in transportation system planning, electric cars deserve to be considered along with such frequently proposed possibilities as parking restrictions, exclusive bus and carpool lanes, automobile-free zones, automobile taxation, transit subsidy, transit expansion, and land-use controls.

REFERENCES

1. GM Plans Electric Car, Van by 1985. Autoweek, Dec. 9, 1977.
2. The Charge Is On! The Changing Challenge (General Motors Corp., Detroit) Vol. 4, No. 2, 1977.
3. Electric Cars Look Attractive, Says GM Exec. GM Today (General Motors Corp., Detroit) Vol. 4, No. 1, Jan. 1978.
4. W. Hamilton. Prospects for Electric Cars. General Research Corp., CR-1-704, Santa Barbara, CA, Nov. 1978.
5. Air Quality, Noise, and Health. Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, U.S. Department of Transportation, TAD-443.1, March 1976.
6. E. M. Dickson and B. L. Walton. A Scenario of Battery/Electric Vehicle Market Evolution. SRI International, Menlo Park, CA, CRESS Rept. 46, Dec. 1977.
7. E. Patrick Marfisi and others. The Impact of Electric Passenger Automobiles on Utility System Loads, 1985-2000. Mathtech, Princeton, NJ, Final Rept., Res. Project 758-1, Nov. 1977.
8. L. L. Liston and C. A. Aiken. Cost of Owning and Operating an Automobile: Suburban-Based Operation. Federal Highway Administration, 1976, 15 pp.
9. Annual Housing Survey: 1974 U.S. and Regions; Part A—General Housing Characteristics. U.S. Bureau of the Census, Final Rept. H-150-74A, 1976.
10. Annual Housing Survey: 1974 Current Housing Report; Part C—Financial Characteristics of the Housing Inventory for the U.S. and Regions. U.S. Bureau of the Census, Final Rept. H-150-74C, 1976.

Publication of this paper sponsored by Committee on New Transportation Systems and Technology.

Assessment of Market Potentials for Electric Vehicles

Oreste M. Bevilacqua, De Leuw, Cather and Company, San Francisco
Victor Maslanka, Wilbur Smith and Associates, New Haven, Connecticut

The widespread use of electric vehicles within the transportation system is essential for improvement of environmental quality and reduction of the consumption of petroleum-based fuels. This paper describes the development and application of a market assessment model that is used to estimate the market potential for alternative electric vehicle technologies by relating service needs to range capabilities. The market assessment model uses stratified household travel data to simulate typical daily travel patterns over a period of a year. Alternative scenarios of vehicle use are introduced to relate the sensitivity of the market potentials to household travel behavior. An approach to analyzing commercial vehicle market potentials is also presented. The analysis results reveal the interrelationships among the market potentials, vehicle-range capabilities, and vehicle-use assumptions and indicate the application of these findings to identification of an effective electric-vehicle technology development program.

Gasoline- and diesel-powered vehicles are the single largest consumer of petroleum supplies. As a means of relieving the demand for petroleum within the transportation sector, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, as amended, was passed to foster the accelerated integration into the market of electric and hybrid vehicles. The act provides resources to encourage the early demonstration of the state-of-the-art technology and the long-range development and commercialization of improved vehicle technology. A total of $160 million has been appropriated to support these activities.

The passage of this act reflects the nation's concern over environmental degradation in urban areas caused by conventional petroleum-fueled vehicles and the need for substitute forms of energy to mitigate the adverse consequences of continued reliance on imported petroleum. Many consider that the key to resolution of these concerns, and the principal objective of the act, is in the large-scale commercialization and operation of electric vehicles (EVs) within the transportation sector. Numerous technical problems must be overcome before an EV system that is capable of replacing a significant share of the conventional and commercial vehicle fleet is available to the transportation consumer. In order to facilitate the early commercialization and marketability of EV technologies within resource constraints, a resource allocation strategy must be developed to guide technology development in an orderly and efficient manner (1).

A critical component of the allocation strategy, and the focus of this paper, is a dynamic market assessment model that identifies the market potential for alternative EV technology configurations. The market assessment model identifies the scale, composition, and requirements of potential EV markets and facilitates the application of an iterative procedure whereby alternative technology and market focus strategies can be analyzed and modified to maximize program objectives.

MARKET ASSESSMENT MODEL

The market assessment model analyzes the potential for the substitution of EVs for conventional vehicles by identification of generic vehicle type and user groups and determination of the compatibility of an EV to the travel and service requirements of the user groups. If a match can be established between the functional service needs of the user and the functional capabilities of the EV, this

Table 1. Single-vehicle household stratification and intracity travel characteristics.

Income Quartile	Number of Daily Vehicle Work Trips	Total Households (%)	Average Work Trip Length (km)	Average Daily Nonwork Trip Frequency	Average Nonwork Trip Length (km)
Low	0	7.9	N/A	1.1	9.0
	2	2.0	13.7	1.1	9.0
Low-middle	0	7.2	N/A	2.0	8.7
	2	8.1	13.5	2.0	8.7
Upper-middle	0	3.5	N/A	2.7	8.2
	2	10.7	15.9	2.7	8.2
High	0	1.6	N/A	3.0	8.0
	2	8.0	18.0	3.0	8.0

Note: 1 km = 0.62 mile.

Table 2. Multivehicle household stratification and intracity travel characteristics.

Income Quartile	Number of Daily Vehicle Work Trips	Total Households (%)	Average Work Trip Length (km)	Average Daily Nonwork Trip Frequency	Average Nonwork Trip Length (km)
Low	0	0.7	N/A	2.0	9.5
	2	0.5	15.3	2.0	9.5
Low-middle	2	4.5	15.3	3.7	9.5
	4	0.7	15.3	3.7	9.5
Upper-middle	2	3.5	18.2	5.1	9.0
	4	5.9	18.2	5.1	9.0
High	2	2.6	20.6	5.7	9.0
	4	12.2	20.6	5.7	9.0

Note: 1 km = 0.62 mile.

is an indication that the potential exists for the EV substitution. This analytical approach was used to study both passenger and commercial vehicles.

Perhaps the most salient, distinguishing characteristic of an EV is its limited range, that is, the number of kilometers that a vehicle may be operated between recharge periods. Other researchers have recognized and addressed the importance of the range limitations in their estimates of the market potential for EVs. Perhaps the most comprehensive work on this subject was conducted by Hamilton, who related the assessment of EV applicability to vehicle range characteristics and the availability of off-street parking (2). Range is a direct function of the limitations of the particular energy storage system used in the vehicle. Because of the restraints posed by energy dissipation and the recharge cycle, these range limitations effectively become the maximum distance that a vehicle can travel in the course of one day. The market potential analysis focuses on the daily range requirements of users as the principal functional determinant for estimating EV substitutability.

The distinction between market potential and vehicle sales projections is important and the limitations of this work should be stressed. This analysis is an assessment of the market potential or market segments that appear to have travel requirements that could adequately be served by an EV. Vehicle sales within this potential market sector is a different issue. The actual sales level achieved will be a function of a much broader spectrum of vehicle attributes, such as initial and life-cycle costs, acceleration, gradability, reliability, style, serviceability, and even who the manufacturer is, as well as the nature of the actual marketing program used. The issue of actual vehicle sales is an extremely complex problem, one that many researchers feel cannot be adequately addressed given the current lack of relevant market data. It will not be addressed directly in this analysis. This limitation notwithstanding, the systematic assessment of the EV market potential provides an important link in the selection of an optimum resource allocation plan to achieve the objectives of the act.

Passenger Vehicles

The analysis of the market potential of the use of EVs for passenger vehicle applications is based on a stratification of all households into market segments that display nearly homogeneous patterns of trip making. Households are stratified by

1. The number of passenger vehicles owned (zero, one, two, or more);
2. Income quartile (low, lower-middle, upper-middle, high); and
3. The number of daily vehicle work trips.

For each market segment, average lengths of work and nonwork trips and average frequency of daily nonwork trips were derived from data provided by the Nationwide Personal Transportation Study (3). The trip length and frequency data reflect typical intraregional travel. Because of the limitations on EV range capabilities, EVs were not considered to be a feasible option for long-distance trips, which are defined as trips that have a one-way distance in excess of 80 km (50 miles). In the analysis, it was assumed that an alternative vehicle would be used to make these long trips, either a conventional vehicle or an alternative mode. The analysis was conducted under the assumption that no more than one EV would be bought by a single household.

The resultant market segment data reflect average weekday intraregional travel characteristics. This information is summarized in Tables 1 and 2. Typical weekend travel was indirectly treated by this orientation. When occasional long-distance trips are disregarded, the daily travel requirement for a typical weekend day is found to be less extensive than a typical weekday's travel (3). Therefore, if the weekday's travel requirement is served, weekend travel needs can be satisfied.

The trip data are used to simulate the use of the passenger vehicles during a period of one year (250 weekdays) in order to determine the range requirement distribution for household groups within each market segment (i.e., the distribution of the vehicle ranges necessary to serve various portions of the market segment). The establishment of the range requirement for each household group within a market segment did not assume a specific percentage of days for which vehicle range requirements must be met; rather, we assumed that the needs of all local trips on all days in a typical 250-workday year must be met.

The derivation of daily range requirements in the simulation is highly dependent on the assumptions made as to the manner in which vehicles in a household are and will be used for making a series of trips.

Seven alternative vehicle-usage scenarios were developed and analyzed. Each scenario represents a unique user response-accommodation behavior to EVs. The scenarios are defined as follows:

Scenario 1—EV used only for work travel in multiautomobile households;
Scenario 2—EV used for all trips in single-automobile households and used principally for nonwork trips in multiautomobile households;
Scenario 3—EV used for all trips in single-automobile households and used principally for work trips in multiautomobile households;
Scenario 4—Same as scenario 2 but one nonwork trip eliminated through better trip planning;
Scenario 5—Same as scenario 2 but two nonwork trips eliminated through better trip planning;
Scenario 6—Same as scenario 3 but one nonwork trip eliminated through better trip planning; and
Scenario 7—Same as scenario 3 but two nonwork trips eliminated through better trip planning.

In general, the first three scenarios represent usage options that approximate typical conventional use of vehicles. The last four scenarios represent situations where the household members willingly modify their typical travel routine to facilitate the use of an EV.

The first vehicle-usage scenario limits the vehicles to work trips only. This restriction dictates that only multiautomobile households may be served, since another vehicle must be used for other trip needs. In addition, an EV would only be used in multiautomobile households that make at least two daily vehicle work trips. Within these market segments, the use of the vehicles are limited to two work trips daily.

The second and third vehicle-usage scenarios are less restrictive. In single-automobile households, all local trips are to be made by the vehicle. In multiautomobile households where no work trips by automobiles are encountered, one-half of the household members' nonwork trips are to be made by the vehicle. In multiautomobile households where four daily work trips are made, the EV must serve two work trips plus one-half of the household members' nonwork trips. The second and third vehicle-usage scenarios differ in their treatment of the multiautomobile household where two daily vehicle work trips are made. In the second scenario, the vehicle performs all of the household members' nonwork trips, and in the third scenario, the vehicle performs the two daily work trips.

The remaining four vehicle scenarios are modifications of the second and third scenarios. Nonwork trips are assumed to be eliminated by either linking more trips, sharing them in a different proportion, or postponing them to another day when fewer trips (and fewer total kilometers driven) are necessary.

When a vehicle-usage scenario is selected to be tested, the appropriate simulation technique must be identified. The simulation procedure distinguishes work trips from nonwork trips because work trips tend to be constant in rate and length, as opposed to the more random nature of nonwork trip rates and lengths.

If the vehicle-usage scenario prescribes that a vehicle is to make only work trips, the simulation is quite straightforward. Since the number of work trips to be made is constant within any segment of the households analyzed, the distribution of round-trip work-trip lengths becomes the distribution of range requirements for the market segment. The distribution of the duration of work trips for each market segment was approximated from the values for the average duration of work trips and the variance in the duration of work trips by using a gamma function (4).

To apply the gamma approximation, the work-trip lengths (distances) were covered to work-trip durations (time). This was accomplished by use of a log-log least-squares fit of the relation between trip length and trip duration from the Nationwide Personal Transportation Study (3). The resultant equation is

$$(\text{Trip Duration}) = 8.884\ (\text{Trip Length})^{0.459} \quad (1)$$

The variance of work-trip duration was calculated from the best-fit line of the relation of work-trip duration variance to average work-trip duration (4). The equation of the best-fit line is

$$(\text{Variance}) = 0.000\,153\,1\ (\text{Average})^{4.944} \quad (2)$$

A gamma distribution was calibrated by conversion of the average work-trip length of a market segment to an average-trip duration and calculation of the variance. This became the distribution of range requirements for the market segment.

When the vehicle-usage scenario prescribes that only nonwork trips are to be made by the vehicle, a Monte Carlo simulation approach is used. The actual simulation is preceded by several steps. First, the average daily nonwork trip rate for the household groups within a market segment is assumed to be distributed normally. This distribution reflects the fact that each household group within the segment makes nonwork trips at a different average daily rate. An upper limit is placed on the normal distribution to reflect the impossibility of obtaining very large average daily nonwork trip rates. Given a value for the average nonwork trip rate, a Poisson distribution is then used to identify the probability of making any particular number of trips during a one-day period. The Poisson distribution reflects the randomness of trip making and was applied previously by Schwartz (5) to simulate automobile use patterns. The relation between the probability that a specific number of trips are made in a day and the average number of trips made in a day can be estimated by

$$P(x) = N^x e^N / x! \quad (3)$$

where

$P(x)$ = the probability that x trips are made in a given day,
N = the mean number of trips made per day, and
x = the number of trips made on a given day.

Once the probabilities of making different numbers of trips in a day are estimated, these probabilities are con-

Table 3. Typical Poisson distribution of nonwork trip rates.

Number of Trips	Days per Year	Number of Trips	Days per Year
0	0	9	19
1	3	10	12
2	10	11	7
3	20	12	3
4	31	13	2
5	39	14	1
6	40	15+	0
7	35		
8	28	Total	250

verted to the number of days in a 250-weekday year that a particular number of trips will be made. Table 3 provides an example of the resulting distribution.

Nonwork trip lengths are also distributed by gamma distribution. Origin-destination survey data from selected transportation studies were used to verify that the gamma distribution could also be applied to approximate the actual nonwork trip duration distribution.

By use of this procedure to estimate the distribution of average daily trip frequency by household group, the distribution of trip frequency by the number of days in a year, and the distribution of nonwork trip lengths, the Monte Carlo simulation can be performed for any particular daily trip frequency. For each daily trip frequency generated by the Poisson distribution, that many trip lengths are randomly chosen from the gamma distribution and added together. This is repeated for the appropriate number of days so that the simulation randomly generates total kilometers driven on each day of the year. For each household group, the maximum number of kilometers driven in any one day of the year, referred to as the maximum daily travel, was used to establish the range requirement. The simulation was performed five times and the maximum daily travel for each iteration was averaged so that the actual value used for the household group's range requirement would be representative of a typical 250-workday year.

This simulation was subsequently performed for each household group within a market segment. Thus, a distribution of required ranges for the market segment was based on the normal distribution of nonwork trip rates. Similarly, the process was repeated for each separate market segment and aggregated to obtain the overall market potential for a specific vehicle-usage scenario.

When the vehicle-usage scenario prescribes that both work and nonwork trips are to be made, the work-trip simulation and the non-work-trip Monte Carlo simulation are performed as described previously. It is assumed that making work trips is independent of making nonwork trips. Two separate range requirement distributions are generated and combined to reflect the requirement that both types of trips be made by the household group.

Commercial Vehicles

The analysis of the market potential of EVs for commercial applications is severely hampered by two factors: (a) the lack of data regarding vehicle usage (such as average daily trip frequency and lengths), which could be used to perform a simulation such as the one used for passenger vehicles; and (b) the great variability in vehicle characteristics and vehicle use, which demands a much more extensive stratification of the commercial vehicle fleet. As a result of these limitations, the market analysis for commercial vehicles is much more descriptive in nature.

The 1972 Census of Transportation Truck Inventory and Use Survey (5) allows a partial stratification of the nation's commercial vehicle fleet by vehicle type, vehicle use, range of operation, and total annual travel. Range requirements for commercial vehicles can only be inferred from the vehicle's stratification characteristics. To do this, a ratio of range requirement to average daily travel needs to be estimated for each market segment. Applying this ratio to the value for the average daily travel will provide an estimate of the vehicle range requirement, the satisfaction of which represents a condition for the potential substitution by an EV. For example, if the range requirement ratio for a certain commercial vehicle is 3.5 and the average daily travel is 32 km (20 miles), this implies that the EV must have a range in excess of 113 km (70 miles) to be feasible as an alternative to the conventional vehicle. Unlike the distribution of range requirements calculated for the passenger vehicle analysis, only a single typical range requirement can be estimated for each commercial vehicle market segment.

Because of the complexity in estimating the ratios of the range requirement to average daily travel market potential, estimates were not available at the time of this writing.

RESULTS

The results of the passenger vehicle analysis are summarized in Figures 1 and 2. Each curve shown in these figures represents the aggregation of range requirements across all household market segments for a particular vehicle-usage scenario. Market potential in these figures is expressed in terms of the percentage of the total passenger vehicle fleet that can potentially be replaced by an EV. A maximum potential of approximately 73 percent corresponds to the assumption that no single household will purchase more than one EV.

Figure 1 shows the relation between the market potential and the range required under vehicle-usage scenarios 1, 2, and 3. The figure shows that in order to achieve a specific market potential, different EV range capabilities would be required, depending on which of these three scenarios is pursued. This has an important implication in terms of identification of an effective market orientation. For example, if the range capability of the EV is less than 97 km (60 miles) the best marketing strategy would be to focus on the use of an EV as a commute-to-work vehicle for multi-automobile families. If the range exceeds 97 km, then the marketing strategy should shift somewhat to stress that the EV is a general purpose vehicle.

These results can be used directly to estimate the market potential for alternative vehicle technologies. For example, an EV powered by a lead-acid battery that has an idealized range of approximately 120 km (75 miles) would have the potential to replace approximately 22-29 percent of the vehicle fleet. A 322-km (200-mile) range nickel-iron battery would be able to replace approximately 70 percent of the vehicle fleet. This latter figure is probably conservative, because as the range increases, the constraint that stipulates only one EV to a household can be relaxed.

It is interesting to compare these basic results to those obtained by Hamilton, if we disregard the requirement that off-street parking be available. Hamilton derived estimates of EV market potentials that are 50-75 percent greater [over the vehicle range interval of 75-225 km (47-140 miles)] than the market potentials depicted in Figure 1 (2). These differences reflect the more relaxed range suitability condition used by Hamilton in his analysis: An EV that could serve the household travel needs for 95 percent of the travel days was

Figure 1. Range requirement distributions for alternative EV usage scenarios.

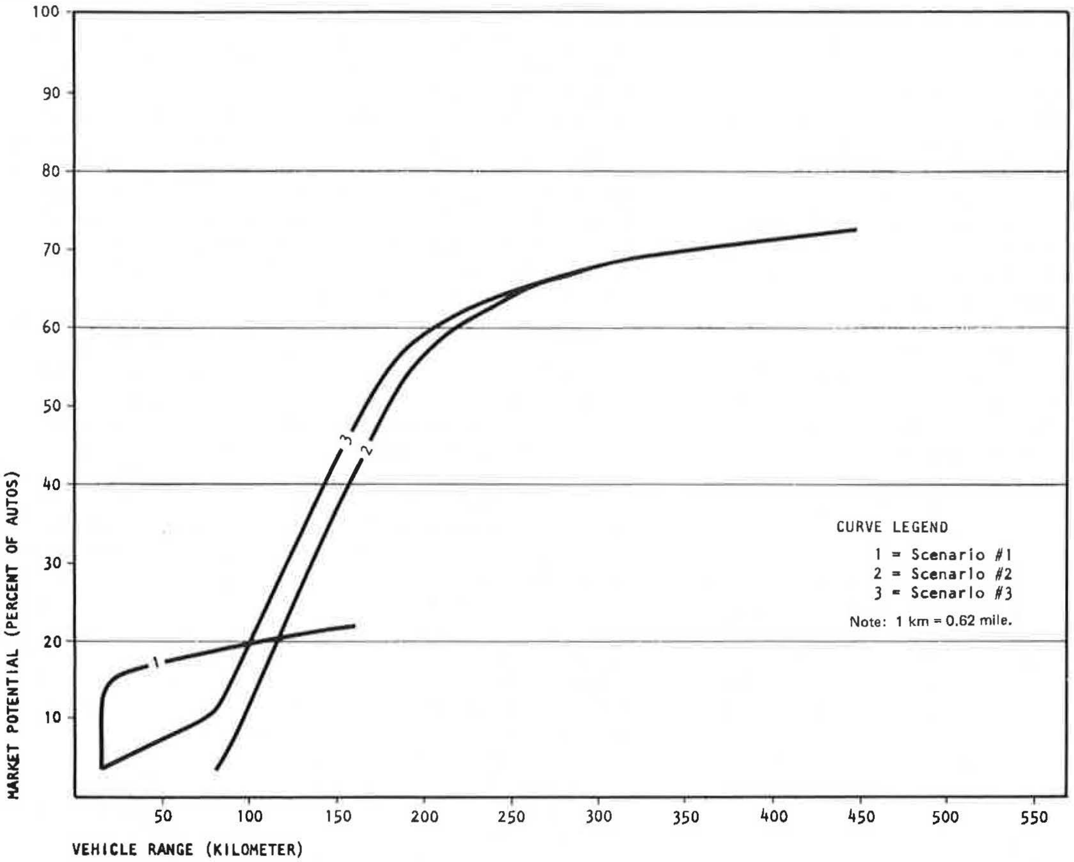
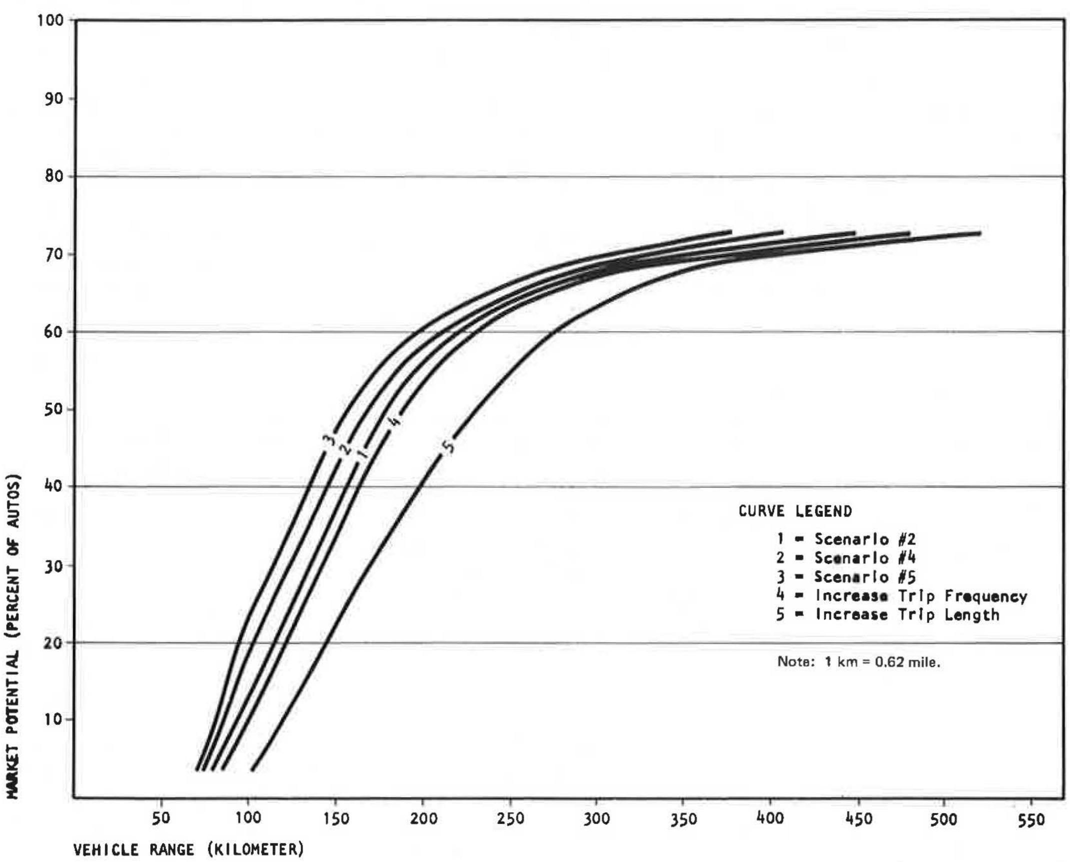


Figure 2. Range requirement sensitivity.



considered to be a reasonable substitute for a conventional automobile. In this paper, the travel requirements for a maximum day of travel established the condition for EV applicability.

Figure 2 demonstrates the sensitivity of the market potential results under conditions of modified travel behavior. This is achieved by showing scenario 2 as the base condition, as well as scenarios 4 and 5, which reflect increasing degrees of travel reductions through trip planning. Also shown are two additional travel variation schemes that reflect the effect of, in one case, a 20 percent increase in the nonwork trip frequency and, in another, a 20 percent increase in trip length.

The curves for scenarios 4 and 5 show that at the 130-km (80-mile) range, if two nonwork trips could be eliminated (through linking, shifting, or postponing), the market potential could be increased by approximately 50 percent, from 26 to 38 percent of the passenger vehicle fleet. As the range increases, the sensitivity of the estimates of market potential decreases. However, for those ranges encompassed by the technology options for the near term, the effect of usage patterns is significant.

Figure 2 also indicates the impacts of increased trip frequency and increased trip length. Of the two, trip length increases have the greatest impact on the market potential. Not shown is the effect of reductions in these travel factors, which tend to reduce the range requirement but to a lesser extent than the effects depicted by the increase in travel.

A separate analysis was conducted to evaluate the range requirement for individual market segments within a given scenario. What was found was that, within an automobile ownership level, as income increases, the range requirement tends to increase as well. For example, for scenario 2, the range required to achieve a market potential of approximately 35 percent (assuming 2 work trips/household) is 120 km (75 miles) for the low-income quartile and 177 km (110 miles) for the high-income quartile. The effect is less pronounced for multiautomobile households but nonetheless present. The effect of increases in automobile ownership level is mixed and depends on the income level. For below-average income levels, increases in automobile ownership have the effect of increasing the range requirement; however, above-average income levels tend to show no change or a small reduction in the range requirement when automobile ownership levels increase.

As lower-income households increase their automobile ownership levels as well as their general household income levels, EV substitution will be made more difficult because of corresponding increases in range requirements. These results are also disturbing in a more indirect manner: Our general contention is that, because of the anticipated higher initial cost of purchasing an EV rather than a conventional vehicle, the higher the household income, the greater the opportunity to replace a conventional vehicle with an EV. However, we find that these same households are more capable of buying an EV but have higher service needs. In a similar vein, multiautomobile households are expected to be more likely to purchase an EV than would a single-automobile household because they still would have a conventional vehicle for long trips. Again, however, we found that these same households have, in general, higher service requirements that frustrate EV substitution.

IMPLICATIONS

This analysis has focused on what is perhaps the single most critical functional characteristic that distinguishes an EV from a conventional vehicle—range. Although other functional attributes of EVs could be used to sort out the market potential, such as their recharge and storage capabilities, these factors are viewed as less absolute and, therefore, less amenable to generalization. These shortcomings notwithstanding, the results of the market potential assessment provide a systematic treatment of travel behavior and a consistent basis on which to estimate the possible substitution of EVs into the nation's vehicle fleet. Subsequently, the market assessment model can be used to test alternative technology configurations and application situations to identify market impacts and to indicate an orientation for the development of a marketing strategy.

An important conclusion is the recognition of the interrelation among the vehicle range distributions, the patterns of vehicle use, and the household travel characteristics, specifically trip frequency and length. Changes in use patterns or travel behavior can have a pronounced impact, both positive and negative, on EV range requirements. What makes these factors difficult to deal with is their dynamic nature. Changes may also be brought about by technology or market factors as well as by changes in lifestyle, which are quite independent of transportation system factors. Whether these changes will be compatible or in conflict with EV commercialization strategies is uncertain. To facilitate successful implementation, the analyst's task is to recognize these options and to identify and test the integrity of the technology development strategy within the scope of possible futures. The analysis framework described here provides an initial step for doing just that.

Identification of the petroleum conservation implications of these results is less direct and requires further analysis. The amount of petroleum saved by implementing the EV as a local travel mode will be a function of the travel behavior of the households that will operate the EV, the battery recharging facilities and policies, and the electric-power-generating characteristics of the particular regions. However, the market potentials obtained in this analysis can be used to provide a first-order approximation of the maximum potential for petroleum savings through EV implementation.

As an example, the analysis of scenario 2 shows that an EV that has a range of 75 km (47 miles) has a market potential of approximately 5 percent yet diverts less than 1 percent of the total number of vehicle-kilometers traveled by all passenger automobiles. EVs that have ranges of 150 and 225 km (93 and 140 miles) could divert approximately 10 and 40 percent of the total vehicle kilometers of travel, respectively, compared to their market substitution potential of 35 and 60 percent. The point is that the correspondence is not one-to-one between the number of conventional vehicles substituted and vehicle kilometers of travel (which is a surrogate for petroleum consumption) diverted to EVs. This suggests that the introduction of low- to medium-range EVs will have only a marginal effect on reduction of petroleum consumption.

This analysis indicates ultimate market potentials. Given that the vehicle fleet replaces itself at a rate of about 10 percent each year, a number of years under economic conditions favorable to EVs will elapse before these market shares can be achieved. Moreover, the extent to which these potentials are in fact achieved is a separate and complex issue. Much more information is needed before credible sales estimates can be made. How will potential EV owners make purchasing decisions? What is the relation between the actual range requirement and the perceived range requirement? To what extent will potential EV users be willing to rely on other vehicles or modes for making long-distance trips? [As part of this analysis, we estimated that the cost of using a rental automobile to make only long trips, amortized over the life of an EV, would be in the range of 2-3 cents/km (3-5 cents/mile).] What factors are considered when deciding whether to purchase a new or used automobile when an existing vehicle is being replaced? These and other questions will need to be resolved. However, in the interim, systematic market potential estimates can play an important role in EV technology and resource allocation decisions.

ACKNOWLEDGMENT

The research on which this paper is based was part of the Opportunity and Risk Assessment Project that is being funded by the U.S. Department of Energy and conducted at Purdue University. The support of these sponsors is gratefully acknowledged and implies no endorsement of the findings.

REFERENCES

1. Opportunity and Risk Assessment Study Draft Program Plan, Task 3: Technology Research and Development Planning. Institute for Interdisciplinary Engineering Studies, Purdue Univ., Lafayette, IN, Feb. 1978.
2. W. Hamilton. Prospects for Electric Cars. General Research Corp., Santa Barbara, CA, CR-1-704, Nov. 1978.
3. Nationwide Personal Transportation Study: Automobile Ownership. Federal Highway Administration, Rept. 11, Dec. 1974, 74 pp.
4. Alan M. Voorhees and Associates. Factors and Trends in Trip Length. NCHRP, Rept. 48, 1968, 70 pp.
5. H. J. Schwartz. The Computer Simulation of Automobile Use Patterns for Defining Battery Requirements for Electric Cars. Presented at 4th International Electric Vehicle Symposium, Dusseldorf, Germany, Paper 211.1 (E), Sept. 1976.
6. 1972 Census of Transportation: Truck Inventory and Use Survey. U.S. Bureau of the Census, Vol. 2, 1974.

Publication of this paper sponsored by Committee on New Transportation Systems and Technology.