 240 km), slow (6-8 hr.) and fast (30 minutes) recharging abilities, home and away from home recharging locations and finally fuel-cell technology (120 km range, 7 minute exchange). The household is able to compare the impact of each type of technology in the context of previous experiences, and make decisions about which technology they preferred, given price differences for simple and advanced technologies. Further games were played in which the household members reallocated trips to optimize their use of their electric vehicle, prompted by increases in gasoline prices. We have completed seven of forty planned interviews and offer some preliminary results from that study.

A final project was designed to view how households will adapt to EVs over a longer period of ownership. Over one hundred owners of electric vehicles in California were interviewed about how they have been using electric vehicles. These interviews are in the final stages of completion and we have begun preliminary analysis, looking at frequencies for the first 76 interviews.

RESULTS

Participants in the drive test reported that their prior knowledge of electric vehicles came from news media (89%) and consumer magazines (37%). After the drive test, 76% said their opinion of EVs improved, indicating that the public media is underestimating EVs. Participants said in focus interviews that they had expected EVs to be egg shaped prototypes or golf cart like. The performance and normal vehicle form of the EVs was a pleasant surprise for a majority of participants.

Even though participants expected EVs to have less performance and be less practical than the vehicles used in the test drive, electric vehicles were favored prior to the drive in at least two ways. First, they were the most familiar alternative fueled vehicle to the participants; 95% had heard of electric vehicles (methanol 83%, NGV 54%). Additionally, when asked prior to the test to select what type of alternative fueled vehicle they would like, 54% selected EVs, with the remainder split among hybrid electric. hydrogen, methanol, CNG, and ethanol. The primary reason for this choice was air pollution and fuel security.

Learning about Range and Recharging EVs

While well known and popular as a solution to air pollution, consumers do not understand range and refueling issues. Their lack of understanding leads to conflicting intentions. In the study by Calfee et al (1985), many participants seemed to be irrational, on the one hand choosing EVs over other vehicles, but insisting on range needs beyond those of the EVs.

Consumers do not have a good idea of how the range limit will affect them - when questioned about range, they fall back on the range of their gasoline vehicle for reference. Beggs et al reported in their 1980 study that participants offer the range of their current gasoline vehicle as the range they needed. Participants in our focus groups responded in the same way. Some did not know the range of their current vehicle, but said that what ever it was, that is what they need.

We asked participants in our post test-drive focus groups to reconsider range needs after calculating their last week of driving. After reflection on their actual driving, participants changed the way they calculated the range they wanted. The changes were somewhat systematic and lead to a two part calculation, a twenty mile safety buffer to remain on the vehicle at all times, and a second usable range amount to the perceived maximum normal day of travel. In all cases, range needs dropped. Furthermore, the same participants were willing to trade away even more range for simple fuel cost cuts. Our PIREG interviews demonstrated the same dynamics. Households were able to calculate range needs in the light of one week diaries and two hour discussions of household travel needs. The range values of these consumers are extremely volatile. These dynamics cast immediate doubt on the conclusions of survey studies in which opinions are asked of participants who have no experience with EVs.

Participants were offered instrumentation on a hypothetical EV which gave them the remaining miles on a charge and not the remaining charge as a percentage or fraction of charge. We have no evidence that manufacturers will offer such instrumentation, but our research would suggest it would improve acceptance. After discussing in some detail the emergency and normal needs of these seven households, fourteen of the sixteen drivers estimated their absolute minimum spare range for an electric car to be twenty miles. This is the amount of charge they would always want on the car, even if returning home. The primary reason was for emergencies; everyone in the study lived within a few miles of a hospital, but wanted a safe range for problems.

The 20 mile safety buffer figure is somewhat surprising given current refueling practices; one would expect higher figures given that gas users refuel when the red light comes on or at 1/4 tank, a level at which drivers often have two or more gallons of gasoline left. The controlling factor is again uncertainty; consumers refuel because they are uncertain how much range thye have left at the red light. Those drivers who knwo with some precision run their tanks much lower.

Drivers in our PIREG interviews report running the fuel level of their present gasoline vehicles down to different levels. Of the sixteen persons interviewed so far in PIREG, two persons run their tank until the fuel light turns on, four to 1/8 of a tank, eight to 1/4 of a tank and 2 refill at 1/2 tank. When refueling, the majority fill the tank. Only two teenage participants report refueling a small amount of fuel, spending a percentage of cash in their pocket. Age has an obvious effect on participants willingness to risk running out of fuel; older participants were emphatic about avoiding running out of fuel. These practices suggest that most drivers are using about 3\4 of the range of their tank on normal refueling practices.

The second component of a households' range needs is composed of commuting needs plus a well known set of trips\ activities which occur on a regular basis such as once per month or week, within a familiar radius from work. Only a few households experience emergencies which require them to travel beyond this normal maximum range. There were business people who must be prepared to respond quickly to needs outside their normal driving areas. Family emergencies occur in near radii, if beyond, were accommodated by switching vehicles.

In contrast to the seeming universality of the 20 mile buffer figure, drivers in the PIREG study differed in their ability to estimate their range needs. At least half of the drivers overestimate daily range needs in their diaries; only a few calculated even daily commute distances with reasonable accuracy. Participants were more concerned with times than distances. The range of their vehicles is not a daily concern.

In contrast, planning to avoid running out of charge is a normal activity for the electric vehicle owners we interviewed. Because of this planning and as a result of the minimal needs for range beyond their electric, they seldom drain their batteries (all rely upon lead acid batteries, and have ranges from 30-100 miles). Initial frequencies from our sample show that only 14% of EV owners drain their batteries, while 71.4 % prefer to top off batteries. 43 % said they topped off to save the batteries, 26 % said they topped off to maximize potential range. Only 10 % said they allowed the vehicle to go to 1/4 of a charge.

Commuting and Electric Vehicles

Electric vehicles have long been considered special purpose vehicles. Researchers have suggested an EV can substitute as second cars - although no precise definition as second car existed except as a "lesser importance vehicle". This designation may have followed stereotypical beliefs about the car used by married women in families, as well as buying patterns in which a first car is the newest and most used while the second is older and less used. Changes in women's work patterns and increases in car use have outdated this stereotype.

Another segmented concept has been that of a dedicated commute vehicle. Commutes are fixed distances and researchers assume many cars used for commutes sit for the entire evening and thus are available for recharging. The average round trip commute distance in the US in 1985 was 24 miles suggesting a large number of potential EV users. A 1989 survey of commuters in Los Angeles finds that 77 % of the population commutes less than forty miles round trip. Fifty-seven percent commute on surface streets while 36 percent commute primarily on freeways (SCAG 1989). These figures suggest that the vehicles being used for commute are an excellent market.

Nearly all the vehicle-driver-use patterns we have examined involve some sort of commute. But our work reveals the importance of other regular and extended travel behavior built around the commute, workplaces, and homes. A closer look is needed to assess how commute lends itself to EV acceptability. In our test drive sample in Pasadena, we found that commute distance had little influence over attitudes or purchase intentions, in the context of a choice between a CNG, EV or Methanol vehicle. Very few persons in our sample had commutes which exceeded the range of EVs. We stratified our sample according to commute distances: 27.3 % did not commute, 30.6 % commute under 20 miles round trip; 15.9 % commute 20-40 miles round trip; and 16.4 % commuted over forty miles round trip. Equal percentages from these groups expressed purchase intentions for the limited range EVs over the unlimited range methanol vehicles.

Commute distance did not influence choices between AFVs with different driving ranges in the drive test. But in PIREG interviews, the vehicle households chose as a potential EV from their household fleet was a commute vehicle, and its uses as a commute vehicle were the primary object of discussion by the household. Travel choices for work journeys, shopping, recreation and other activities are built upon the commute; it provides the underlying structure for most travel choices during the work week. The distance of the commute seldom strains EV ranges, but the residual range after the commute shapes additional choices and adaptive responses. Commute does figure prominently in the uses of current EVs. Our sample of current EV owners contains a sample of 38 commuters; 31 use their EV to commute while 7 use a gas car.

Planning, Predictability and Recharging

In post-test drive focus groups, many participants discussed flexibility as a basic want; their need for unlimited range was a "lifestyle" issue; they wanted that freedom. Another group of participants stated less need for unlimited range; their travel behavior is more routine. In a survey of Los Angeles commuters only 20 % say they stop on their way to work, and only 30 % say they stop on the way home from work (SCAG 1990).

The distinction between those who recognize their routine and those who demand unlimited range for their lifestyle may be related to life-cycle and age. In focus groups and test drive participants, those who professed routine were mid-aged. This may account for the finding that the most receptive to EVs in the test drive were in the age category 45-55. In this group, night-time recharging was a reasonable requirement, their cars were seldom used during the evenings. Younger drivers considered unlimited range a need in the evening and suggested they could not always count on recharging.

In all PIREG interviews thus far, the amount of time the vehicle is parked exceeds all recharging needs, especially considering the vehicle is seldom used for its maximum range, thus recharge times are relatively short. In the interviews, we offered participants a very slow hypothetical recharging rate of one hour for each ten miles of range.

Only on a few occasions at work places was a need found for faster recharge, caused by errands or business needs. Participants in PIREG studies had a good idea of what errands were done from work. Excessive variation and unpredictability in travel range was found only in two households. Thus we find that more important than commute distance was the perceived and actual degree of routine in the travel patterns of participants and their households. The issue of routine was related also to perceptions about evening activities.

Adaptations to limited range

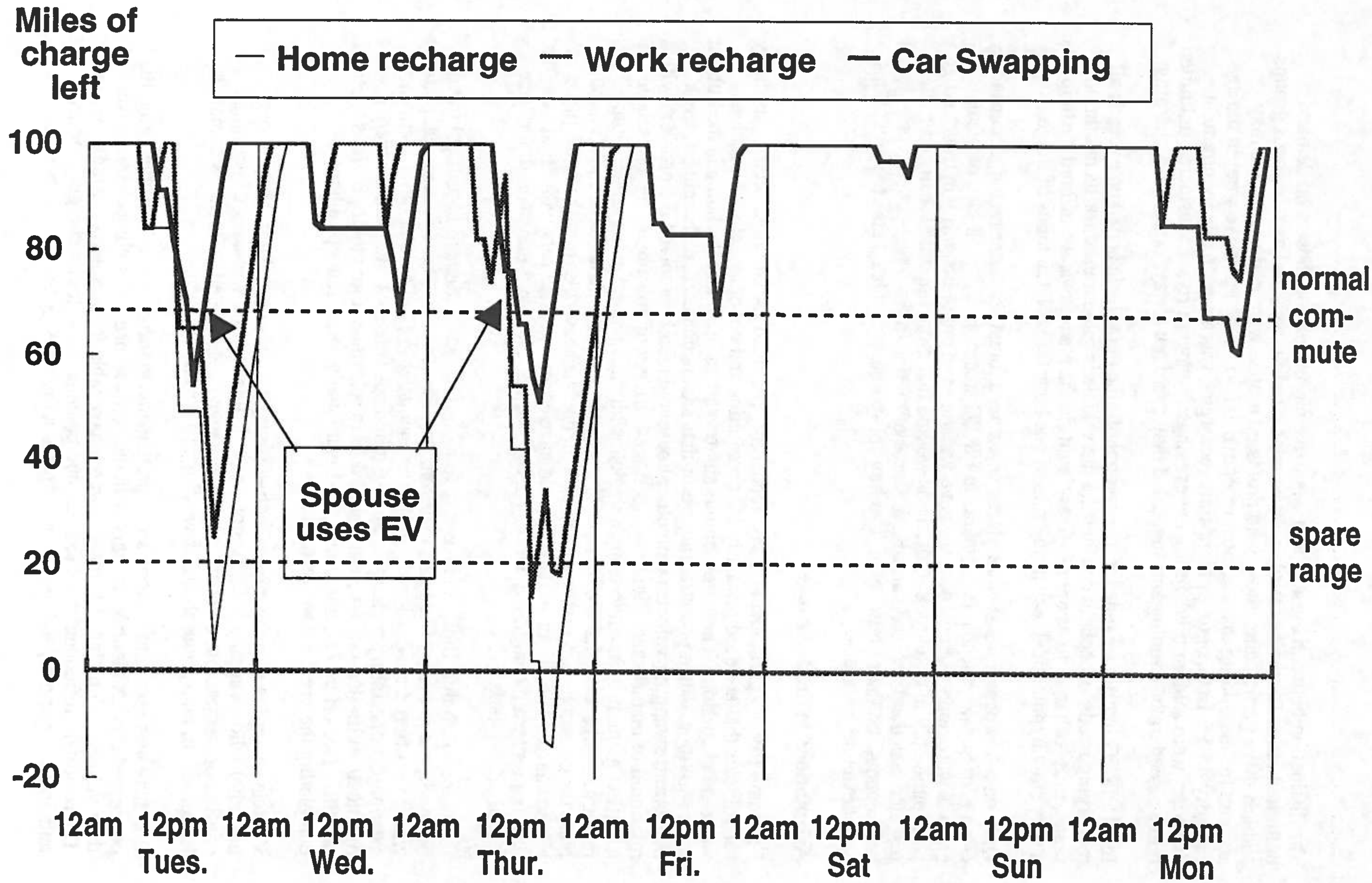
For some PIREG participants, home recharging provided for all range needs, especially for vehicles that are used primarily for commuting and not other activities such as weekend excursions. These households share vehicles often and the home is the hub for most activities. When potential range conflicts are encountered, recharging at work places and swapping vehicles with other household members solved the problem with a minimum of disturbance. Figure number one is a chart of how one of the households in a PIREG game responded to using a vehicle with one hundred miles range. Home recharge represents what would have happened in the previous week without adapting. Note the commute is no strain on the charge, but business trips from the work place use all the charge. The driver of the car could have easily swapped cars with his spouse that day, but preferred charging at work. This couple was confident they would purchase electric if available.

In other households, limited range may require some adaptations in household travel behavior; the amount of adaptation depends on travel needs. These primary adaptations which we offered as solutions to problems encounter in PIREG interviews were car swapping, opportunity recharging and 30 minute fast charges. Households were given a hypothetical limited range vehicle and asked to substitute it into their previous week of activities (we offered a limited range to intentionally cause some problems in completing the previous weeks travel).

Vehicle swapping was the most effective strategy to solve problems. Only in one household did swapping vehicles not work - and the reason was not a direct range conflict but a systematic uncertainty about range needs related to business demands. Moreover, in many households, swapping is a normal practice.

But there was resistance among some participants to increased vehicle swapping; the concerned drivers identify strongly with the performance and styling characteristics of their vehicles. Vehicles of teenagers were unavailable for swapping for these reasons. The relatively infrequent need to swap and potential opportunity charging reduce anticipated swapping and loss of one's personal vehicle for the day. Opportunity

One week adaptation to 100 mile charge limit
Household # 4 (1992 Saturn)



recharging met little resistance as a strategy. Most vehicles in the study are parked for long periods in potential charging locations such as parking lots at work.
At least two households were not potential limited range users, despite fitting our market segment criteria in all other ways. These participants use their vehicles for work purposes which may involve unplanned excursions during the day. While such excursions are rare, the primary problem is that they are important enough to require unlimited range. Planning, by swapping vehicles with another household member was not feasible. The remaining vehicles in the household were not easily replaced by EVs because of their special uses for recreation or other duties or because the purchase pattern of the household was to retire first vehicles to a second vehicle (here we define second vehicle as an older vehicle). The daily schedule of these two vehicles involved trips of such frequency that recharge at work place was untenable, and when such unplanned excursions were required, they involved an accelerated schedule; a quick-charge of even twenty minutes duration was untenable. These participants could only use EVs if equipped with fuel-cell technology, which could be recharged rapidly by fuel exchange. These cases demonstrated that different EV technologies will attract different market segments.

An unexpected result of the PIREG interviews was that two households chose not to substitute an EV for one of their current vehicles and instead said they were most likely to purchase an EV as an additional household vehicle. These households were affluent and distinct from other households in that they own more vehicles, including recreational vehicles and pickups. Apparently these household devote a much higher ratio of household income to maintaining larger household fleets; adding vehicles to their fleet is not unusual. This strategy agrees with attitudes in the larger sample of drivers in Pasadena. In that sample we found that the higher the number of vehicles in a household the better its attitude towards EVs. In addition, households with more specialized vehicles, such as four wheel drive were more likely to express an interest in EVs.

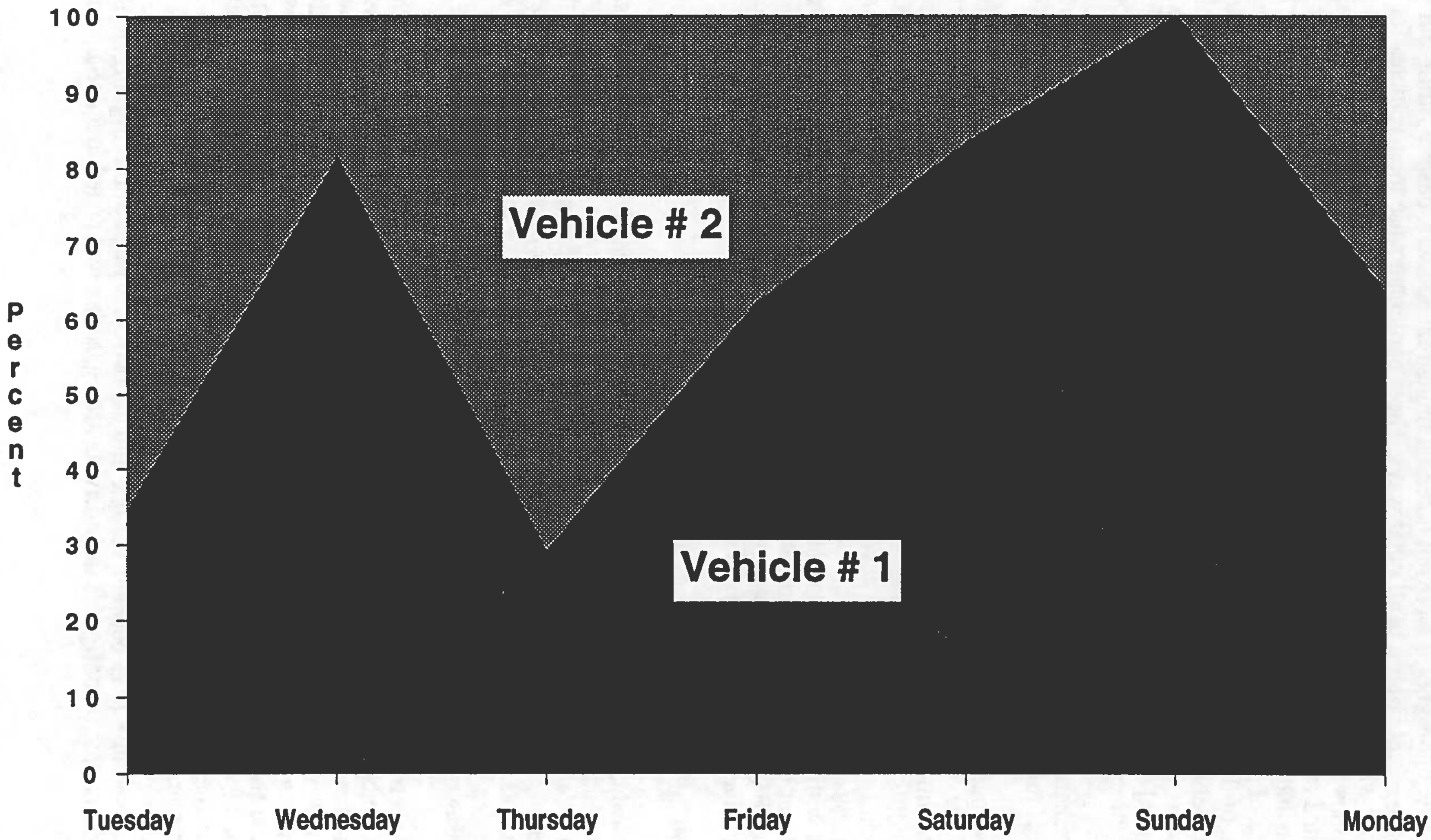
Optimizing use of the EV

Technical constraint studies have assumed some adaptive behavior by EV owning households, proposing substitution of the least used vehicle in a household with an EV. In the previous sections we shows that it may not be the least used vehicle, but rather the vehicle which is most predictable. In this section we propose that in some cases, where EVs fit the travel patterns of a household particularly well, households may even shift more travel to the EV to take advantage of its other features, such as lower operating costs, starting characteristics and convenience of home recharging.

The final round of the PIREG interviews involves motivating households to use their EV as much as is possible. In some games this was accomplished by rationing gasoline so that they were forced to either combine trips or use their EV. In other interview games we raised the price of gasoline to $ 5 per gallon (American). Participants then were given the opportunity to reallocate trips from the previous week. The increase in gasoline was a significant motivation and induced households to shift a significant portion of their travel to the EV. Households were able to shift travel to EVs because prior to the price switch, the amount of range used by the EV was only a fraction of the total range. In most cases, after a price rise, the EV switched from being the least utilized vehicle to the most utilized vehicle in the household. Figure two is a comparison of VMTs between car one and car two for a week of driving. Figure three is how the couple reconfigured their driving after gasoline was rasied to 5 dollars per gallon.

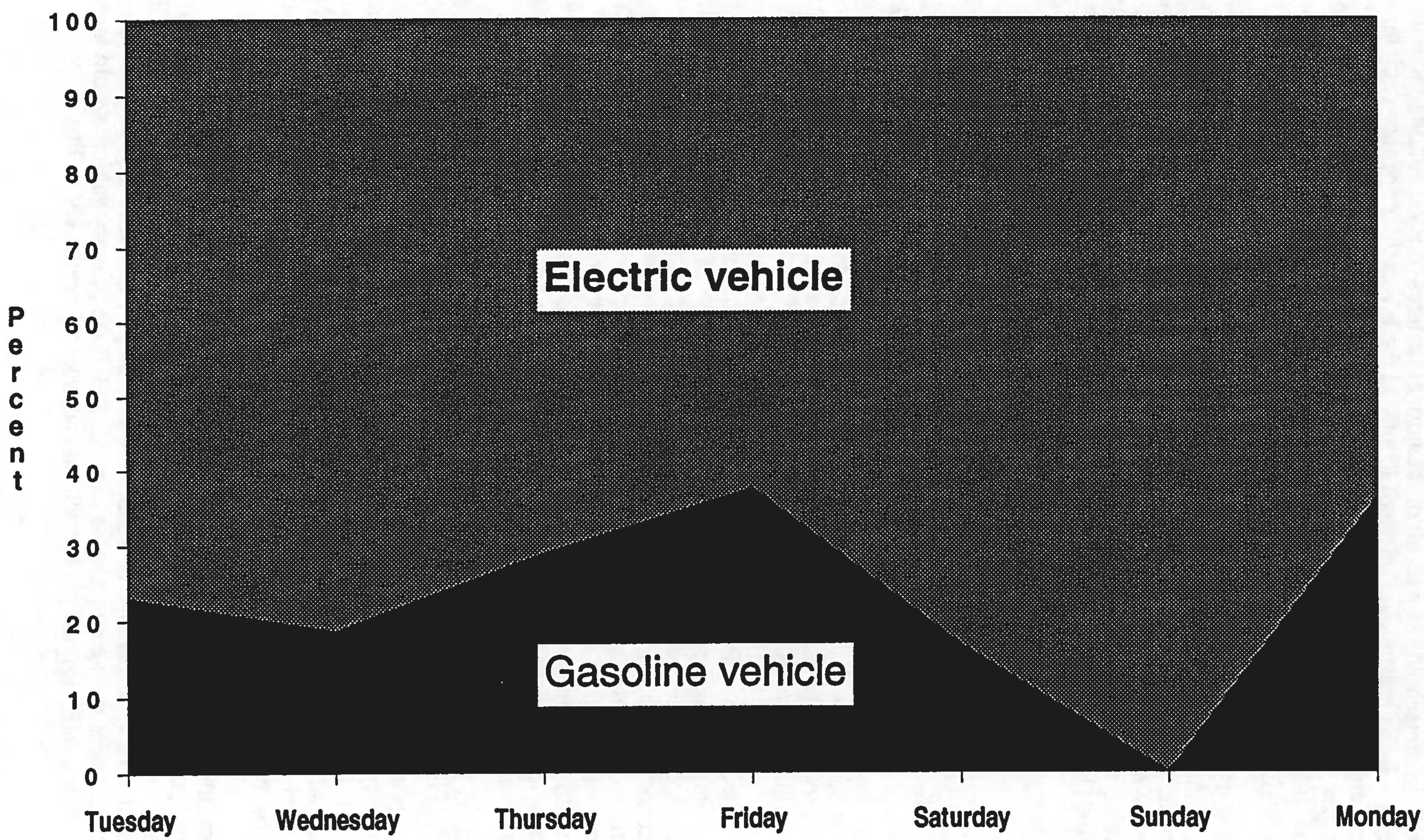
Household # 4

Week use of vehicle 1 & vehicle 2



Household # 4

$ 5 gallon for gasoline and vehicle # 2 is electric



While gas rationing and steep rises in gasoline prices was used in the PIREG interviews to stimulate participants to shift gasoline use to EV use, this motivation may occur routinely in households as a result of the normal features of EVs. Among the EV owners we interviewed, over one-half identified the EV as their primary vehicle, and this was among hobbyists, many of whom are using unconventional vehicles. The miles driven per year of EVs in these households was equivalent to that of their gasoline vehicle. If we look only at vehicles in this sample with systems of seventy volts or more, the percentages of EV use rises.

Many of these current users are EV enthusiasts and not representative of the general population, but their reasons for optimizing the use of their EV are most frequently economic, a feature that will affect the general population as well. The operating costs of the EV are so low, and refueling is so convenient, that these individuals are motivated to use the EV for most high frequency journeys. Several EV owners have even shifted to renting gasoline vehicles for out of range driving, to further reduce costs.

CONCLUSIONS

In this study we use an interactive research method, PIREG, in conjunction with product testing and survey methods to gain a broader understanding of the coming EV market. In particular, PIREG, allowed us to test hypotheses about how households will change their current travel behavior in response to electric vehicle options and price environments. The PIREG interview both educates the consumer about the utility of future options and educates the researcher about important details in the consumer household which affect choice outcomes.

The limited range of EVs and long recharge times have been major blocks to the entry of EVs into the market; it is feared that they cannot compete with gasoline vehicles. and consumers will want unlimited range even if it is for infrequent journeys. Stated preference studies confirm this suspicion. However, constraint studies find that a significant percentage of households do not need unlimited range, even though their current vehicles have unlimited range. Moreover, most daily travel of all vehicles is well within the range of current EVs. Also, citizens are realizing the need for cleaner vehicles; and affluent citizens express a willingness to experiment with limited range electric vehicles.

These are influences which could push the market either way. If we believe EVs are good public policy, citizens should be rewarded for buying and using EVs. If given proper price incentives, these households will find EVs to be advantageous, and discover from other EV owners that adaptations to the range limits to be minor issues. In fact, if the operating costs are different enough from gasoline vehicles, many households will make the EV their primary vehicle, using it for the bulk of household driving chores, and using the gasoline vehicle for long distance trips and trips which must be made at the same time as the electric.

Optimization of EVs makes good sense if the goals are to replace vehicle miles traveled, or percentage of household trips currently taken by gasoline vehicles with EV travel. First generation EVs will be expensive, but if they become the primary vehicle (defined here as percentage of household VMTs and trips), their higher price may be justified. Encouraging households to make an EV the primary vehicle would mean a greater air quality impact per household and would promote EV utility.

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