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# The Nanocar: A Consumer Driven Solution For a More Sustainable California

A Group Project submitted in partial satisfaction of the requirements for the degree of
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by

Claudia C. Anticona
Jason Peery
Jonathan Saben
Jota Shohtoku
Clarice Wilson

Committee in charge:
Professor Jeff Dozier
Assistant Professor Catherine Ramus

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Claudia C. Anticona

Jason Peery

Jonathan Saben

Jota Shohtoku

Clarice Wilson


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The Group Project is required of all students in the Master's of Environmental Science & Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

Professor Jeff Dozier

Assistant Professor Catherine Ramus

Dean Dennis Aigner

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***Group Members***: *Claudia Anticona, Jason Peery, Jonathan Saben, Jota Shohtoku, Clarice Wilson.*

Since the mid-20th century, California has witnessed unprecedented population growth matched with an equally significant increase in the number of drivers who use private vehicles as their primary means of commuting. This growth in population and reliance on private vehicles has strained urban transportation infrastructure systems to the point that personal mobility, the economy, and the environment is increasingly experiencing negative repercussions. The Nanocar is an alternative transportation solution that, unlike many existing policies, utilizes existing consumer preferences to ameliorate the pressures associated with a growing and sprawling population. The Nanocar is designed to be a safe, low emissions commuter vehicle that seats two people in tandem. Due to its unique size, the Nanocar increases personal mobility by maximizing land-use and the efficiency of existing transportation systems.

A stated preference survey was conducted to evaluate what transportation or monetary incentives, if any, would induce Californian consumers to purchase the Nanocar. The results indicated that a market exists in California for the Nanocar. Consumers routinely accepted a reduction in the size of the Nanocar for infrastructure incentives that marginally saved them time and money. As to be expected, price was the most significant purchasing factor, but consumers gained more utility from parking advantages and specific infrastructure changes than increases in tax rebates for the Nanocar. In addition, incentives such as savings from increased fuel efficiency, tax incentives, and the ability to refuel at home, were not significant purchasing factors of the Nanocar, rather rewards for those that purchased the Nanocar for other reasons.

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**List of Acronyms**

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ADT | Average Daily Traffic |
| AFV | Alternative Fuel Vehicle |
| AQIP | Air Quality Improvement Program |
| AQMD | Air Quality Management District |
| BRT | Bus Rapid Transit |
| CAA | Clean Air Act |
| CALTRANS | California Department of Transportation |
| CARB | California Air Resources Board |
| CO | Carbon Monoxide |
| DMV | Department of Motor Vehicles |
| DOT | Department of Transportation |
| EMFAC | Emissions Factor |
| EPA | Environmental Protection Agency |
| EV | Electric Vehicle |
| FHWA | Federal Highway Administration |
| HOV | High Occupancy Vehicle |
| IIA | Independence from Irrelevant Alternatives |
| IID | Independent and Identically Distributed |
| IIHS | Insurance Institute for Highway Safety |
| LDV | Light Duty Vehicle |
| LEV | Low Emission Vehicle |
| MNL | Multinomial Logit |
| MSRP | Manufacturer's Stated Retail Price |
| NAAQS | National Ambient Air Quality Standards |
| NEV | Neighborhood Electric Vehicles |
| NGO | Non Government Agency |
| NHTSA | National Highway Traffic Safety Administration |
| NMHC | Non-Methanol Hydrocarbons |
| $NO_x$ | Nitrogen Oxides |
| RTP | Regional Transportation Plan |
| SIP | State Implementation Plan |
| SULEV | Super Ultra Low Emission Vehicle |
| TCM | Transportation Control Measure |

| | |
|---|---|
| TDM | Transportation Demand Measure |
| TEA-21 | Transportation Equity Act of the 21st Century |
| VIP | Vehicle Incentive Program |
| VMT | Vehicle Miles Traveled |
| ZEV | Zero Emission Vehicle |

## **EXECUTIVE** SUMMARY

### Introduction

Population growth in metropolitan America has been steadily increasing. Since 1969, the population of the United States has increased by approximately 40% (US Census 2000) with 75% of the population living in urban areas by 1990 (US Census 1995). This trend was matched with a proportional increase in the number of drivers who use private vehicles as their primary means of commuting. Most urban transportation systems are currently not equipped to handle the increasing travel demands and consequently, peak hour congestion in major cities is increasing. This slowdown results in the loss of potential revenue and productivity, as more and more commuters sit idle in congestion for longer periods of time (TTI 2001). Furthermore, even with the advent of more efficient engines, the continued rise in fuel consumption and congestion has deleterious effects on the air quality of these metropolitan areas and National Ambient Air Quality Standards (NAAQS) continue to be exceeded, particularly for ground level ozone (EPA Greenbook 2002).

Existing and emerging non-traditional solutions such as, High Occupancy Vehicle (HOV) lanes, Regional Transportation Plans (RTPs), state implemented tax incentive programs, and California's Air Resources Board (CARB) Zero Emission Vehicle (ZEV) Mandate, have begun to address these problems. However, there are several issues that hamper the effectiveness of these plans. Firstly, land-planning based solutions are developed mainly to increase the overall mobility of commuters in the region and do not specify the type of vehicle that will use the infrastructure. Second, vehicle-based solutions do not consider the infrastructure that will be required to ensure the proliferation of these vehicles on the road. Clearly there is a dichotomy between these two solutions when they are in fact attempting to achieve complementary objectives. Finally, a major factor that is being ignored when implementing these plans is consumer preferences regarding mobility. Commuting statistics show that commuters overwhelmingly prefer to commute alone in their private vehicles (U.S. Census 2000). New solutions to the impending mobility crisis tend to view this behavior as an obstacle to overcome rather than a key to success. Furthermore, it is unclear whether sales forecasts for zero emission vehicles will be met or regional transportation plans be implemented, questioning whether or not the NAAQS will be attained and personal mobility be improved.

### The Nanocar Concept

The research presented in this paper focused on synthesizing existing commuter behavior and preferences with innovative technology to provide an alternative transportation solution that integrates both vehicle design and land-planning based incentives. The Nanocar is a unique vehicle that seats a maximum of two people in tandem, making it narrower and shorter than any mass-produced vehicle on the road today, in the United States. It is designed primarily as a commuter vehicle that meets all recognized safety standards. It is also expected to meet or exceed the USEPA's SULEV

(Super Ultra Low Emission Vehicle) standard.[1] Advantages of the Nanocar include a lowered demand placed upon transportation infrastructure and land due to its unique size, increases in personal mobility due to various infrastructure incentives, and a reduction of total vehicle emissions.

The underlying research questions being addressed in this paper were 1) Is there a market for ultra compact environmentally friendly vehicles such as the Nanocar? 2) What transportation and policy incentives are necessary for consumers to purchase the Nanocar? 3) Do current programs in California that aim to increase the purchase likelihood of environmentally friendly vehicles or reduce congestion observe consumer preferences? 4) Are consumers willing to trade-off automobile size for these incentives? and 5) Are there any quantifiable air quality benefits resulting from the gradual introduction of the Nanocar?

**Survey Design and Administration**

Nine attributes of the Nanocar (vehicle price, tax incentives, preferential parking, parking fee reduction, annual fuel cost reductions, refueling advantages, price of gas, side-street infrastructure additions, and highway infrastructure additions) were included in the survey in the form of various inventive packages. The final survey took the form of a web-based stated preference survey where respondents were presented with five scenarios of which four were Nanocar packages with different incentives and a fifth "no-buy" scenario.[2] In total, 891 responses were returned from a wide range of urban and suburban localities in California with an estimated response rate of 8%.

**Respondent Demographics**

In general, the respondent set mirrored the demographics of the entire population of California. In total, approximately 75% of the respondents came from the largest Californian urban areas with the majority coming from the greater Los Angeles county area, including Orange County (36.7%). 199 respondents stated that they did not have a commute to work.

**Survey Results**

78% of respondents chose to purchase the Nanocar given a certain set of monetary and non-monetary incentives with the majority indicating that they would use the Nanocar as a primary vehicle. The most significant attributes in a respondent's purchasing decision were determined through logit and multinomial logit (MNL) regression analyses of the survey responses.

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[1] The current SULEV standards for light duty vehicles (< 8500lbs) are 1.0 g/mi and 0.02 g/mi for carbon monoxide and oxides of nitrogen (for 120,000/11yrs)

[2] This survey methodology, which is based on the theoretical economic model of utility maximization and random utility, allowed the researcher to determine the statistical significance of specific attributes and predict the choice probability of specific scenarios through multinomial logit (MNL) regression analysis.

The results of the logit regression showed that the highest income-range had the greatest inclination towards purchasing the Nanocar.[3] Other lower income brackets also were inclined to purchase the Nanocar. The oldest respondent range indicated that they would not purchase the vehicle. No other demographic and commuting characteristics remained significant. A MNL regression was conducted for all respondents as well as two subsets of these respondents, commuters and non-commuters. The three variables that had the greatest utility for the entire respondent set were preferential parking at stores, and 50% and 100% reductions in parking fees. Preferential parking at work and stores, own-lane away from existing side-streets with an associated 50% reduction in commute time and own-lane on highways with an associated 25% reduction in commute time also had positive utilities. Similar utility factors were obtained for commuters. The analysis of non-commuters indicated that this subset mainly concentrated on price and preferential parking as purchasing factors, implying that this subset was more price sensitive than the commuting subset. Through these parameter estimates, the probabilities of choosing various Nanocar scenarios over other scenarios were subsequently calculated.

**Implications of Survey Results**

When the above factors are taken into account, the following conclusions can be drawn:

1. There is a market for the Nanocar
2. Price will be the main determinant to whether or not the vehicle is purchased, but other monetary and non-monetary incentives will increase the purchase likelihood.
3. The most value is gained from parking advantages and specific infrastructure changes, while annual fuel cost reductions do not influence the decision to purchase.
4. Tax incentives are not likely to have a great impact on whether or not the Nanocar is purchased as compared to other incentives.
5. Fuel savings, tax breaks and refueling advantages at home are incentives that reward the consumers who purchase the Nanocar rather than significant factors that are included in the consumer's purchasing decision.

**Air Quality Benefits**

From the standpoint of the California Air Resources Board (CARB) and the individual air quality management districts of California, the goal of increasing the proportion of environmentally friendly vehicles on the road is to attain or exceed the NAAQS in California.

To determine the potential air quality benefits of the introduction of a Nanocar and the associated infrastructure, projections of the emissions reductions of carbon monoxide (CO) and oxides of nitrogen ($NO_x$), were calculated for the Los Angeles County Region.[4] For 10% sales of the Nanocar, the reductions in emissions achieved for CO and $NO_x$ in

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[3] A logit regression was conducted to determine whether or not a specific demographic characteristic of the respondent set was more inclined to purchase the Nanocar.

[4] The Draft EMFAC2001 (Emissions FACtor)[4] model produced by the California Resources Board (CARB) was used to calculate the air quality benefits.

2020 were 496 tons/yr and 25.55 tons/yr, respectively. For 20% sales, the emissions reductions were 1533 tons/yr and 62.05 tons/yr, respectively. The corresponding number of Nanocars on the road in the year 2020 was estimated to be 741,708 (10%) and 1,483,416 (20%).

## Recommendations

Rather than the development of incentive programs that target the entire population, we recommend a program tailored towards the specific needs of the commuting population. We believe from our analysis of the California survey results and air quality model that this tailored program will have the greatest impact on improving personal mobility and air quality in the state of California. Therefore, the following recommendations are based on the responses of the commuting subset of the entire respondent population.

Recommendations to Policymakers and Automakers:

- Timing: The vehicle and its associated incentives must come on-line simultaneously to meet the multiple policy objectives. If done correctly, the collaboration between policymakers and automakers will achieve cleaner air, improve mobility and increase economic productivity; enable automakers to comply with regulations and remain profitable; and increase commuter convenience and employee productivity without altering the consumer's purchasing preferences drastically.
- Good faith marketing: For the successful introduction of environmentally preferable vehicles such as the Nanocar, companies must be willing to commit as much resources into advertising the vehicle and its incentives as any other vehicle in their fleet. Regulators must also increase consumer awareness of these incentives through marketing programs of their own. In addition, the involvement of non-governmental agencies (NGO's) may be beneficial in reaching advertising parity for the Nanocar and improve the dialogue between the various stakeholders.
- In order to receive 10%-15% sales on price alone, the price of the Nanocar should be set between $10,000 and $15,000.

Infrastructure Recommendations:

The political environment, geographic location, regional planning agendas and finances must be considered for the efficient and safe incorporation of the Nanocar into society. Infrastructure modifications and additions could potentially come in a variety of forms to best suit the Nanocar. These changes to current infrastructure include, but are not limited to, highway modifications, side street modifications and parking modifications.

## Practical Applications

In an ideal situation where all incentives are provided the probability of commuters choosing to purchase a Nanocar package was 88.0%.[5] In reality, however, all incentives would not be provided and therefore a combination of the incentives would have to suffice. The variables that had the most utility for commuters were 50% and 100%

[5] For this package, the price is set at $14,000 and price of gas is $1.28 as specified by the Department of Energy's Energy Information Administration of February 18, 2002.

reductions parking fees and preferential parking at stores.[6] Even at high amounts, tax incentives had the lowest utility among positive variables. Based on this information the following practical applications are recommended.

- Shopping areas can be the focus of incentive programs. A 25% or greater reduction in parking fees, while still maintaining revenues, can be achieved through the modification of parking lots to fit more Nanocars. Both private and municipal parking lots should be modified in order to create preferential parking areas near to stores or lot exits. Side-street infrastructure should also be provided in order to increase the convenience of getting from home to stores and work. If all these incentives are implemented the choice probability is increased from 10.49% (Price and gas cost only) to 47.5%.[7]
- Tax incentives can be given to businesses rather than consumers to promote the placement of preferential parking areas and refueling stations at work.[8] New highway and side-street infrastructure built on existing highways and streets can be modified to reduce commute times and thus increase mobility. If all of these incentives are provided, the choice probability is increased from 10.49% (Price and gas cost only) to 52.95%.

**Conclusions**

The results from the survey indicated that there is a substantial market for an ultra-compact vehicle such as the Nanocar given that a certain set of incentives are provided at the time of purchase. In addition, commuters regarded parking advantages and specific infrastructure changes as the incentives that they believe are the most important to them in their purchasing decisions. Furthermore, the results indicated that in many cases, tax incentives and fuel-savings which are traditionally utilized as incentives in statewide programs are not the most effective way of swaying the consumer towards purchasing an environmentally friendly vehicle or altering their commuting patterns.

The ideal package of incentives should be area-specific since commuter preferences and the political environment will differ across regions. Solutions such as the shopping area and workplace based incentive programs are examples of how incentive programs can be practically implemented.

It is important to note that the Nanocar concept is not the panacea that will solve all of California's congestion and air quality problems. It is meant to be an alternative transportation solution that can be incorporated into various regional transportations plans and other statewide plans. However, the concept does provide a different take on achieving reduced congestion, increased personal mobility and improved air quality since

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[6] Preferential parking at work, own lane away from existing side-street infrastructure with an associated 50% reduction in commute time and own lane on highway with an associated 25% reduction in commute time also had high utility factors.

[7] For all the packages, the price is set at $15,000 and price of gas is $1.28 as specified by the Department of Energy's Energy Information Administration of February 18, 2002.

[8] Tax breaks for the placement of charging stations at the workplace already exist in California.

it is first, based on the consumer preferences towards a vehicle and its associated incentives and second, it attempts to tackle the problem in an integrated manner.

# CHAPTER 1

## PROJECT CONCEPT AND SIGNIFICANCE

## 1.1 Introduction

Population growth in metropolitan America has been steadily increasing. Since 1969, the population of the United States has increased by approximately 40% (US Census 2000) with 75% of the population living in urban areas by 1990 (US Census 1995). This trend has been matched by an increase in the number of commuters who use private vehicles as their primary means of traveling to work (TTI 2001). This is illustrated by the Department of Transportation's estimate that 78.2% of all workers use private automobiles as their main means of commuting (DOT 2000). The growing levels of peak hour congestion in major cities such as Los Angeles and Houston are evidence of the consequences of these trends. In addition, it also shows that current transportation systems are not equipped to handle the projected increases in urban population growth and corresponding transportation demands.

The resultant slowdown in mobility has significant costs not only for commuters, but also for the environment and the economy as a whole. In many metropolitan areas, peak time commutes are, on average, at least 30% longer per trip than non-peak commutes. It has been estimated that the average delay per driver is up to, or greater than, one workweek per year in extra travel time. The associated costs of delays and excess fuel were assessed at approximately $500 per driver, often exceeding $1000 in many urban areas where severe congestion occurs. The aggregate estimate of the economic cost of congestion in 1999 totaled $78 billion (TTI 2001).[9]

Even with the advent of more efficient automobile engines, the continued rise in fuel consumption has deleterious effects on air quality and contributes to persistent non-attainment of National Ambient Air Quality Standards (NAAQS), particularly for ground level ozone (EPA Greenbook 2002). Several initiatives have been undertaken in Regional Transportation Plans (RTPs) to address these issues including existing and emerging non-traditional solutions, such as High Occupancy Lanes (HOV), car sharing, Bus Rapid Transit (BRT), and California's Zero Emission Vehicle (ZEV) Mandate, have begun to address these problems. However, further research and new approaches are needed to simultaneously accommodate the growing pressures on transportation infrastructure and the environment, while increasing personal mobility.

## 1.2 The Nanocar Concept

The primary focus of this study was to examine whether there is a way of utilizing current commuting behavior and preferences as a means of mitigating transportation pressures and reducing the associated human health and environmental impacts. It was observed that most of the existing alternative transportation policies and ideas involve changing commuter behavior as opposed to modeling incentive programs around consumer preferences. Furthermore, existing alternative transportation policies have not had the desired level of success in lowering urban congestion. This led to the conceptualization of the "Nanocar", which is a unique vehicle that seats a maximum of two people in tandem, making it narrower and shorter than any vehicle currently on the

[9] This estimate includes 4.5 billion hours of delay and 6.8 billion gallons of excess fuel consumed.

market in the United States.[10] The current estimate for the dimensions of the Nanocar are that it is no more than 10½ feet long by 4 feet wide (compared to a common mid-size commuting vehicle that is 15.4 feet long by 5.7 feet wide).[11] The vehicle also has a cargo capacity of 4 cubic feet (the equivalent of 6 grocery shopping bags). The motivation behind the design of the Nanocar was to capitalize on the fact that most drivers commute to work alone. Therefore, it is intended be used primarily as a commuter vehicle that meets all recognized safety standards, as prescribed by the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS). It is also expected to meet or exceed the Environmental Protection Agency's (EPA) Super Ultra Low Emission Vehicle (SULEV) standard[12].

The features that distinguish the Nanocar from the majority of other vehicles available on the market today include the lower demands it places on transportation infrastructure, as its size allows for a re-thinking of urban and suburban transportation systems resulting in an increase in mobility, and reduced tailpipe emissions. The Nanocar does not require as much infrastructure support as traditional vehicles, thereby reducing the land use burden. Examples of ways in which the Nanocar could fit into current commuting patterns include the redesigning of existing highways and side streets to accommodate more vehicles without necessitating the construction of additional lanes; creating throughways connecting dead-end streets to arterial streets; or altering other vehicle paths such as bike lanes, where current automobiles cannot fit, to accommodate the Nanocar. Moreover, parking lots could be resized to accommodate the Nanocar, thus increasing the number of cars that can be parked in a given space, thereby again reducing the land use burden. A further elaboration of the infrastructure benefits associated with the Nanocar can be found in Appendix D-1.

### 1.3 Policymaking Environment

Various plans have been introduced in California with the objectives being to reduce congestion, increase mobility and improve air quality. For example, complex Regional Transportation Plans (RTPs) that incorporate a variety of Transportation Demand Measures (TDMs) and Transportation Control Measures (TCMs) have been developed in several localities to address these issues.[13,14,15] These RTPs are commonly a part of

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[10] Though it is referred to as "the Nanocar", it is viewed as a class of vehicles rather than a single vehicle.

[11] These are the dimensions of a Volkswagen Passat.

[12] The current SULEV standards for light duty vehicles (< 8500lbs) are 1.0 g/mi and 0.02 g/mi for carbon monoxide and oxides of nitrogen (for 120,000/11yrs)

[13] Regional Transportation Plans consist of programs designed to manage transportation growth and demand and associated impacts. They are typically used by States and Counties to map out plans to meet or maintain federal air quality and transportation acts among others.

[14] Transportation Demand Management (TDM) is a broad term for strategies that result in more efficient use of transportation resources. These strategies can vary from region to region and can include methods for addressing issues such as congestion reduction, improved transportation choice, efficient land use etc.

[15] Under the Transportation Conformity Rule, Transportation Control Measures (TCMs) are strategies that are specifically identified and committed to in State Implementation Plans (SIPs), and are either listed in Section 108 of the Clean Air Act (CAA), or will reduce transportation-related emissions by reducing vehicle use or improving mobility (USDOT).

State Implementations Plans (SIPS) which are required under the Clean Air Act if the region in question has air quality that exceeds the National Ambient Air Quality Standards (NAAQS). In addition to these land-planning based approaches, technology-forcing measures have also been placed on automakers that wish to capture the large market for vehicles in California. One of the better-known measures is the Zero Emission Vehicle (ZEV) mandate introduced by the California Air Resources Board (CARB) in 1990. The mandate, which was finally enacted in 2001, requires two percent of all vehicles sold by the seven major automakers in California to be ZEVs by 2003. The objectives of such a mandate is to reduce the amount of mobile source emissions being emitted each year into the atmosphere. Another type of program that has been established in recent years by both State and Federal regulators is the tax incentive program. This program offers tax breaks to consumers who purchase environmentally friendly vehicles (such as electric vehicles) as well as employers that place electric vehicle charging stations at the workplace.[16] Other incentives programs such as free parking and allowing clean vehicles to use High Occupancy Vehicle (HOV) lanes, have also been established by local and State governments to induce the purchase of environmentally friendly vehicles.[17,18]

The above examples are a select few of the vast number of plans that have been developed to reduce congestion, increase mobility and improve air quality. It is important to note that not all the plans attempt to tackle the issues simultaneously; in other words, some plans, such as HOV lane construction, attempt to only reduce congestion while other plans, such as the low emission vehicle (LEV) program, attempt to improve air quality. In addition to these State plans, Federal acts such as the Transportation Equity Act, have also been enacted to address some of these issues. Furthermore, private companies have attempted to capitalize on current driving conditions by developing innovative alternatives to existing transportation systems such as car-sharing programs and communities that have traffic networks that accommodate for Neighborhood Electric Vehicles (NEVs).

### 1.4 Project Significance

Several issues arise when analyzing current transportation plans that attempt to meet the objectives of increasing mobility and improving air quality. First, land planning based solutions are developed mainly to decrease congestion and increase the overall mobility of commuters in the region. These plans do not concentrate on the type of vehicle that will be used on the road networks when they are introduced. Second, vehicle-based solutions do not consider the infrastructure that will be required to ensure the

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[16] Federal tax incentives include tax credits of up to $4,000 for the purchase of electric vehicles (EVs) and the Clean Fuel Vehicle tax deductions for businesses. State tax incentives include the Zero Emission Vehicle Incentive Program (VIP) that provides up to $3,000 per year for three years towards the purchase or lease of electric vehicles.

[17] The City of Sacramento Off-Street Parking Department offers free parking to electric vehicles in downtown parking lots.

[18] California Assembly Bill 61 (AB61) allows single-occupant use of High Occupancy Vehicle (HOVs) lanes by certain electric and alternative fuel powered vehicles.

proliferation of these vehicles on the road. Clearly there is a dichotomy between these two solutions when they are in fact attempting to achieve complementary objectives. Finally, the one major factor that is ignored in both types of solutions is the existing consumer preferences towards the issue of mobility.

The significance of the Nanocar concept presented here is that it aims to encompass all the aforementioned objectives in an integrated manner. The vehicle accommodates consumer preferences, but its success in the marketplace will depend upon timing to coincide with infrastructure modifications so that the incentives are provided to the consumer at the time of purchase. Furthermore, the concept integrates both the aspects of land-use planning and future vehicle design. Simply stated, the vehicle and the infrastructure compliment each other. The Nanocar's size allows it to fit into an infrastructure network that requires less land area compared to traditional infrastructure designs and the new infrastructure network for the vehicle will act as a purchasing incentive for consumers, thus increasing the demand for such a vehicle.

It is important to understand that the Nanocar concept is not an all-encompassing solution that will solve all of California's congestion and air quality problems. The concept is intended to be an alternative transportation management solution that could be integrated into regional transportation plans or future development projects so as to work in tandem with other programs to form an effective overall plan to address the aforementioned issues.

### 1.5 Document Structure

The remainder of this report is divided into seven additional chapters consisting of the survey methodology, survey results, analysis of consumer preferences, an analysis of air quality benefits associated with the Nanocar, research recommendations, a case study that illustrates the different changes that could take place, and concluding remarks. The second chapter, Survey Methodology, is broken into multiple subsections that logically describe the creation and theoretical underpinnings of the survey, the process of conducting the survey, and the method of analysis. The third chapter, Results of Survey Responses, provides the results of the survey analysis. The forth chapter, Analysis of Results, attempts to explain results provided in chapter three. Next, the fifth chapter, Air Quality Analysis, is presented. This section builds on the results of the Nanocar survey and provides the model and the method of quantifying environmental benefits related to the Nanocar. The sixth chapter, Recommendations and Practical Applications, synthesizes the results of the survey and air quality analysis sections to create broad recommendations and to illustrate practical applications of the Nanocar. The seventh chapter, the Nanocar Case Study, is presented to illuminate the meaning of the recommendations. In addition, the case study helps illustrate a holistic view of how the Nanocar can fit into society. Finally, eighth chapter, Conclusion, brings together the research, recommendations, and case study to reiterate the importance and advantages of the Nanocar.

# CHAPTER 2

## **SURVEY**METHODOLOGY

## 2.1 Question Characterization

The underlying research questions being addressed were 1) Is there a market for ultra compact environmentally friendly vehicles such as the Nanocar? 2) What transportation and policy incentives (attributes) are necessary for consumers to purchase the Nanocar? 3) Do current programs in California that aim to increase the purchase likelihood of environmentally friendly vehicles or reduce congestion observe consumer preferences? 4) At what point (if any) are consumers willing to trade-off automobile size for these incentives? and 5) Are there any quantifiable air quality benefits resulting from the gradual introduction of the Nanocar?

The study focused on urban areas within California due to the high growth rate of its major cities, corresponding transportation demands, and the existence of a progressive legislative environment. The utilization of a wide focus area ensured that the majority of commuting preferences would be represented and could be applied to other regions in the United States.

## 2.2 Attribute Identification and Description

In order to establish which attributes to use in the survey, multiple focus groups were surveyed. The purpose of the focus group studies was to determine which factors consumers view as important regarding their own transportation preferences and commutes to work. The studies were conducted either in person or via e-mail in various urban areas in California, and a total of 93 people were surveyed.[19] The results of this initial survey were collated to produce a complete list of attributes that were to be included in the actual survey.[20]

A total of nine attributes were identified, representing the range of factors that were considered by commuters to influence their commuting preferences. They included vehicle price, tax incentives, preferential parking, parking fee reductions, annual fuel cost reductions, refueling advantages, price of gas, side-street infrastructure additions, and highway infrastructure additions. Based on the focus group survey, existing incentive programs, and advisor consultation, each attribute was assigned a number of different levels to represent the different magnitudes that could be offered for each incentive.[21]

## 2.3 Experimental Design

A consumer preference analysis was conducted using stated preference survey methodology. This type of survey is modeled on choice theory and the theoretical economic model of utility maximization.[22] Essentially, the survey replicated a market and

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[19] The survey locations were San Francisco, Los Angeles, San Diego, and Orange County.

[20] A sample of the focus group survey and a summary table of the results are provided in Appendices A-1 and A-2.

[21] The attributes and corresponding levels and the definition of each attribute, as it appears on the survey, are provided in Appendices A-3 and A-4.

[22] In simple terms, random utility theory states that a person will choose the alternative or goods that returns the "greatest happiness" or "utility" to the respondent out of a group of choices.

asked the respondent to make a simulated purchase.[23] The advantage of combining choice theory with random utility maximization theory is that choice probabilities could then be estimated for the purchase of the Nanocar.

## 2.4 Scenario Development

For the nine attributes and the different levels associated with them, there were a total of 2,160,900 different combinations that could be generated. Though the respondents should ideally have been presented with all the different choice scenario combinations, asking a respondent to evaluate all 2,160,900 scenarios and select the one that provides them the most utility was unrealistic. Therefore, a fractional factorial was used to reduce the combinations to a manageable size (Louviere, Hensher, Swait 2000). The goal in any fractional factorial is to reduce the combination of scenarios, while minimizing the errors (variances and co-variances) associated with the parameter estimates, without losing the statistical efficacy of the survey design. In essence, the minimization of variances and co-variances can be considered as the goodness of an experimental design or a design's efficiency (Kuhfeld, Tobias, Garratt 1994).

The SAS/QC statistical package and its ADX interface were used to narrow down the full factorial to a more manageable design. An optimal design method was selected, since it searches for the most efficient, non-orthogonal design.[24] Various algorithms and efficiency criterion exist that affect how the choice set is eventually determined. In this survey, the goodness of design was measured by its *D-efficiency* and the algorithm used in the fractional factorial was the modified Federov.[25] The optimal design was chosen to exclude second-order interactions because the majority of observed variance can be explained solely through the main effects.

The full factorial was reduced to 40 scenarios or "runs" that had a *D-efficiency* of 98.7 (a balanced, orthogonal design has a *D-efficiency* of 100), and the average standard error was 0.8524. They were then assembled into groups of four, creating 10 scenario matrix structures.[26] In addition to the four scenarios in each matrix, a "no buy"[27] option was included as a fifth scenario.

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[23] A technical explanation of the relevant economic theories is provided in Appendices A-5 and A-6

[24] Orthogonal design is ideal for this type of analysis, as when a linear model is fit with an orthogonal design, the parameter estimates are uncorrelated, implying that each estimate is independent of the other terms in the model. More importantly, orthogonality usually implies that the coefficients will have minimum variance, which makes this kind of analysis ideal (Kuhfeld et al. 1994). However, given the different levels of attributes associated with the Nanocar, it was not possible to use an orthogonal design and a non-orthogonal design was used instead.

[25] *D-efficiency*, the modified Federov algorithm, and how the optimal design program works is described further in Appendix A-7.

[26] This was done to present the respondent with a realistic number of scenarios that could be clearly distinguished from each other. According to Carson, Louviere, Anderson, Arabie, Bunch, Hensher, Johnson, Kuhfeld, Steinberg, Swait, and Timmermans (1994), the average questionnaire only has four choice sets or scenarios that the respondent must evaluate and we were able to reduce the matrices without reducing the overall efficiency.

## 2.5 Survey Administration

Given the nature of our study and the type of information that needed to be conveyed, an online survey was chosen because it was deemed to be the most effective way of distributing the survey to the widest audience. Mail-in surveys were deemed impractical due to the time and monetary resources required. In addition, in-person interviews were disregarded due to the inherent informational bias associated with interviewer-interviewee interaction. Though there are inherent biases associated with online surveys, such as the fact that they are only available to people that have computers and Internet users on average tend to be younger, on average, than the general population, online surveys avoid the informational bias related to in-person interviews. The biases associated with online surveys were therefore considered the least significant and restrictive out of the possible set of administration techniques.

The final survey took the form of a web-based stated preference survey where the 40 scenarios were broken down into five scenarios, of which four were Nanocar packages with different incentives, and a fifth "no-buy" scenario. Before issuing the final survey, a pretest was conducted to ensure that the respondents understood what they were being asked. The pretest group consisted of nine respondents, all of whom were University of California, Santa Barbara (UCSB) students. The survey was conducted using in-person interviews on the UCSB campus. Although the location and the in-person administration of the survey resulted in biases that would have not occurred for the actual online survey, the purpose of the focus group was to determine comprehension and clarity, not the answers themselves. The pretest group was, therefore, believed capable of adequately conveying any survey problems. [28, 29, 30]

The survey targeted Californians in urban areas over the age of 18.[31] Each time the survey site was accessed, a code embedded in the web survey randomly pointed the respondent to one of ten matrices. They were then asked to make a choice of buying the Nanocar over one of the four other scenarios. The question that was posed to the respondent was:

> "When you are looking to buy your next car, under which scenario, if any, would you be <u>most likely</u> to purchase the Nanocar?"

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[27] The no buy option was intended to be interpreted as, "I would not buy the Nanocar under any of these scenarios," even though the scenario was worded as, "I would not buy the Nanocar under any scenario." Since no respondent submitted a blank matrix, it is assumed that the respondents who chose the "no buy" scenario interpreted it as it was intended.

[28]A copy of this survey and comments can be found in Appendix A-8.

[29] This survey methodology, which is based on the theoretical economic model of utility maximization and random utility, allowed the researcher to determine the statistical significance of specific attributes and predict the choice probability of specific scenarios through multinomial logit (MNL) regression analysis.

[30] The no buy scenario was interpreted as, "I would not buy the Nanocar under any of these scenarios."

[31] The e-mail sent to the respondents is provided in Appendix A-9. As an incentive to taking the survey, a $0.50 donation to the Twin Towers Fund was pledged for every valid response.

The respondents were provided with detailed background information and explanations to ensure that they knew what they were being asked to evaluate.[32]

### 2.5.1 The Respondent Pools

The respondents were pooled from the following sources:

Opt-in E-mail

In addition to the e-mails sent to the University of California schools, 9,750 e-mail addresses were purchased from Survey Sampling Inc. of Connecticut. Survey Sampling has a database of over 7 million e-mail addresses that were narrowed down to only Californians over the age of 18. E-mails inviting potential respondents to take the survey were then sent to 9,750 randomly selected e-mail addresses. These email addresses were drawn from Survey Samplings general database with the only qualification that the email recipient be over the age of 18 and reside in California. The Survey Sampling database is compiled from multiple sources such as when a user registers to certain web sites and allows e-mail messages to be sent to them. Survey Sampling then re-confirms this selection. There may be an unavoidable selection bias in purchasing email addresses in that those that accept emails from Survey Sampling may have inherent biases unknown to the researchers. To mitigate these unforeseen biases, respondents were selected by alternative means.

University of California Schools

Faculty, staff and students from the University of California at Santa Barbara, Berkeley, Davis, Irvine, Riverside and Los Angeles were randomly selected and sent the survey via e-mail. In order to compensate for the aforementioned age bias, the respondent group was purposefully targeted in a 4:1 faculty/staff to student ratio.

Online User Groups:

Additional respondents were sought through web-based groups such as Yahoo.com Groups and Google.com Groups. The sole criterion for the selection of specific groups was for the groups' members to reside in metropolitan areas of California. This information was easily found in the description of the group. Once a group was selected, a standard message was posted on the group's website inviting all members to take the survey. The standard message was the same message that was sent to potential respondents at the University of California schools and the one distributed by Survey Sampling. Twenty groups met the criteria and they are listed in Appendix A-11. It should be noted that none of the user groups stated a bias towards the environment.

Once the survey was created and distributed, the survey responses were automatically inputted into a database. The responses included both the answers to the matrix and the demographic questions. The survey was online for a little over one and one half months (the survey was online from November 15th, 2001 to January 4, 2002). The initial database of responses consisted of 949 respondents, each identifiable by the survey

[32] A sample of the final survey is provided in Appendix A-10.

version they took and the order in which they took it. After removing 58 invalid responses[33], the database was narrowed down to 891 respondents.[34]

## 2.6 Method of Analysis

A number of analyses were run to determine whether specific demographic and/or geographic groups were statistically more willing to purchase the Nanocar. Logarithmic regressions were also run to assess which parameters remained significant and to isolate the different levels of the attributes that were (or were not) influencing the respondents' decision. Although it is important to examine the general demographics of the survey respondents to test the validity of the sampled population, for the purpose of this study, the commute to work preferences and commute times were also considered to be the integral factors.

The runs that were initially conducted included:

1. The full dataset (i.e. all the respondents and all the variables)
2. The full dataset with grouped infrastructure variables in order to determine whether the presence of specific side street and highway infrastructure incentives were inducing respondents to purchase the Nanocar regardless of the commute time reduction associated with them.
3. The full dataset with grouped commute time variables in order to assess whether commute time reductions, rather than the type of transportation infrastructure change was inducing respondents to purchase the Nanocar.

In addition to the above runs, the same analyses were performed for commuting and non-commuting subsets in order to assess whether there is a difference in transportation preferences between those respondents that stated they had a commute to work and those that stated they did not have a commute to work. Runs were also conducted for net cost.[35]

### 2.6.1 Logit and Multinomial Logit (MNL) Analysis

First, a logit regression with commute time, age, income and location as dependent variables was conducted to determine whether or not a specific demographic characteristic of the respondent set was more likely to purchase the Nanocar.[36] A MNL regression was then run using the SAS software. The MNL model is an individual response model that helps to explain the choices that the respondent made and the extent to which the attributes influenced the respondents' decision to purchase the Nanocar. It also helps to analyze and explain the choices individual customers make in

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33 Responses were deemed to be invalid when duplicate e-mail addresses were submitted for different surveys or when the survey was submitted from an out-of-state location.

34 The approximate response rate for the survey was 8%. A more accurate response rate could not be calculated due to distribution methods.

35 The net cost takes into account price reductions resulting from tax incentives.

36 The logit transformation Y of the probability of an event P is the logarithm of the ratio between the probability that the event occurs and the probability that the event does not occur i.e. $Y=\log(P/(1-P))$

the market. The Nanocar's purchase probability at the individual level is a rough indicator of its market share at the market level (Kuhfeld et al. 2001). The MNL equation for calculating the probability of selecting a choice in a given choice set is shown below:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in J_n} e^{V_{jn}}}, \text{for all i in } J_n$$

Where, $P_{in}$ is the probability of decision maker *n* choosing alternative *i*, $J_n$ is the set of alternatives that *n* faces, $V_{in}$ is the observed portion of the utility derived by alternative *i*, and $V_{jn}$ is the observed utility derived from the set of alternatives. The MNL model determines parameter estimates for the entire set of attributes within $J_n$ which then allows for the conditional probability that the decision maker, *n*, chooses alternative *i*.

Two critical assumptions were made when the MNL model was used:

- That an efficient design for a linear model (D-efficiency) performs as well for a nonlinear, MNL model (i.e. if efficiency is the goal for a linear model then it is also a good design for measuring the utility of each alternative and the contributions of the factors to that utility in a non-linear model).
- That the Independence from Irrelevant Alternatives (IIA) assumption holds for the model (Kuhfeld 2001).

For analysis purposes, the categorical attributes, such as side street infrastructure and parking incentives, were transformed into binary codes and the continuous attributes (price and tax incentive) were left as is. In addition, since several categorical variables had more than one level, binary dummy variables were also created. To code the "no buy" option, the assumption was made that the respondent chooses the status quo and therefore was coded as such.[37]

### 2.6.2 Hypotheses

To better illustrate the results of the MNL model a series of hypotheses were tested. These hypotheses were designed to evaluate consumer rationality and to observe whether current programs in California to induce consumers to purchase environmentally friendly vehicles or to reduce congestion account for consumer preferences. The hypotheses included:

1. The respondents' decision to purchase the Nanocar is solely dependent on the price.
2. Tax breaks and the advertisement of greater fuel efficiency are not an effective way of creating incentives for purchasing environmentally friendly vehicles.
3. Parking benefits and refueling advantages are not an effective way of creating incentives for purchasing environmentally friendly vehicles.

[37] An example of binary coding and the MNL procedure in SAS is given in Appendix A-12.

### 2.6.3 Choice Probabilities

The results of the parameter estimates were then used to calculate the respondents' choice probabilities of selecting one Nanocar scenario over another. The calculated choice probabilities are as follows:

1. The effect of changes in the price variable (i.e. no incentives given).
2. The effect of adding one incentive to the price variable.[38]
3. The choice probability when incremental levels of all the significant and positive attributes were presented as a Nanocar package to the respondents. This was done for the entire respondent set and the two respondent subsets (commuters and non-commuters).

It was acknowledged that it is improbable that all the attributes could be offered in one all-encompassing package. For this reason, incentive programs directed towards shopping/commercial districts and workplaces[39] were developed and choice probabilities were calculated for each.[40]

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[38] For this analysis, the price was set at $15,000 and the price of gas was set at $1.28 (DOE 2002).

[39] The incentive programs directed towards the shopping district were combinations of the following incentives: 25% parking fee reductions, preferential parking, own path away from existing side-streets with a 50% reduction in commute time, and own lane on existing highways with a 25% reduction in commute time. The incentive programs directed towards. The incentive programs directed towards workplaces were combinations of the following incentives: Refueling ability at work, preferential parking at work, own path away from existing side-streets with a 50% reduction in commute time, and own lane on existing highways with a 25% reduction in commute time.

[40] Note that the probabilities for hypothetical scenarios are the probabilities that a respondent would purchase a specific incentive-laden package over the no buy scenario.

# CHAPTER 3

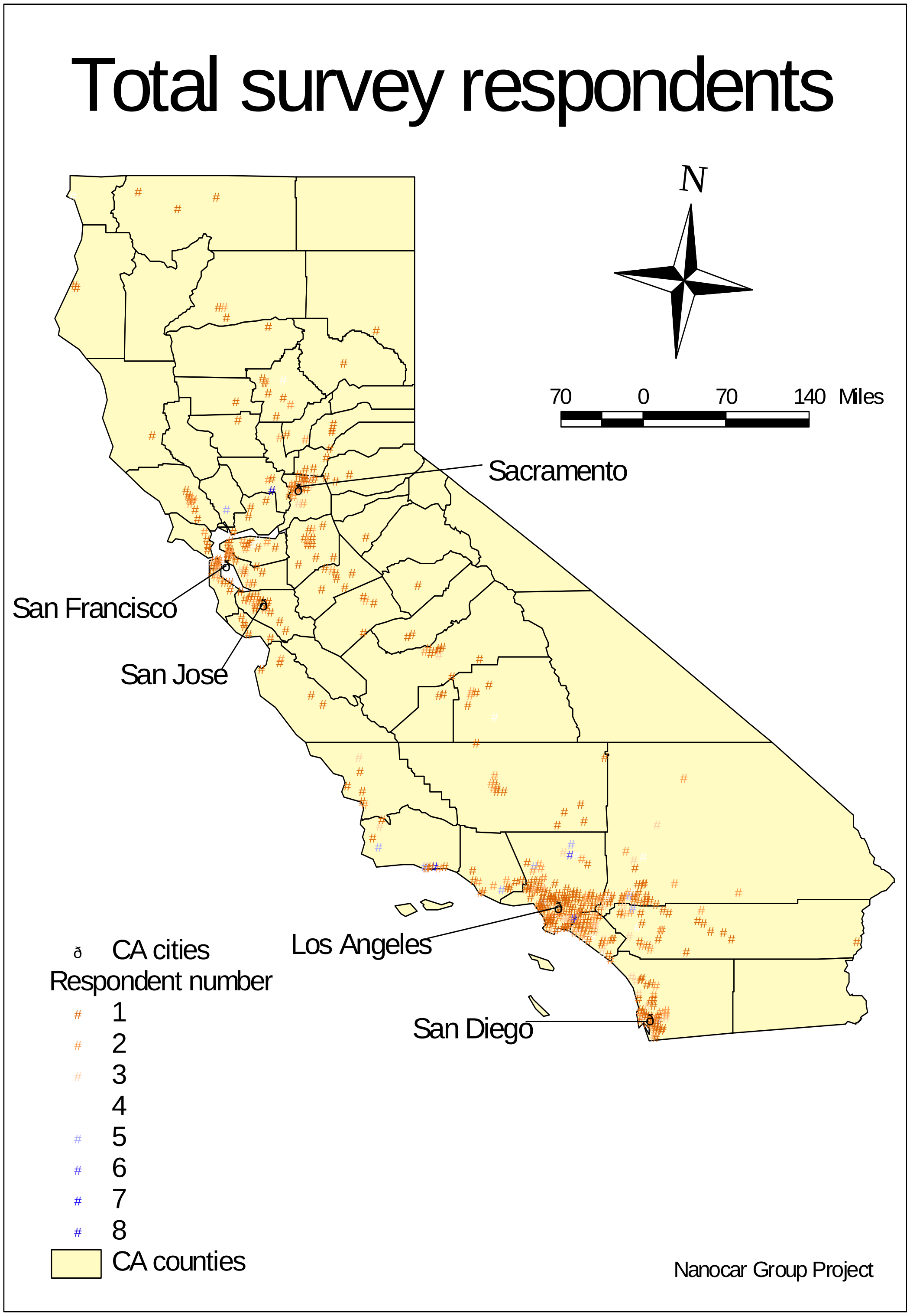
## **RESULTS** OF **SURVEY** RESPONSES

## 3.1 Descriptive Statistics

### 3.1.1 Geographic Distribution of Respondents

Figure 3.1 shows the overall distribution of respondents in California. As the graph indicates, most of the respondents originated from the major urban areas within California (San Francisco / San Jose, San Diego, Santa Barbara / Ventura, Sacramento / Davis and Los Angeles / Orange County). 75% percent of the respondents came from the largest Californian urban areas with the majority originating from the greater Los Angeles County area, including Orange County (36.7%) with the next major locale being the Bay Area (16.61%).

**Figure 3.1**



Total survey respondents
N
70 0 70 140 Miles
Sacramento
San Francisco
San Jose
Los Angeles
San Diego
CA cities
Respondent number
1
2
3
4
5
6
7
8
CA counties
Nanocar Group Project

### 3.1.2 General Demographics

The aggregate demographic data was useful in determining whether or not the sampled subset was representative of the overall Californian population. In general, when compared to the census data (1990-2000), the survey respondents represented a fair depiction of the Californian population. The similarities can be seen in the age and income distributions of the respondents, as well as their commuting behavior and preferences. Respondents had comparable commute times, methods of commuting to work, and preferences to carpooling as compared to the statewide population. They tended to be middle aged[41], making less than $100,000 per year[42]. Most of all respondents tended to own their own car, drive alone during their commute, and commute for distances of less than 20 miles and for less than 30 minutes (though some commutes were much longer) and drive less than 15,000 miles per year. They preferred not to carpool and when they had to make a stop during their commute, they would typically make only one. Most respondents view the Nanocar as a "primary" vehicle, though it is assumed that those considering it a "secondary" vehicle still would use it for commuting purposes. Respondents tended to be relatively highly educated and were not generally associated with environmental organizations.

### 3.1.3 Transportation Demographics

Overall, survey respondents had very similar commute to work preferences and commute times as the general California population. Of the sample population, 692 (78%) stated that they had a commute to work. The survey intended to capture the primary commute, which includes the drive to work, school, and/or the grocery store. As mentioned above a large majority of the commuting population uses a private vehicle for their primary commute.[43] The percentage of commuters who said that they carpooled was similar to that of the census data, reiterating the fact that most commuters drive to work alone.[44] Approximately 64% of respondents reported that they make stops during their commute and out of those that do, only 22% make multiple stops.[45] An in-depth

[41] Most of the survey respondents were between the ages of 36-45 and 46-55, though the age ranges of 18-25 and 26-35 were heavily represented as well. For all of these age ranges, the percentage of survey respondents represented a larger portion of the total survey population as compared to census data for California. As a result of this, older respondents, 65 or older, were underrepresented in the survey as compared to 2000 U.S. Census data for California (see Appendix B-1a).

[42] The most represented income bracket for the survey was for the $20,000-$40,000 range and this parallels the income data for California. However, a greater percentage of respondents in this income bracket and the lowest income bracket (less than $20,000) were represented in the survey as compared to 2000 U.S. Census data for California. The survey was also over-represented in the highest income bracket as compared to the 2000 Census data (see Appendix B-1b).

[43] One of the more notable deviations is that there were a slightly higher percentage of survey respondents that commute via mass transit than the 2000 Census data indicate. This may have been a result of how the survey was distributed (see Appendix B-1f).

[44] See Appendix Figure B-1h.

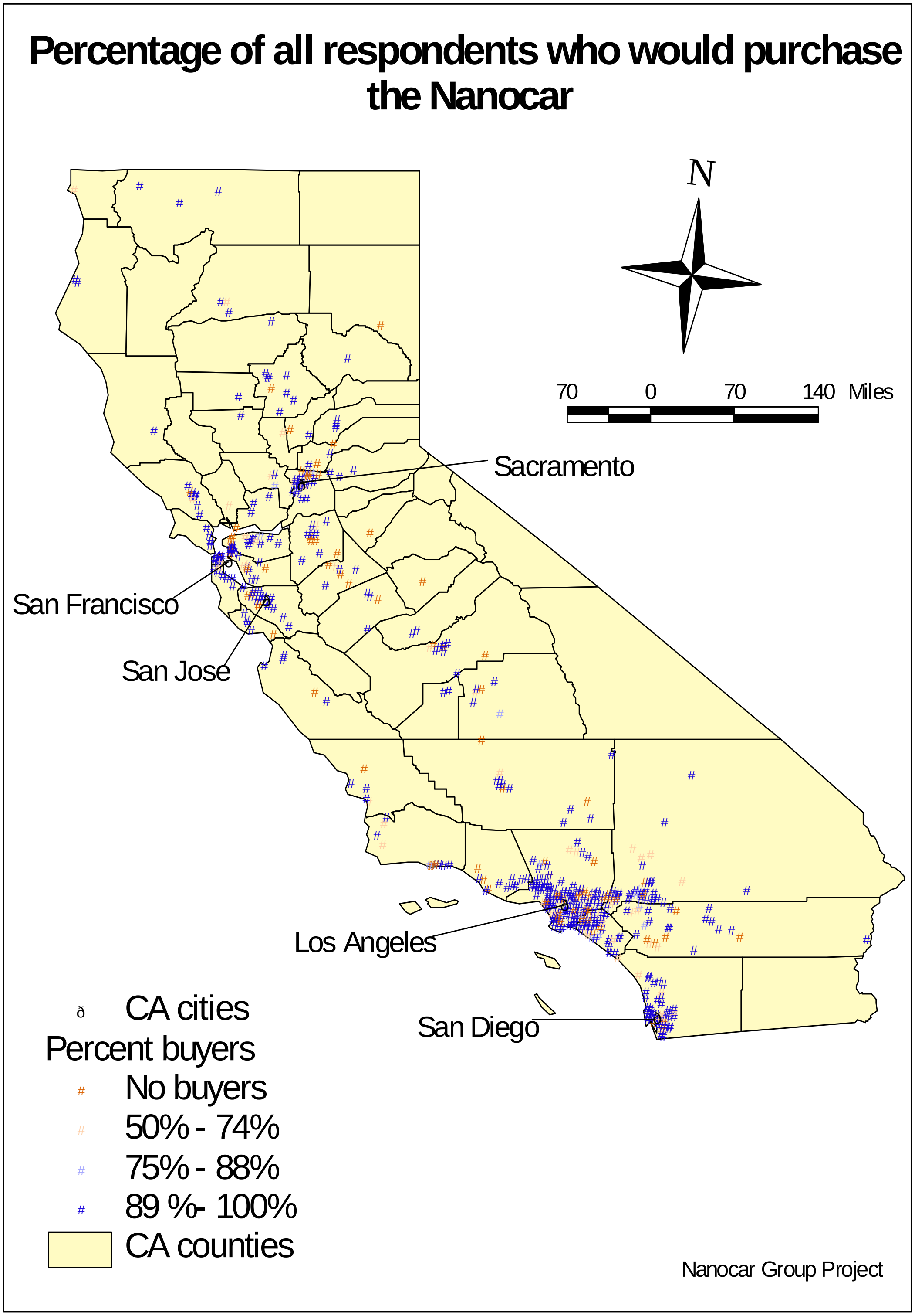
[45] Although the survey included only the stops that had the highest frequency from the initial focus group, most of the respondents chose the category "other" as one of their stops. This response could be expected since it is impossible for the survey to accommodate every stop that a respondent might make during a commute (see Appendix B-1l).

discussion of descriptive statistics for both general and transportation demographics is found in Appendix B-1.

### 3.2 Distribution and Demographic Preferences of Nanocar Buyers

In total, 78% of respondents indicated that they would buy a Nanocar given a certain set of incentives (see Figure 3.2). The geographical distribution of Nanocar buyers showed that there is a higher density of Southern Californians who would purchase the Nanocar than Northern Californians.

**Figure 3.2**


Percentage of all respondents who would purchase the Nanocar
N
70 0 70 140 Miles
Sacramento
San Francisco
San Jose
Los Angeles
San Diego
CA cities
Percent buyers
No buyers
50% - 74%
75% - 88%
89 %- 100%
CA counties
Nanocar Group Project

Although a simple geographic distribution showed this trend, the logit analysis of demographic information pertaining to the respondent indicated that the no-one geographic location had a greater inclination to purchase the Nanocar. In fact, the results showed that the highest income-range ($100,000+) had the greatest inclination towards purchasing the Nanocar. In addition, the two lowest income brackets also had an inclination towards purchasing the Nanocar. The parameter estimate for the oldest respondent range was negative, indicating that this age group was not inclined to purchase the Nanocar. No other demographic and commuting characteristics remained significant. The complete results of the logit regression are given in Appendix B-2.

### 3.3 Attribute Preferences for all the Respondents

For the entire dataset, eleven specific levels of attributes (out of 32) remained significant. The three variables that had the greatest utility were preferential parking at stores, and 50% as well as 100% reductions in parking fees. Preferential parking at work and stores, own lane on side streets with an associated 50% reduction in commute time and own lane on highways with an associated 25% reduction in commute time also had positive utilities (see Table 3.3a).[46]

[46] Statistical significance for this research is determined to be at the 95% confidence level.

**Table 3.3a**[47]

| MNL Results - All Respondents | | |
|---|---|---|
| Variable | Parameter Estimate | P-value |
| HWOLO25 | 0.524 | 0.0061** |
| HWOLO50 | -0.185 | 0.459 |
| HWOLA25 | 0.0373 | 0.0645 |
| HWOLA50 | 0.157 | 0.491 |
| HWBOTH25 | -0.0875 | 0.639 |
| HWBOTH50 | 0.0452 | 0.866 |
| HWSAME | 0 | - |
| SSOLO25 | 0.147 | 0.442 |
| SSOLO50 | -0.375 | 0.062 |
| SSOLA25 | 0.187 | 0.497 |
| SSOLA50 | 0.597 | 0.0021** |
| SSBOTH25 | 0.232 | 0.231 |
| SSBOTH50 | 0.335 | 0.642 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.000107 | <.0001*** |
| Tax Incentives | 0.000111 | 0.0482* |
| Price of Gas | -0.527 | <.0001*** |
| Parking Fee Reduction 25 | 0.41 | 0.0154* |
| Parking Fee Reduction 50 | 0.84 | <.0001*** |
| Parking Fee Reduction 75 | 0.225 | 0.2524 |
| Parking Fee Reduction 100 | 0.735 | <.0001*** |
| No Parking Fee Reductions | 0 | - |
| Refueling Ability at Home | -0.269 | 0.632 |
| Refueling Ability at Work | 0.29 | 0.0376* |
| Refueling Ability at Home and Work | 0.115 | 0.4 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.232 | 0.869 |
| 50% Annual Fuel Reductions | 0.214 | 0.118 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.871 | <.0001*** |
| Preferential Parking at Work | 0.699 | <.0001*** |
| No Preferential Parking | 0 | - |

The main infrastructure changes that remained significant were own lane on an existing highways with an associated 25% reduction in commute time (HWOLO25) and a separate lane on side streets with an associated 50% reduction in commute time (SSOLA50). The price of the Nanocar and associated tax incentives both remained

[47] * denotes p-value ≤ 0.05
** denotes p-value ≤ 0.01
*** denotes p-value ≤ 0.001

significant as well. As expected, the parameter estimate for price was negative while the parameter estimate for tax incentive was positive indicating that the higher the price, the lower the demand for the Nanocar and the higher the tax incentives, the higher the demand for Nanocar. Three out of the four parking fee reductions remained significant with positive parameter estimates, as did preferential parking at stores and work. In addition, the ability to refuel at work remained significant with a positive parameter estimate and price of gas remained significant with a negative parameter estimate. The lowest positive parameter estimate relating to the purchase of the Nanocar was tax incentives.[48]

### 3.3.1 Attribute Preferences for All Respondents with Infrastructure Variables

Table 3.3b shows the MNL results for all respondents with infrastructure variable groupings. The results imply that the attribute with the strongest utility contribution was parking fee reductions of 50%, followed by parking fee reductions of 100% and preferential parking at stores. None of the highway or side street infrastructure additions remained significant. As with the prior analysis, the attributes of parking fee reduction, price of gas, and preferential parking remained significant with the same parameter estimate sign. However, the ability to refuel at work lost its significance. Again, the smallest positive parameter estimate was tax incentive.

[48] Since "Price of Vehicle" and "Tax Incentive" are continuous variables, they must be multiplied by the actual numbers assigned to them so that their utilities can be appropriately compared to those of other categorical variables. In this example, the parameter estimate for tax incentive was multiplied by $3,000, the largest available tax break for environmentally friendly vehicles today.

**Table 3.3b**

**MNL Results - All Respondents With Infrastructure Variables**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HWOLO | 0.284 | 0.0968 |
| HWOLA | 0.139 | 0.43 |
| HWBOTH | -0.0313 | 0.855 |
| HWSAME | 0 | - |
| SSOLO | -0.155 | 0.306 |
| SSOLA | 0.291 | 0.066 |
| SSBOTH | 0.168 | 0.251 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.0000956 | <.0001*** |
| Tax Incentive | 0.000169 | 0.0015** |
| Price of Gas | -0.499 | <.0001*** |
| Parking Fee Reduction 25 | 0.395 | 0.0127* |
| Parking Fee Reduction 50 | 0.669 | <.0001*** |
| Parking Fee Reduction 75 | 0.266 | 0.105 |
| Parking Fee Reduction 100 | 0.643 | <0.0001*** |
| No Parking Fee Reductions | 0 | - |
| Refueling Ability at Home | -0.214 | 0.117 |
| Refueling Ability at Work | 0.172 | 0.146 |
| Refueling Ability at Home and Work | 0.0542 | 0.685 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.0779 | 0.498 |
| 50% Annual Fuel Reductions | 0.247 | 0.559 |
| No Annual Fuel Reductions | - | - |
| Preferential Parking at Stores | 0.647 | <.0001*** |
| Preferential Parking at Work | 0.583 | <.0001*** |
| No Preferential Parking | 0 | - |

### 3.3.2 Attribute Preferences for All Respondents with Commute Time Variables

Table 3.3c shows the results of the MNL analysis for all respondents with commute time variable groupings. The results show that the only infrastructure change to remain significant was highway infrastructure changes with a 25% reduction in commute time; the associated parameter estimate was positive. Price of vehicle and price of gas remained significant with the same parameter estimate signs as in the previous tables. However, tax incentives did not remain significant. In terms of parking advantages, the preferential parking attributes that were significant in the previous tables also remained significant in this analysis. Furthermore, the parking fee reductions that remained significant in the previous analysis remained significant, except for parking fee reductions of 25%. The attribute of refueling at work no longer remained significant. However, a 50% reduction in annual fuel costs became significant and had a positive parameter estimate. Again, the attribute with the strongest parameter estimate was parking fee reductions of 100% and the weakest positive parameter estimate was tax incentive.

**Table 3.3c**

**MNL Results - All Respondents With Commute Time Variable**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HW25 | 0.309 | 0.0472* |
| HW50 | 0.146 | 0.395 |
| HWSAME | 0 | - |
| SS25 | 0.0786 | 0.5976 |
| SS50 | 0.247 | 0.0716 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.000102 | <.0001*** |
| Tax Incentives | 0.000161 | 0.0818 |
| Price of Gas | -0.601 | <.0001*** |
| Parking Fee Reduction 25 | 0.454 | 0.0839 |
| Parking Fee Reduction 50 | 0.659 | <.0001*** |
| Parking Fee Reduction 75 | 0.0376 | 0.836 |
| Parking Fee Reduction 100 | 0.849 | <.0001*** |
| No Parking Fee Reductions | 0 | - |
| Refueling Ability at Home | -0.207 | 0.121 |
| Refueling Ability at Work | 0.0669 | 0.588 |
| Refueling Ability at Home and Work | 0.0429 | 0.749 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.117 | 0.32 |
| 50% Annual Fuel Reductions | 0.303 | 0.0169* |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.697 | <.0001*** |
| Preferential Parking at Work | 0.63 | <.0001*** |
| No Preferential Parking | 0 | - |

### 3.4 Attribute Preferences for Commuters

Table 3.4a shows the MNL results for commuters. The attribute that contributed the most to the utility derived from purchasing the Nanocar was once again the parking fee reductions of 50%. The highway infrastructure changes that remained significant were the ones that gave respondents a 25% reduction in commute time (excluding the "both" option) and the side street infrastructure changes that gave respondents a 50% reduction in commute time remained significant. These attributes had positive parameter estimates except for an own lane on existing side streets with a 50% reduction in commute time (SSOLO50), which had a negative parameter estimate. Other parameters that remained significant were the price of the Nanocar, price of gas, reductions in parking fees, refueling ability at work, preferential parking at stores and at work, and a 25% reduction in annual fuel costs.

**Table 3.4a**

| MNL Results - Commuters | | |
|---|---|---|
| Variable | Parameter Estimate | P-value |
| HWOLO25 | 0.55245 | 0.0119* |
| HWOLO50 | -0.13154 | 0.641 |
| HWOLA25 | 0.52484 | 0.0221* |
| HWOLA50 | 0.14591 | 0.578 |
| HWBOTH25 | -0.12285 | 0.5718 |
| HWBOTH50 | 0.01877 | 0.9534 |
| HWSAME | 0 | |
| SSOLO25 | 0.10185 | 0.6363 |
| SSOLO50 | -0.48163 | 0.035* |
| SSOLA25 | 0.29447 | 0.3145 |
| SSOLA50 | 0.65105 | 0.0028** |
| SSBOTH25 | 0.31858 | 0.1403 |
| SSBOTH50 | 0.47372 | 0.0245* |
| SSSAME | 0 | |
| Price of Vehicle | -0.0000995 | <.0001*** |
| Tax Incentives | 0.0000775 | 0.2244 |
| Price of Gas | -0.50875 | <.0001*** |
| Parking Fee Reduction 25 | 0.51515 | 0.0074** |
| Parking Fee Reduction 50 | 0.99391 | <.0001*** |
| Parking Fee Reduction 75 | 0.33428 | 0.1414 |
| Parking Fee Reduction 100 | 0.83033 | <.0001*** |
| No Parking Fee Reductions | 0 | |
| Refueling ability at home | -0.30185 | 0.0686 |
| Refueling ability at work | 0.35525 | 0.0227* |
| Refueling ability at home and work | 0.04638 | 0.764 |
| Refueling at Fuel Stations | 0 | |
| 25% Annual Fuel Reductions | -0.33935 | 0.0261* |
| 50% Annual Fuel Reductions | 0.09255 | 0.5501 |
| No Annual Fuel Reductions | 0 | |
| Preferential Parking at Stores | 0.87808 | <.0001*** |
| Preferential Parking at Work | 0.70304 | <.0001*** |
| No Preferential Parking | 0 | |

### 3.4.1 Attribute Preferences for Commuters with Infrastructure Variables

Table 3.4b shows the results for commuters with infrastructure variable groupings. The only infrastructure attribute that remained significant was the attribute for an own lane away from existing side streets. The other noteworthy deviation from the general analysis for commuters is the significance of all four parking fee reduction attributes and the loss in significance of a 25% reduction in annual fuel cost. Again, the attribute with the strongest parameter estimate was parking fee reductions of 50% with tax incentive being the smallest positive parameter estimate to remain significant.

**Table 3.4b**

| MNL Results - Commuters With Infrastructure Groupings | | |
|---|---|---|
| Variable | Parameter Estimate | P-value |
| HWOLO | 0.31531 | 0.11 |
| HWOLA | 0.22696 | 0.2638 |
| HWBOTH | -0.0528 | 0.7646 |
| HWSAME | 0 | |
| SSOLO | -0.22025 | 0.1966 |
| SSOLA | 0.37661 | 0.0343* |
| SSBOTH | 0.24794 | 0.1413 |
| SSSAME | 0 | |
| Price of Vehicle | -0.0000903 | <.0001*** |
| Tax Incentives | 0.0001401 | 0.0182* |
| Price of Gas | -0.44982 | <.0001*** |
| Parking Fee Reduction 25 | 0.49129 | 0.0055** |
| Parking Fee Reduction 50 | 0.81934 | <.0001*** |
| Parking Fee Reduction 75 | 0.38122 | 0.044* |
| Parking Fee Reduction 100 | 0.76494 | <.0001*** |
| No Parking Fee Reductions | 0 | |
| Refueling ability at home | -0.24314 | 0.1713 |
| Refueling ability at work | 0.23646 | 0.0707 |
| Refueling ability at home and work | 0.00784 | 0.9589 |
| Refueling at Fuel Stations | 0 | |
| 25% Annual Fuel Reductions | -0.15452 | 0.2317 |
| 50% Annual Fuel Reductions | 0.16334 | 0.2623 |
| No Annual Fuel Reductions | 0 | |
| Preferential Parking at Stores | 0.64158 | <.0001*** |
| Preferential Parking at Work | 0.53925 | 0.0003** |
| No Preferential Parking | 0 | |

### 3.4.2 Attribute Preferences for Commuters with Commute Time Variables

Table 3.4c shows the results of the MNL model for commuters only with commute time variable groupings. Again, similar to the analysis for commuters with infrastructure groupings, none of the infrastructure attributes (highway and side street infrastructure change) remained significant, regardless of the commute time associated with the change. However, some attributes were significant at the 94% confidence interval (these are highlighted in light blue). As before, price, tax incentive, and price of gas continued to remain significant with same parameter estimate signs. Three of the four parking fee reduction attribute levels remain significant as well as the preferential parking attribute levels. As in the previous analyses, the tax incentive variable continued to have the weakest positive parameter estimate while parking fee reductions of 100% had the strongest.

**Table 3.4c**

**MNL Results - Commuters With Commute Time Groupings**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HW25 | 0.346 | 0.0531 |
| HW50 | 0.153 | 0.44 |
| HWSAME | 0 | - |
| SS25 | 0.159 | 0.342 |
| SS50 | 0.302 | 0.0527 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.000968 | <.0001*** |
| Tax Incentives | 0.000126 | 0.0272* |
| Price of Gas | -0.549 | <.0001*** |
| Parking Fee Reduction 25 | 0.571 | 0.0013** |
| Parking Fee Reduction 50 | 0.806 | <.0001*** |
| Parking Fee Reduction 75 | 0.0931 | 0.639 |
| Parking Fee Reduction 100 | 0.996 | <.0001*** |
| No Parking Fee Reductions | 0 | - |
| Refueling Ability at Home | -0.237 | 0.118 |
| Refueling Ability at Work | 0.118 | 0.385 |
| Refueling Ability at Home and Work | 0.00368 | 0.981 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annul Fuel Reductions | -0.205 | 0.124 |
| 50% Annual Fuel Reductions | 0.223 | 0.118 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.714 | <.0001*** |
| Preferential Parking at Work | 0.602 | <.0001*** |
| No Preferential Parking | 0 | - |

### 3.5 Attribute Preferences for Non-Commuters

For this subset, only price and parking advantages (preferential parking at stores and work and parking fee reductions of 50%) remained significant. This is in direct contrast to the number of significant attribute levels that remained significant for the commuter subset. Furthermore, the results of the model for aggregated commute time reductions for non-commuters showed that there is a loss in the number of attribute levels that remained significant as compared to the results of the commuter subset and the original data set. In this analysis, parking fee reductions of 50% was almost significant at the 95% confidence level, being significant at the 94% confidence level (the results for the MNL of non-commuters are provided in Appendix B-3).

### 3.6 Multinomial Logit Results for Net Cost Variable

In both the commuting and non-commuting subset, the net cost variable remained negative and significant. The significance of the other variables that were significant when the price and tax incentives were separate remained significant in this analysis. The results for the MNL of net cost variables are provided in Appendix B-4.

## 3.7 Choice Probability Results

The ten scenarios that had the highest choice probabilities out of the 40 matrices for the entire respondent set, the commuting subset, and the non-commuting subset with their associated incentive packages are shown in Table 3.7a.

Figure 3.7a illustrates the changes in choice probability when price is varied for all three respondent sets. As expected, the choice probabilities decrease exponentially for all respondent sets as the price of the vehicle is increased.

**Figure 3.7a**

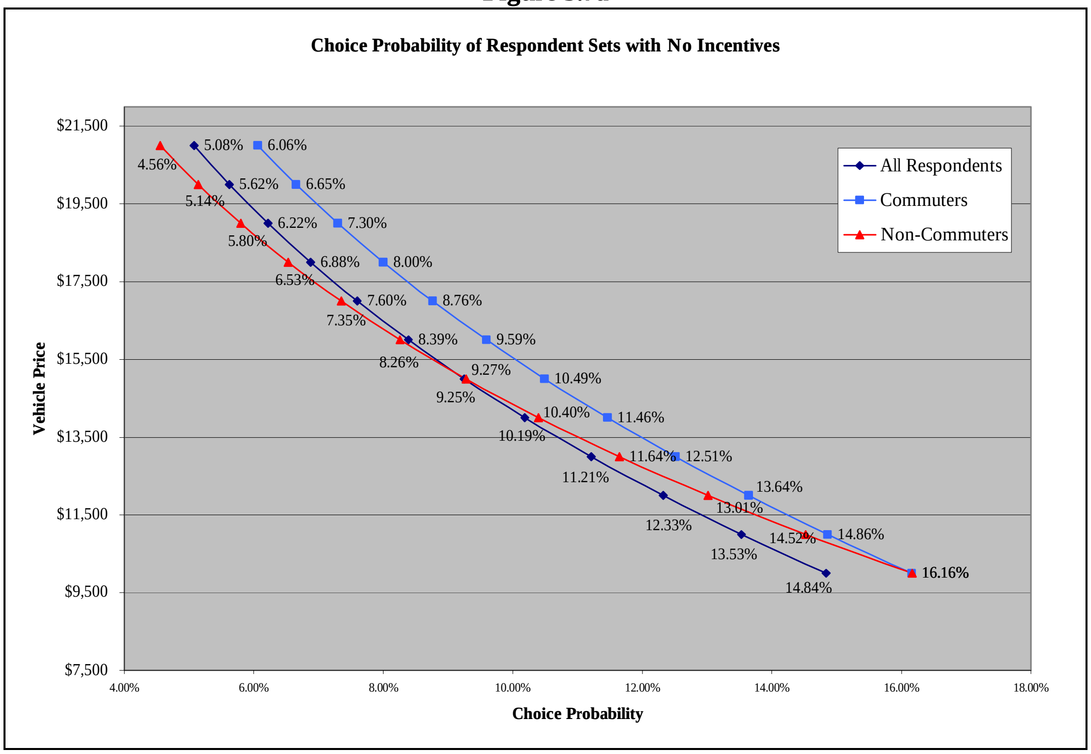


**Table 3.7a**

| Respondent Choice Probabilities | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rank | Matrix # | HW | SS | Price | Tax Inc. | Net Price | Price Rank | Gas Cost | Parking Fee | Refueling | Fuel Cost | Park | P |
| All Respondents | 1 | 2 | HWOLO50 | SSOLA50 | $10,000 | 3000 | $7,000 | #1 | 1.5 | PF100 | RFH | AFNONE | Work | 63.27% |
| | 2 | 3 | HWOLO50 | SSBOTH25 | $8,000 | 2500 | $5,500 | #1 | 2.5 | PF100 | RFS | AF50 | Stores | 47.25% |
| | 3 | 5 | HWOLO25 | SSOLA50 | $12,000 | 5000 | $7,000 | #2 | 2.5 | PF25 | RFS | AF50 | Work | 47.25% |
| | 4 | 1 | HWOLO50 | SSOLA25 | $12,000 | 0 | $12,000 | #2 | 1.5 | PF50 | RFALL | AF50 | Work | 42.12% |
| | 5 | 9 | HWBOTH50 | SSSAME | $10,000 | 1000 | $9,000 | #1 | 1.5 | PF100 | RFW | AF25 | Stores | 38.74% |
| | 6 | 4 | HWSAME | SSBOTH50 | $10,000 | 500 | $9,500 | #1 | 1.5 | PF50 | RFS | AF25 | Stores | 38.22% |
| | 7 | 10 | HWBOTH50 | SSOLA50 | $16,000 | 2500 | $13,500 | #1 | 1.5 | PF50 | RFW | AF50 | None | 37.83% |
| | 8 | 7 | HWOLO25 | SSBOTH50 | $8,000 | 3000 | $5,000 | #1 | 2.5 | PF75 | RFH | AFNONE | Stores | 34.38% |
| | 9 | 6 | HWBOTH25 | SSSAME | $12,000 | 2000 | $10,000 | #2 | 1.5 | PF25 | RFALL | AF50 | Stores | 33.61% |
| | 10 | 8 | HWOLA25 | SSOLA50 | $8,000 | 2000 | $6,000 | #1 | 2.5 | PF25 | RFALL | AF25 | None | 33.06% |
| Commuters | 1 | 2 | HWOLO50 | SSOLA50 | $10,000 | 3000 | $7,000 | #1 | 1.5 | PF100 | RFH | AFNONE | Work | 66.00% |
| | 2 | 3 | HWOLO50 | SSBOTH25 | $8,000 | 2500 | $5,500 | #1 | 2.5 | PF100 | RFS | AF50 | Stores | 51.11% |
| | 3 | 1 | HWOLO50 | SSOLA25 | $12,000 | 0 | $12,000 | #2 | 1.5 | PF50 | RFALL | AF50 | Work | 45.83% |
| | 4 | 6 | HWOLO25 | SSOLA50 | $12,000 | 500 | $11,500 | #2 | 2.5 | PF25 | RFS | AF50 | Work | 42.22% |
| | 5 | 9 | HWBOTH50 | SSSAME | $10,000 | 1000 | $9,000 | #1 | 1.5 | PF100 | RFW | AF25 | Stores | 39.28% |
| | 6 | 10 | HWBOTH50 | SSOLA50 | $16,000 | 2500 | $13,500 | #1 | 1.5 | PF50 | RFW | AF50 | None | 38.25% |
| | 7 | 7 | HWOLO25 | SSBOTH50 | $8,000 | 3000 | $5,000 | #1 | 2.5 | PF75 | RFH | AFNONE | Stores | 36.65% |
| | 8 | 8 | HWOLA25 | SSOLA50 | $8,000 | 2000 | $6,000 | #1 | 2.5 | PF25 | RFALL | AF25 | None | 36.20% |
| | 9 | 4 | HWSAME | SSBOTH50 | $10,000 | 500 | $9,500 | #1 | 1.5 | PF50 | RFS | AF25 | Stores | 32.28% |
| | 10 | 6 | HWBOTH25 | SSSAME | $12,000 | 2000 | $10,000 | #2 | 1.5 | PF25 | RFALL | AF50 | Stores | 31.79% |
| Non-commuters | 1 | 5 | HWOLO25 | SSOLA50 | $12,000 | 500 | $11,500 | #2 | 2.5 | PF25 | RFS | AF50 | Work | 44.60% |
| | 2 | 4 | HWOLO25 | SSBOTH50 | $10,000 | 500 | $9,500 | #1 | 1.5 | PF50 | RFS | AF25 | Stores | 44.16% |
| | 3 | 2 | HWOLO50 | SSOLA50 | $10,000 | 3000 | $7,000 | #1 | 1.5 | PF100 | RFH | AFNONE | Work | 40.63% |
| | 4 | 6 | HWBOTH25 | SSSAME | $12,000 | 2000 | $10,000 | #2 | 1.5 | PF25 | RFALL | AF50 | Stores | 38.20% |
| | 5 | 8 | HWSAME | SSSAME | $0 | 0 | $0 | NO BUY | 1.5 | PFNONE | RFS | AFNONE | None | 37.54% |
| | 6 | 9 | HWBOTH50 | SSSAME | $10,000 | 1000 | $9,000 | #1 | 1.5 | PF100 | RFW | AF25 | Stores | 35.80% |
| | 7 | 10 | HWSAME | SSSAME | $0 | 0 | $0 | NO BUY | 1.5 | PFNONE | RFS | AFNONE | None | 34.86% |
| | 8 | 3 | HWOLO50 | SSBOTH25 | $8,000 | 2500 | $5,500 | #1 | 2.5 | PF100 | RFS | AF50 | Stores | 34.78% |
| | 9 | 10 | HWBOTH50 | SSOLA50 | $16,000 | 2500 | $13,500 | #1 | 1.5 | PF50 | RFW | AF50 | None | 33.63% |
| | 10 | 7 | HWOLO25 | SSBOTH50 | $8,000 | 3000 | $5,000 | #1 | 2.5 | PF75 | RFH | AFNONE | Stores | 33.08% |

### 3.7.1 The Effect of Adding One Incentive to the Price Variable

The upward sloping trend in Figure 3.7b to 3.7d indicates that the incentives at the far right of each graph are the ones that increase the utility of the respondent the most. In other words, offering that single incentive to the respondent maximizes the likelihood that the person would choose to buy that package if only one incentive can be provided. It is interesting to note that tax incentives of $3,000 ranks lower than all or most of the other incentives in the entire respondent set and commuting subset. On the other hand, because many of the attributes were not significant for non-commuters, the graph for non-respondents indicates that the $3,000 tax break ranks higher than three other incentives.

**Figure 3.7b**

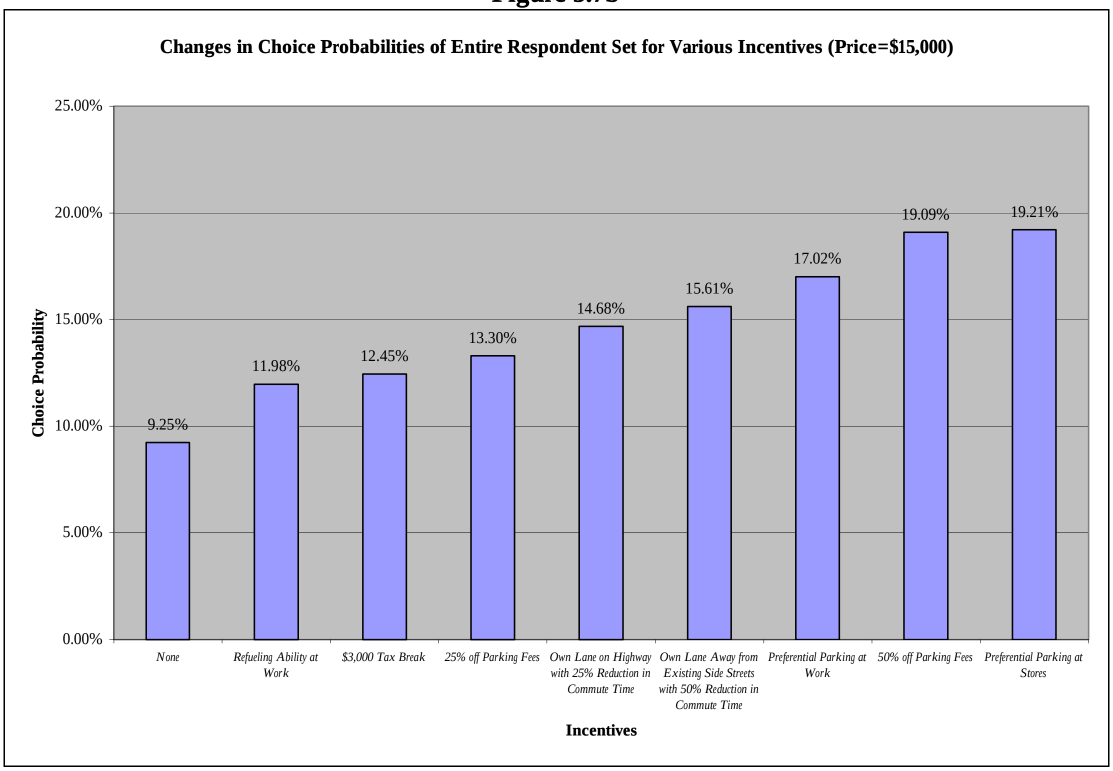


**Figure 3.7c**

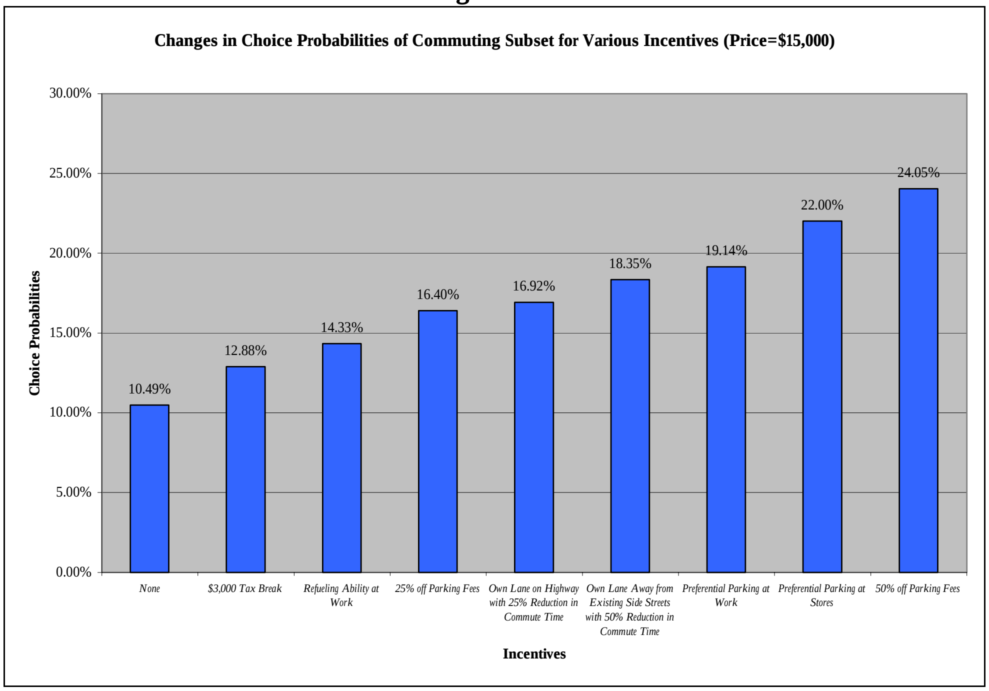
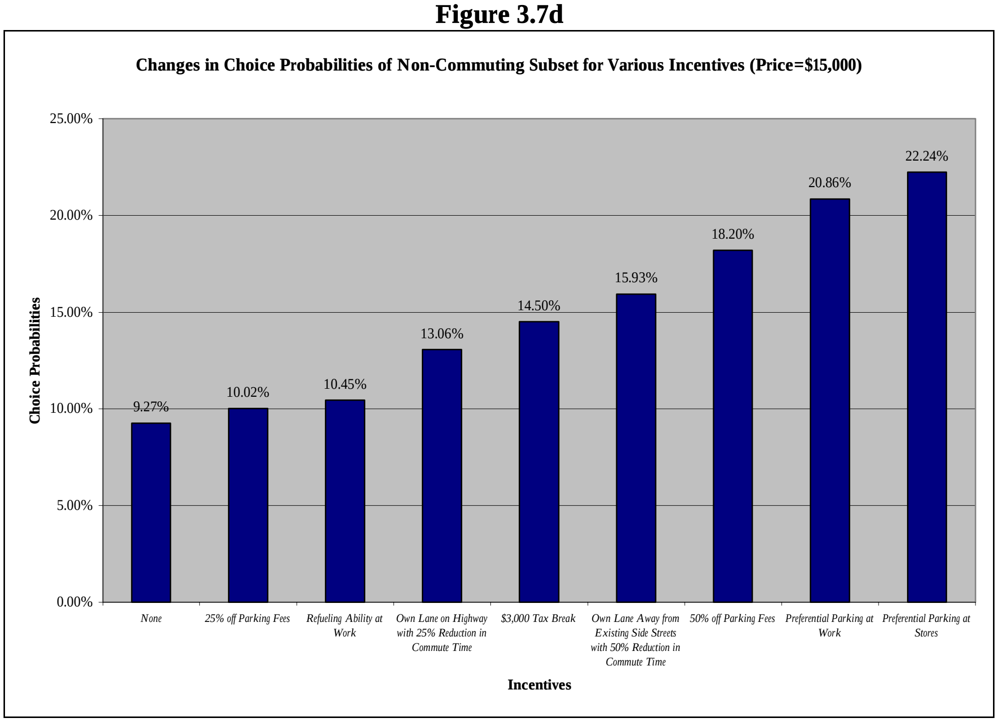



**Figure 3.7d**



### 3.7.2 The Effect of Offering Incremental Incentives

As Figure 3.7e illustrates, a combination of the incentives rather than a single incentive increases the choice probability margin. The choice probability increases approximately nine fold when all the significant and positive attributes are presented to a respondent from the entire respondent set as well as a respondent in the commuter subset. The result was slightly less (seven fold) for the non-commuting subset since only four attributes remained significant and positive in the results of the MNL, while the other two subsets had eight attributes included in the choice probability formula.

**Figure 3.7e**

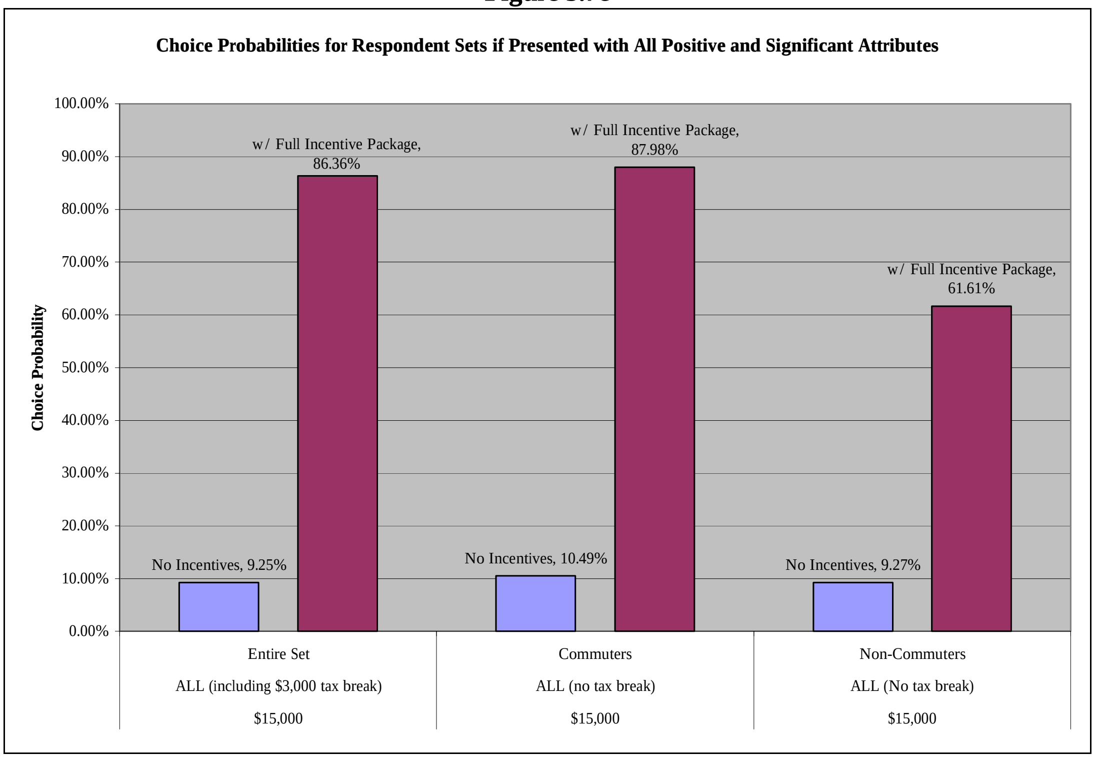


**Figure 3.7f**

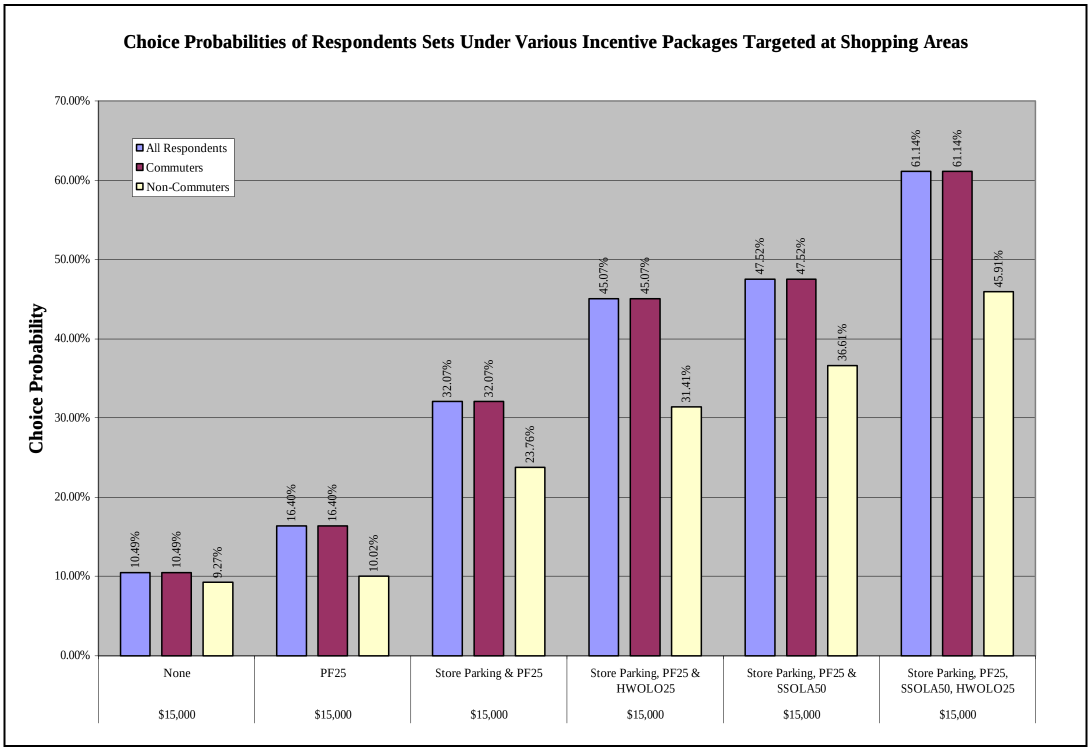
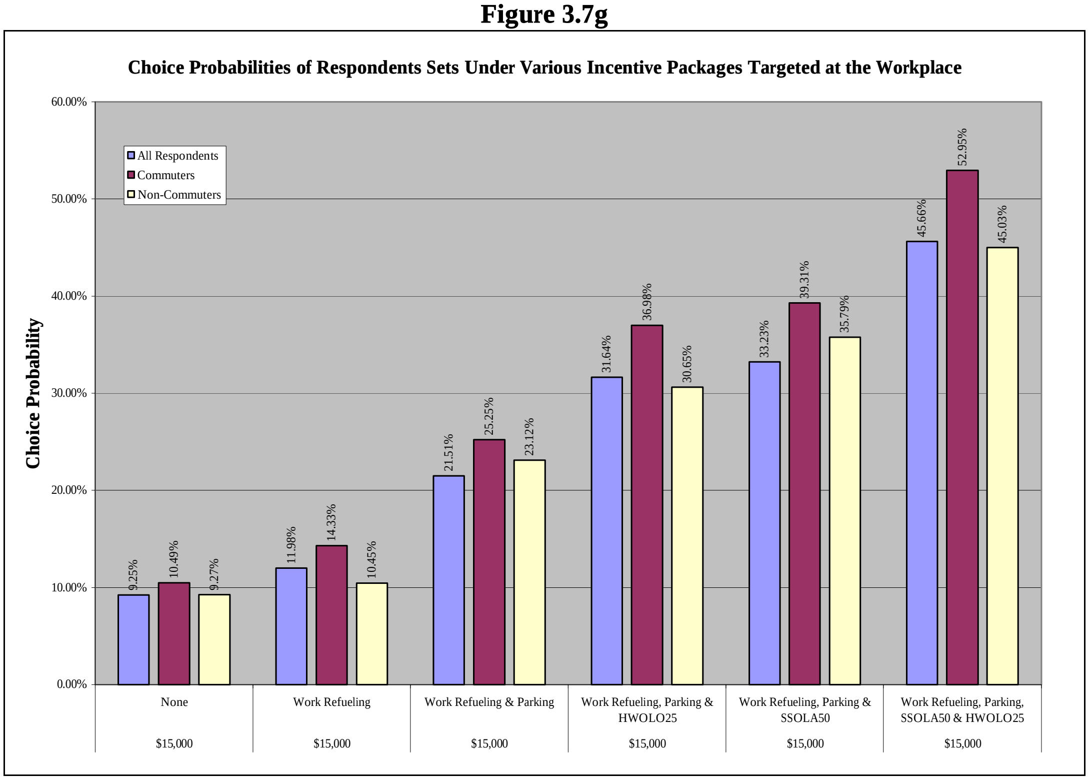



**Figure 3.7g**



As mentioned before, since the feasibility of implementing all the positive and significant incentives is difficult to envision, two practical incentive packages were developed and the choice probabilities analyzed. The results of these two packages are shown in Figure 3.7f and 3.7g. For the entire respondent set, the results for workplace incentive programs indicate that choice probabilities ranged between 12% and 46% (Price=$15,000) depending on the incentive package presented to the consumer. For shopping district incentive programs, the choice probabilities varied between 13% and 52%, implying that incentive programs for shopping districts would have a greater impact in increasing the choice probability than the workplace program if full incentives were provided for both. The results for the commuting and non-commuting subsets are analogous to the above results.

# CHAPTER 4

## ANALYSIS OF RESULTS

## 4.1 Implications of the Survey: Results of the Hypotheses Testing

1. *Survey respondents purchase the Nanocar solely on the basis of price and are not trying to get the most "bang for the buck" by including other variables into their purchasing decision.*

   The price of the vehicle (either MSRP or net price) always remained significant and the parameter estimate was always negative. In other words, the respondents exhibited normal demand and are more likely to purchase the vehicle at a lower cost rather than a higher cost. However, in three of the ten scenarios that had the highest choice probabilities among the 40 scenarios (shown in Table 3.7a), the respondents did not select the package with the lowest price. This suggests that in some cases respondents are willing to pay a higher price in order to take advantage of an incentive and therefore, are willing to make tradeoffs on price. In other words, though price is a significant purchasing factor for the Nanocar, it is not the only determining factor.

2. *Tax breaks and the advertisement of greater fuel efficiency are not an effective way of creating an incentive for environmentally friendly vehicle.*

   The results indicated that although the respondents account for tax incentives, it is not the primary purchasing factor. This is shown in the tax incentive parameter estimates of the full respondent set where the parameters were always positive and significant, but the utility gained from the highest tax break ($3,000) was relatively less than the utility derived from many of the other significant, positive, parameter estimates. Conversely, though the parameter estimates were positive for commuters and non-commuters alike, they did not remain significant, implying that these subsets of the full respondent set did not take tax incentives into account. This is probably due to the fact that the incentive does not result in "instant gratification." In other words, there is a lag between the time the initial vehicle payment is made and receiving the tax benefits or long-term savings from fuel efficiency result in consumers not including the monetary value of these benefits into their purchasing equation. However, the analyses utilizing net price as a variable showed that the net price variable was negative and significant for both cases implying that these subset populations are accounting for some combination of monetary incentives, rather than just the tax incentive. This is in line with the rational consumer theory since it states that consumers are more likely to buy at lower costs.

   This "instant gratification" theory also holds for annual fuel cost reductions which did not remain significant for the entire population set and non-commuting subset. This variable was negative and significant for the commuting subset. This result implies that in general, consumers do not take into account the savings associated with fuel efficiency into their purchasing formula and in cases where they did, the incentive was actually a deterrent to purchasing the vehicle. Therefore, for this variable, the theory of temporal discontinuity (i.e. instant gratification) holds.

It should be noted that parking fee reductions can also be grouped into the category of incentives that do not achieve instant gratification. In contrast to the other incentives that fall into this category however, survey respondents indicated that several levels of the parking fee reduction variable was important in their purchasing decision and increased the likelihood that they would purchase the Nanocar significantly. This result could be due to consumers being able to monetize parking fee reductions more effectively compared to an annual fuel cost reduction or a tax incentive, since they incur the cost everyday when they park at the store or at the workplace.

3. *Parking benefits and refueling advantages are not an effective way of creating incentives for purchasing environmentally friendly vehicles.*

   The variables associated with parking advantages remained significant for the full respondent set and the two subsets. In contrast, refueling advantages at stores or work was not a significant purchasing factor for the overall respondent set. Refueling advantages at work only remained significant for commuters. Therefore, the preliminary analysis suggests that existing programs in California to increase the number of refueling stations for alternative fuel vehicles (AFVs), such as charging stations in municipal parking lots, may not be an effective method to induce the purchase of environmentally friendly vehicles. Offering parking advantages is a more effective of way of swaying the consumer towards purchasing an environmentally friendly vehicle.

## 4.2 Other Implications of the Survey Results

- The variables that remained significant and had the highest positive utility factors for the entire respondent set as well as the commuting subset were parking advantages (e.g. preferential parking at stores and work and parking fee reductions) and infrastructure modifications on highways and side streets.
- Highway and side-street infrastructure modifications needs are similar for the entire respondent set and the commuting subset. In terms of the actual type of infrastructure, own lane away from existing side-streets with an associated 50% reduction in commute time and own lane on highway with a 25% reduction in commute time gives the greatest utility. Although these infrastructure modifications are the ideal types that could be implemented, the analysis using infrastructure grouping and commute time groupings indicates that there is also a compromise that can be made. For example, the responses of the entire respondent set showed that some variety of highway infrastructure modification is adequate if commute times are reduced by 25%. Another example is where the commuting subset indicated that some form of commute time reduction is sufficient but the side-street infrastructure modifications must be in the form of an own lane away from existing side-streets. It is important to note however that although these attributes remained significant, the positive utility factors associated with them are significantly lower than those of the ideal attributes thus questioning the effectiveness of these attributes in increasing the purchase likelihood.

- There is a significant difference between the purchasing preferences of commuters and non-commuters. For instance, the only variables that remained significant for non-commuters were price, preferential parking at stores and work, and parking fee reductions of 50%. On the other hand, price, various parking advantages and several levels of infrastructure modifications on both highways and side streets remained significant for commuters. This implies that non-commuters base their purchasing decision on price more than commuters, and commuters are more willing to trade off a higher price for the Nanocar for increased conveniences. In other words, the non-commuters are more price-sensitive than commuters. This is clearly illustrated in Figure 2.7.6a where the slope of the probability-price curve for non-commuters is steeper than that of the commuters. Furthermore, it is intuitive that non-commuters regard parking advantages as a purchasing factor since non-commuters tend to do household chores during the day rather than commute long distances during peak traffic times.
- The price of gas variable remained significant and negative throughout the survey for the entire respondent set and the commuting subset implying that as gas price increases the purchase probability decreased. Although this is intuitive, the implications are not as simple to decipher. First, this result may mean that the higher gas prices would lead potential buyers to not purchase the Nanocar or any other vehicles on the market due to the high fuel costs associated with driving in these conditions. On the other hand, the result may mean that higher gas prices lead potential buyers toward the purchase of other vehicles and therefore is a deterrent to purchasing the Nanocar. It is important to note that the initial intention of including this variable was to gauge whether consumers would be likely to purchase the Nanocar in high gas price conditions due to the fuel-efficiency advantages associated with the vehicle. Although the first explanation seems the most plausible, since it is difficult to determine the exact meaning of consumers' preferences to this variable, a conclusive remark is not presented.

### 4.3 Summation of Survey Results

When the above factors are taken into account, the following conclusions can be drawn:

1. There is a market for the Nanocar
2. Price will be the main determinant to whether or not the vehicle is purchased, but other monetary and non-monetary incentives will increase the purchase likelihood.
3. The most utility is gained from parking advantages and specific infrastructure changes, while annual fuel cost reductions do not influence the decision to purchase.
4. Tax incentives are not likely to have a great impact on whether or not the Nanocar is purchased as compared to other incentives.
5. Fuel savings, tax breaks and refueling advantages at home are incentives that reward the consumers who purchase the Nanocar rather than significant factors that are included in the consumer's purchasing decision.

### 4.4 Survey Analysis Caveats

Further research regarding these analyses should keep in mind the following caveats regarding the findings of the paper.

1.) The main caveat that must be noted when reviewing the research performed is that the IIA assumption holds for the MNL model. Although the MNL is the most "popular choice modeling framework" for stated preference surveys, it does rest on a number of assumptions (Louviere et. al. 2001). The "no buy" option given to respondents in the survey matrix makes the IIA assumption tenuous. In an attempt to solidify the IIA assumption, the researchers assigned status quo values to the "no buy" option during the coding of the database and survey analysis stage. Given the timeframe and resources of the researchers, this step was necessary to support the use of the MNL model as opposed to another, more statistically sound model that allows for a relaxing of the IIA assumption, such as a nested logit model.[49] Further research should explore this statistical avenue.

2.) Another qualification that must be noted is the selection of only main effects in the creation of the optimal design. Two-way interactions and higher-order interactions were ignored in determining the optimal design out of which the scenario matrices were made. Two-way and higher-order interactions were ignored because of the already large number of main effect combinations and the high levels of variance that can be explained by looking only at main effects. Main effects can account for 70% to 90% of the variance while two-way interactions account for an additional 5% to 15% of observed variance. Higher order interactions account for the remainder of the observed variance. Therefore, main effects can explain the majority of the variance observed in choosing the Nanocar. Further research should focus on the impact of two way and higher order interactions of the attributes and their corresponding levels.

For this reason, some attributes may show significance when in fact significance is caused by the interaction between multiple attributes. In particular, the significance of categorical attributes with small number of levels, such as preferential parking, may be more likely to show this effect because the way the optimization program matched these attributes with other attributes.

3.) It was assumed that by specifying safety and amenity features of the Nanocar, respondents truly took this information into account when making their purchasing decision. This assumption removes the effect of safety and automobile amenities from a respondent's choice equation. Therefore, these factors are not accounted for in the error term of a respondent's choice equation.

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[49] A nested logit model is essentially a set of "hierarchical MNL models, linked by a set of conditional relationships" (Louviere et. al. 2001). A nested logit model in this case would first predict the probability of choosing to purchase the Nanocar and the probability of not purchasing the Nanocar. The nested logit model would next predict the probability of buying a given Nanocar scenario taking into account the fact that a number of respondents chose the "no buy" option. The researchers believe, however, that by coding the "no buy" option in the manner stated above, the use of a MNL model is acceptable.

# CHAPTER 5

## **AIR** QUALITY **ANALYSIS**

## 5.1 Introduction

Since the largest number of survey respondents in a given geographic area originated in the greater Los Angeles region and due to their history of poor air quality throughout the 20th Century, this area was targeted for a detailed air quality analysis. According to the 1990 U.S. Census, 85.6% of Los Angeles commuters used a private automobile as their primary source of transportation. This means approximately 3.5 million people in 1990 traveled to work via automobile. Los Angeles County has had a history of non-attainment for criteria pollutants and as of January 15, 2002, the EPA designated Los Angeles County as being in "serious non-attainment" for Carbon Monoxide (CO) (EPA Greenbook 2002). The introduction of the Nanocar allows for a means of potentially bettering air quality conditions in Los Angeles.

This section investigates the contribution that the Nanocar could make to the overall decrease in automobile emissions by considering the impact of introducing the Nanocar onto urban roads in Los Angeles County based on the number of respondents that said they would actually purchase the vehicle in the area.[50]

## 5.2 Nanocar Air Quality Research

It is assumed that the emissions of the Nanocar will meet the SULEV requirements set by the EPA.[51] The SULEV and Tier 1 standards are listed in Table 5.2.

**Table 5.2:Tier 1 Federal and California Certification Exhaust and Emission Standards**

| | | | | |
|---|---|---|---|---|
| | | **5year/50,000 Miles, grams/mile** | | |
| Federal | | Non-Methanol Hydrocarbons (NMHC) | Carbon Monoxide (CO) | Nitrogen Oxides (NOx) |
| California | Tier 1 | 0.25 | 3.4 | 0.4 |
| Federal & California | Tier 1 | 0.25 | 3.4 | 0.4 |
| | SULEV | 0.01 | 1.02 | 0.02 |
| | | **10 years/100,000miles, grams/mile** | | |
| Federal | Tier 1 | 0.31 | 4.2 | 0.6 |
| California | Tier 1 | 0.31 | 4.2 | 0.6 |
| Federal & California | SULEV | 0.0124 | 1.26 | 0.03 |

### 5.2.1 The Model

The analysis was conducted using California Air Resources Board's (CARB) draft EMFAC (EMissions FACtor) 2001[52] model. The model was produced by CARB to

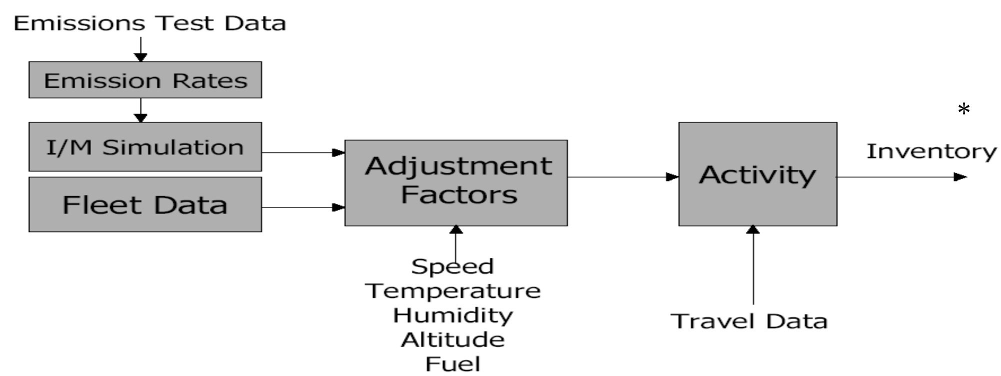
[50] Refer to Appendix C-1 for further information regarding the history of air quality problems, current air quality regulations, and a summary of atmospheric chemistry relating to air pollution.

[51] SULEV vehicle must achieve reductions in hydrocarbon emissions of 96%, carbon monoxide emissions of 70% and nitrogen oxide emissions of 95% when compared with the minimum (Tier 1) standard.

calculate California's emissions inventory for on-road motor vehicles and provide estimates of the amounts and types of pollutants emitted from the millions of vehicles operating in California. The model schematic is shown in Figure 5.2. The data that provides the basis for EMFAC2001 are obtained from extensive testing of motor vehicles conducted by the CARB and the EPA (see Appendix C-2 for the list of data sources). The emission inventories are used to form the basis of clean air plans required under State and Federal law.

The model estimates include the total emissions for the entire state and subtotals for each of the 17 air basins, 13 districts and 58 counties. Emission rates and inventories are produced for 45 different vehicle classes (see Appendix C-3) for exhaust and evaporative hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter associated with exhaust, tire-wear and brake-wear, oxides of sulfur, lead, and carbon dioxide. EMFAC2001 also incorporates hourly and county specific estimates of temperature, wind speed, vehicle miles traveled (VMT), and humidity. The carbon dioxide inventory is used to estimate fuel consumption. The model can be used to calculate current year inventories and to back-cast and forecast inventories for calendar years 1980 to 2040.

**Figure 5.2: Flow Diagram of EMFAC2001**




**The activity includes:**

- New population estimates derived through the analysis of DMV data.
- Registration distributions, the population of vehicles by age using DMV data.
- Vehicle class and county specific mileage accrual rates derived through the analysis of BAR smog check records.
- Vehicle class specific retention rates, the number of vehicles of a particular model year that remain in the fleet in a given calendar year.
- Estimates of vehicle miles of travel for heavy-duty vehicles, buses and motorcycles calculated as the product of vehicle population and mileage accrual rates.

[52] The Model is under revision and is therefore only available in the draft version. It is currently only being used by the Bay Area as a pilot study.

## 5.3 Method

Based on travel statistics for Los Angeles County, the model was used to forecast the changes that would result in emission reductions of CO and NOx due to the introduction of the Nanocar. The default vehicle sales fraction values included the EMFAC2001 model was used to establish a 1990 baseline. The introduction date for the Nanocar was set at January 2005 and projected to 2020. It was assumed that the Nanocar's emissions would meet SULEV standards and only affect the Light Duty Vehicles (LDV) category.

Although the 78% purchase rate obtained for Los Angeles County from the survey results represents the number of respondents that opted to purchase the Nanocar given a certain set of incentives, this value was thought to be extremely optimistic. Therefore, the sales fractions for the different technology classes were adjusted to include a conservative 10% and 20% purchase rate for the Nanocar (see Appendix C-4 baseline and adjusted sales).

## 5.4 Results

The emissions of NOx and CO for the status quo (baseline) and for the 10% and 20% introduction Nanocar sales are presented in Table 5.4a. What the results indicate is that for 10% sales of the Nanocar, the reductions in emissions achieved for CO and NOx in 2020 were 1.36 tons/day (496 tons/yr) and 0.06 tons/day (25.55 tons /yr) respectively. For 20% sales the emissions reductions were 4.2 tons/day (1533 tons/yr) and 0.17 tons/day (62.05 tons/yr) respectively, see Table 5.4b.[53] The corresponding number of Nanocars on the road in the year 2020 is 741,708 (10% sales) and 1,483,416 (20% sales), see Table 5.4c.

[53] Refer to Appendix C-5 for further results from the emissions analysis

| Table 5.4a : NOx and CO Emissions For the Baseline Scenario, 10% Nanocar and 20% Nanocar Introductions (tons/day) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | | | 10% SULEV (Nanocar) | | | | 20% SULEV (Nanocar) | | | |
| | Total CO | | Total NOx | | Total CO | | Total NOx | | Total CO | | Total NOx | |
| YEAR | LDV TOTAL | ALL TOTAL | LDA TOT | ALL TOTAL | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL |
| 2006 | 982.13 | 1806.22 | 85.66 | 311.41 | 981.91 | 1806.01 | 85.65 | 311.40 | 981.69 | 1805.79 | 85.63 | 311.39 |
| 2010 | 699.03 | 1335.33 | 59.28 | 234.38 | 697.57 | 1333.87 | 59.18 | 234.28 | 696.36 | 1332.66 | 59.10 | 234.19 |
| 2016 | 426.18 | 849.77 | 32.87 | 137.27 | 424.45 | 848.04 | 32.79 | 137.18 | 422.54 | 846.13 | 32.69 | 137.09 |
| 2020 | 206.37 | 415.08 | 13.91 | 73.04 | 205.01 | 413.72 | 13.84 | 72.98 | 202.17 | 410.88 | 13.74 | 72.87 |

| Table 5.4b: Reductions in Emissions From the Baseline | | | | | |
|---|---|---|---|---|---|
| | | 10% Nanocar | | 20% Nanocar | |
| | Year | Total CO | Total NOx | Total CO | Total NOx |
| Tons/day | 2006 | 0.22 | 0.01 | 0.44 | 0.03 |
| | 2010 | 1.46 | 0.1 | 2.67 | 0.18 |
| | 2016 | 1.73 | 0.08 | 3.64 | 0.18 |
| | 2020 | 1.36 | 0.07 | 4.2 | 0.17 |
| Tons/yr | 2006 | 80.3 | 3.65 | 160.6 | 10.95 |
| | 2010 | 532.9 | 36.5 | 974.55 | 65.7 |
| | 2016 | 631.45 | 29.2 | 1328.6 | 65.7 |
| | 2020 | 496.4 | 25.55 | 1533 | 62.05 |

| Table 5.4c: Projection of the Volume of Nanocars | | | | | | |
|---|---|---|---|---|---|---|
| | 10% Nanocar | | 20% Nanocar | | Total Vehicles | |
| Year | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL |
| 2005 | 2,352,690 | 3,993,470 | 4,705,380 | 7,986,940 | 23,526,900 | 39,934,700 |
| 2010 | 3,834,750 | 6,410,140 | 7,669,500 | 12,820,280 | 38,347,500 | 64,101,400 |
| 2015 | 22,717 | 36,039 | 8,539,140 | 14,359,960 | 42,695,700 | 71,799,800 |
| 2020 | 741,708 | 1,162,300 | 1,483,416 | 2,324,600 | 7,417,080 | 11,623,000 |
| **Table: Projection of Vehicle Miles Traveled (VMT/1000) by Nanocars** | | | | | | |
| | 10% SULEV | | 20% SULEV | | VMT | |
| Year | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL | LDV TOTAL | ALL TOTAL |
| 2005 | 13,136 | 21,503 | 26,271 | 43,006 | 131,356 | 215,032 |
| 2010 | 20,600 | 32,580 | 41,199 | 65,160 | 205,996 | 325,800 |
| 2015 | 22,717 | 36,039 | 45,434 | 72,077 | 227,169 | 360,386 |
| 2020 | 24,699 | 39,249 | 49,397 | 78,498 | 246,986 | 392,491 |

## 5.5 Implications of the Air Emissions Results

Despite the remarkable progress that has been made in improving the air quality of the Los Angeles air basin and California since the 1970s, there still remains much to be done. Southern California still has over 100 days per year of high ozone levels (Hall 2001). As part of the EPA's 1970 Clean Air Act, states are required to prepare State Implementation Plans (SIPs) in order to meet the health-based National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, two of which are CO and $NO_2$. As a result of progressive state laws, the reduction of automobile emissions in California has become a primary objective for current transportation systems. These transportation objectives must be balanced against traditional planning goals of increasing mobility and reducing congestion while fostering economic growth. In order to meet the aforementioned objectives and fulfill the SIP requirements, counties have developed Regional Transportation Plans (RTP). These plans provide comprehensive, long-range views of transportation issues, needs and opportunities, and actions necessary to achieve them. One aspect of the RTP is the development of Transportation Control Measures (TCMs) that are designed to address congestion and associated air quality problems.

Though reductions in emissions were only calculated for Los Angeles County, all the other metropolitan areas in California could potentially benefit from the introduction of the Nanocar. Based on the findings of the emissions reduction analysis for Los Angeles County, successful introduction of the Nanocar in the major metropolitan areas could result in significant reductions in regional air emissions. However, it is important to note that the introduction of the Nanocar alone will not be sufficient to meet the regional attainment goals. Though it could potentially result in substantial emissions reductions, the Nanocar is essentially an innovative TCM that would contribute to California's plans to meet the SIP requirements.

# CHAPTER 6

## RECOMMENDATIONS AND PRACTICAL APPLICATIONS

## 6.1 Introduction

We have developed a set of incentive programs that target the commuting population as they have the greatest potential for improving mobility and air quality. The commuting subset is the main cause of high air pollution concentrations during peak rush hours and the major mobility problems are caused by peak hour traffic. By developing a supplemental program that could be incorporated as a transportation demand measure (TDM) into various RTPs, the potential results could be an increase in the proportion of SULEV vehicles on the road, and the consequent decrease in air emissions and a quality of air closer to the NAAQS. In addition, reduced traffic congestion, reduced commute times and a resultant increase in worker productivity would be achieved because of the ultra-compact size of the Nanocar. Moreover, the respondent set of only commuters were 10% more likely to purchase a Nanocar, under any scenario, than for non-commuters. This implies that market proliferation of the Nanocar would depend primarily on commuters purchasing the vehicle.

Our recommendations to improve the likelihood of commuters purchasing Nanocars are divided into two areas; broad recommendations to policymakers and the auto industry, and specific infrastructure recommendations.

## 6.2 Recommendations to Policymakers and the Auto Industry

- Timing: A collaborative effort between all levels of policymakers and the automotive industry must be made so that the incentives and the vehicles come on-line in the same timeframe. In addition, there must be common understanding that by doing so, a win-win situation can be realized for all concerned parties; policymakers achieve cleaner air, reduced traffic congestion and an increased tax base due to increased worker productivity; automakers are able to comply with regulations as well as profit from the increased market size; and commuters are able to make a purchase that increases convenience without having to drastically alter their purchasing preferences.
- Good faith marketing: The results indicate that tax incentives are a significant purchasing factor, albeit with the lowest purchasing influence out of the entire set of significant purchasing factors. However, in the purchasing scenario presented to the respondent, they were given full information at the time of purchase. It is thought that this does not mirror the current purchasing scenario because the availability of Federal and State tax incentives is not advertised at the time of purchase. Therefore, in order to create a purchasing scenario that is on par with buying a standard automobile, the automotive companies must be willing to commit as much resources into advertising the Nanocar and its incentives as any other vehicle in their fleet and regulators must also increase consumer awareness of these incentives through marketing of their own. In addition, non-government agencies (NGO's) may be able to assist in educating the public towards the incentives associated with the Nanocar.
- The price of the Nanocar should be set between $10,000 and $15,000 in order for the choice probability (without any incentives) to fall between 10 and 15%. However, the price of the vehicle should not compromise the safety and environmental

performance of the vehicle, since it was already assumed that the Nanocar would meet or exceed EPA's SULEV standards as well as NHTSA's highest safety standards.

- Tax incentives by itself should not be the primary marketing tool for attracting consumers to purchase the Nanocar, since consumers did not indicate that they derived a high value from this incentive. In other words, the price of the automobile should be set as low as possible so that tax incentives are not required. Nevertheless, a low tax incentive could be provided to offset some of the initial costs to the consumer and the remaining allocated tax amount could be used to provide other incentives that commuters value more. Any tax incentive provided could be in the form of point of purchase tax breaks so that the consumer will "see" the price reduction at the time they purchase the vehicle.
- If feasible, parking preferences at shopping districts and workplaces should be offered. In addition, a 50% reduction in parking fees should also be offered. The taxes that were not collected due to existing programs that offer tax breaks could then be redirected towards tax incentive programs for private corporations that provide preferential parking and to subsidize parking lots to reduce fees. Moreover, infrastructure modifications should be made; first to side streets then to highways.

### 6.3 Infrastructure Recommendations

The variables that commuters valued the most were 50% and 100% reductions in parking fees and preferential parking at stores. Preferential parking at work, own path away from existing side-streets with an associated 50% reduction in commute time, and own lane on existing highways with an associated 25% reduction in commute time were also highly valued by commuters. As mentioned before, in an ideal situation, all incentives would be provided. If this were the case, the probability of commuters choosing to purchase the Nanocar package would be 88.0%.[54] However in reality, all incentives would not be provided and therefore a combination of the incentives will have to suffice. Moreover, if the specific type of side-street infrastructure modification mentioned above is not a possibility, the modification should at least have an own-lane away from existing side-streets in order for commuters to retain the variable in their purchasing equation.

### 6.4 Practical Applications

When implementing such incentives, it is important to understand the characteristics of the target consumer group. Ideally, the incentives offered would be taken advantage of by all automobile owners, rather than a small fraction of the group, but this may not always be the case. For example, in urban areas where mass transportation is used by a large portion of commuters, some would not be able to take advantage of an incentive such as preferential parking at work. Another example is where the majority of commuters mainly travel on highways and therefore, would not be able to take advantage of side-street infrastructure modifications.

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[54] For this package, the price was set at $15,000 and price of gas was $1.28 as specified by the Department of Energy's, Energy Information Administration of February 18, 2002.

Keeping these concepts in mind, below are two practical incentive programs that could be implemented for areas with differing needs or differing legislative rulemaking settings.

### 6.4.1 Incentive Program Targeted at Shopping Areas

This incentive program would target shopping areas in and around the urban cities of California and increase convenience for Nanocar owners to get to these areas. The first part of the program is to convert private and municipal parking lots so that preferential parking spaces for Nanocar owners will be placed in the most convenient locations. The incentive for lot owners participating in such a program could come in the form of tax breaks for the developer or a provision of funds to pay for the conversion. It is also important to note that the conversion itself already has a built in incentive since the narrowness of the vehicle will allow more vehicles to be parked in a specific area. Another parking advantage that should be implemented is a reduction in parking fees. As indicated in the survey, the greatest value is gained by a 50% reduction in parking fees. From a private parking lot owner's perspective, it would appear that this reduction would cut profit margins for a single Nanocar parking space to half of what it would be for a normal size vehicle, but the increased amount of Nanocars that can park in these areas will, in fact, offset it. For example, if a row of parking spaces could fit 20 vehicles and this resulted in revenues of $60 per hour at $3 per hour per vehicle under the original scenario, the same row could potentially fit 25 Nanocars. In order to maintain the $60/hour revenue, the parking fees for Nanocars could be reduced to $2.40 per hour per vehicle or a 25% reduction in parking fees. This reduction may in reality be higher because the unused areas in current parking lot designs could be more efficiently used (i.e. converted) due to the Nanocar's unique size. As the example shows, the conversion itself already warrants at least a 25% reduction in parking fees. If 50% parking fee reductions are required, the additional 25% reduction could be achieved through subsidies granted by State or Federal governments for providing incentives for alternative fuel vehicles[55]. In addition, for shopping areas that offer free parking, a premium is placed on proximity and convenience to the desired locale, such as a grocery store. By increasing the amount of premium spaces available for Nanocars, additional consumers, and thus revenue, may be drawn to the shopping area due to the increase in availability of premium parking spaces.

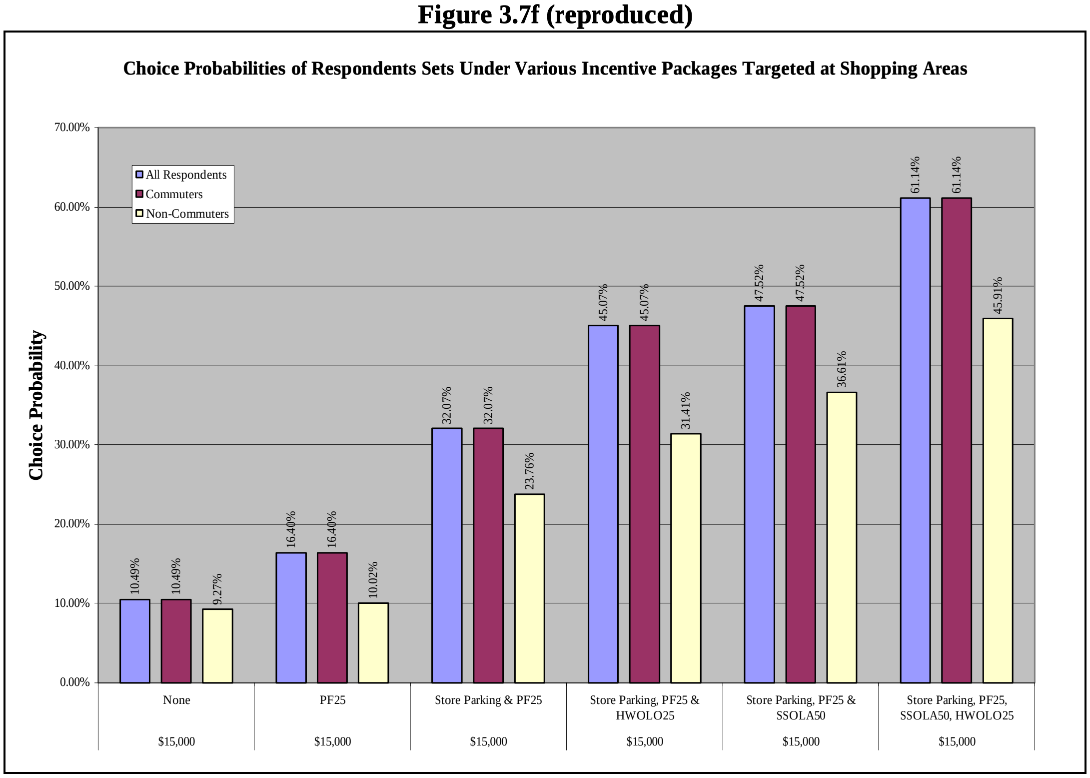
The final incentive that needs to be provided for this scenario is the infrastructure to increase convenience and provide safety for Nanocar owners to move from home or work to the *shopping area*. In many cases, the additional infrastructure would be limited to side-streets since shopping areas are located close to neighborhoods. The commuting subset indicated that an own path away from existing side-street infrastructure with an associated 25% reduction in commute time was an incentive that was influential in their purchasing decision. Therefore, providing this incentive would be a sensible option for

[55] It should be noted that as lot sizes increase, the multiple effect of being able to park more Nanocars in a given area will lead to a larger percentage (greater than 25%) of parking fees to be made without affecting revenues.

increasing the purchasing likelihood of the Nanocar. The cost of building new infrastructure for Nanocars is likely to be an expensive task. Although some new construction is expected to be necessary, creative methods of modifying existing streets can also be utilized to reduce the overall cost of introducing such additional infrastructure. For example, lanes currently used to provide on-street parking could be removed to provide a driving lane for the Nanocar. Also, because of its size, the lane itself would not cost as much as traditional roadways because the width and tensile strength of the road can be reduced. In areas where space is in large demand, raised pathways could also be created. Appendix C discusses these creative modification methods further.

As shown in Figures 3.7f in Section 3.7.2 and reproduced below, the choice probability, if all these incentives are implemented, is increased from 10.5% (Price and gas cost only) to 16.4% (Price, gas cost and a 25% reduction in parking fees) to 32.1% (Price, gas cost, 25% reduction in parking fees and preferential parking at stores) to 47.6% (Price, gas cost, 25% reductions in parking fees, preferential parking at stores, and side-street infrastructure additions).[56]

**Figure 3.7f (reproduced)**




[56] Again for this model, the price was set at $15,000 and price of gas was $1.28 as specified by the Department of Energy's Energy Information Administration of February 18, 2002.

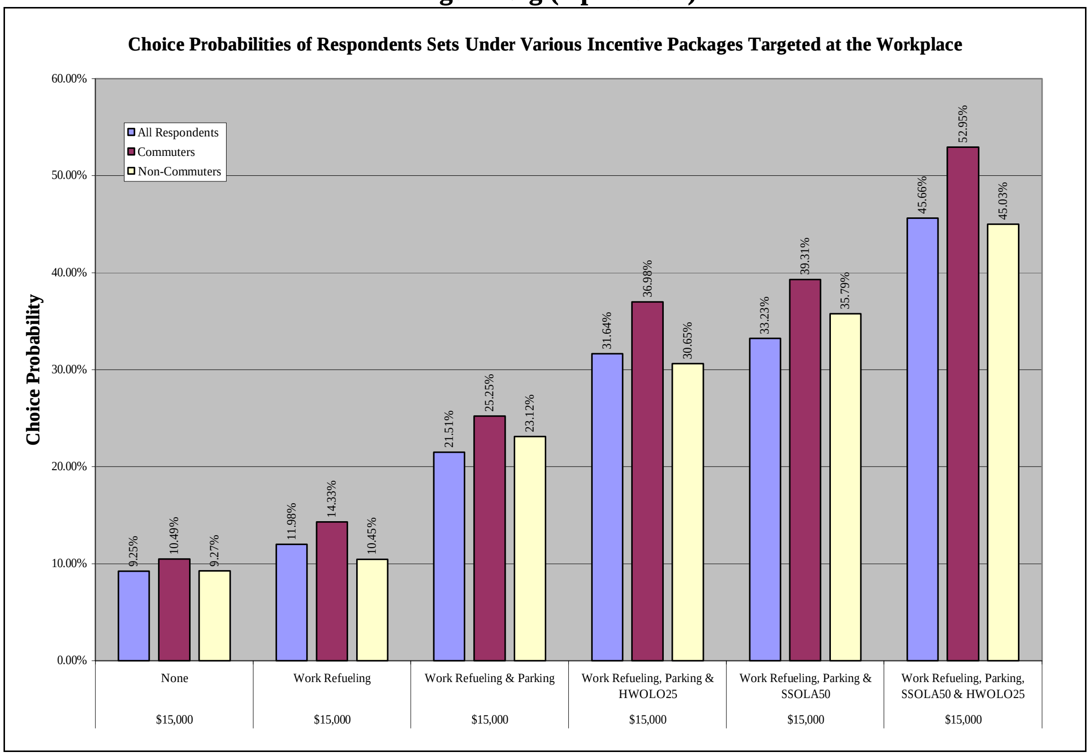
### 6.4.2 Incentive Program Targeted at the Workplace

This incentive program would target commuter workplaces. In this program, the first part is to provide incentives for employers to convert convenient parking spaces into preferential parking for Nanocars. The incentive for the conversion could again come in the form of funding for the modification work as well as tax subsidies, similar to current tax breaks offered to employers that promote carpooling and electric vehicle charging stations at the workplace. Following on from this concept, although the fuel source of the Nanocar is not yet known, the next part of the program is to provide refueling stations for the Nanocar at the workplace.

The final piece of the puzzle, in terms of this incentive program, is to construct additional infrastructure that would increase convenience and maintain the safety of Nanocar drivers from their home to the *workplace*. In order to do this, both highways and side-streets would be constructed since commuters generally use both types of roadways during their commute to work. In terms of the specific infrastructure, the analysis of the survey results indicated that own lane on highway with an associated 25% reduction in commute time as well as own path away from existing side-streets with an associated 25% reduction in commute time were the infrastructure incentives that remained important in their purchasing decision. As mentioned before, building new infrastructure inevitably results in a high cost. However, creative solutions for both types of infrastructure exist in order to defray the overall costs of the infrastructure construction. These solutions remain based on the concept of the Nanocar (smaller size and lighter overall weight as compared to standard vehicles) as well as the idea that modifying current infrastructure in creative ways, rather than solely building new infrastructure, is the key to cost-effectively implementing these infrastructure incentives. Again, a further discussion of these creative infrastructure solutions is found in Appendix D-1.

As shown in Figure 3.7g in Section 3.7.2 and reproduced below, the choice probability, if these incentives are provided, is increased from 10.5% (Price and gas cost only) to 19.1% (Price, gas cost and preferential parking at work) to 25.3% (Price, gas cost, preferential parking at work and refueling advantages at work) to 53.0% (Price, gas cost, preferential parking at work, refueling advantages at work, and both side-street and highway infrastructure additions).

**Figure 3.7g (reproduced)**




## 6.5 Potential Market Size

According to the 2000 US Census, the number of commuters in the urban counties of California[57] was approximately 8.9 million people. Table 6.5 illustrates the potential market share of the vehicle in three scenarios; the ideal situation where all the incentives are implemented, the shopping district incentive program and the workplace incentive program. The calculation assumes a proportion of the number of people in the commuting population that could take advantage of the specific incentive package. Table 6.5 shows the total number of vehicles that would be bought in the California under certain incentive programs.

[57] Urban counties included were Los Angeles, Orange, Riverside, Sacramento, San Diego, San Francisco, San Mateo, Santa Barbara and Ventura counties.

**Table 6.5: Potential Vehicle Sales in California**

| Incentive Programs | | Market Size | | | |
|---|---|---|---|---|---|
| **Price** | **Ideal Incentive Program** | **%** | **# of People** | **P** | **Vehicles** |
| $ 15,000 | $3,000 tax break | 5% | 453,377 | 12.88% | 58,395 |
| $ 15,000 | $3,000 tax break, highway modifications | 10% | 906,753 | 20.44% | 185,340 |
| $ 15,000 | $3,000 tax break, highway and sidestreet modifications | 10% | 906,753 | 33.01% | 299,319 |
| $ 15,000 | $3,000 tax break, HW and SS modifications, work parking, work refueling | 20% | 1,813,507 | 58.68% | 1,064,166 |
| $ 15,000 | $3,000 tax break, HW and SS modifications, store parking, 50% off parking fee | 20% | 1,813,507 | 76.21% | 1,382,074 |
| $ 15,000 | 3,000 tax break, HW and SS modifications, store parking, 50% off parking fee, work parking, work refuelin | 35% | 3,173,637 | 90.23% | 2,863,573 |
| | **TOTAL** | 100% | 9,067,534 | | **5,852,867** |
| | **Shopping Incentive Program** | **%** | **# of People** | **P** | **Vehicles** |
| $ 15,000 | $0 tax break | 0% | 0 | 10.49% | 0 |
| $ 15,000 | Highway modifications | 40% | 3,627,014 | 16.92% | 613,691 |
| $ 15,000 | Highway and sidestreet modifications | 35% | 3,173,637 | 28.09% | 891,475 |
| $ 15,000 | Highway and sidestreet modifications, store parking, 25% off | 25% | 2,266,884 | 61.14% | 1,385,973 |
| | **TOTAL** | 100% | 9,067,534 | | **2,891,138** |
| | **Workplace Incentive Program** | **%** | **# of People** | **P** | **Vehicles** |
| $ 15,000 | $0 tax break | 0% | 0 | 10.49% | 0 |
| $ 15,000 | Highway modifications | 35% | 3,173,637 | 16.92% | 536,979 |
| $ 15,000 | Highway and sidestreet modifications | 35% | 3,173,637 | 28.09% | 891,475 |
| $ 15,000 | Highway and sidestreet modifications, work parking and refueling | 30% | 2,720,260 | 52.95% | 1,440,378 |
| | **TOTAL** | 100% | 9,067,534 | | **2,868,832** |

Note 1: % is the percentage of the commuting population that could potentially take advantage of the various incentives

Note 2: The number in bold is the total number of Nanocars predicted to be bought by commuters given that the incentives are provided and full information is available at time of purchase

Note 3: P is the choice probability of commuters under a given incentive scenario

The above calculation assumes that the proportions of the commuting population being able to take advantage of the incentives were accurate. Our projections shows that if incentive programs are implemented and full information about the incentives are available at the time of purchase, from 2.8 million to 5.8 million Nanocars might be purchased. This number is substantial. It shows that the potential market size is quite large.[58] However, it is important to note that all the purchases would not be executed in one period, rather, the timeframe that that purchases would occur is completely dependant on when potential buyers (i.e. respondents) intend to purchase their next vehicle. When this question was posed to the survey respondents, the results indicated that more than 75% of the respondents bought or leased a new vehicle every four years or more. This timeframe for personal vehicle turnover may be reduced due to the presence of incentives that encourage consumers to purchase the Nanocar.

### 6.6 Political and Economic Implications

In implementing the above scenarios, there are several qualifications that must be made. First, many parties (both government and private organizations) would have to collaborate to implement such incentives. It is believed that in many cases, opposition towards the incentives would exist because of the varying views of the stakeholders involved. In addition, the cost to implement such incentives as infrastructure modifications would also become an additional barrier. Needless to say, the incentives that should be implemented first would be the ones that generate the greatest value for consumers at the lowest cost and would require the least amount of stakeholder collaboration. An example of this may be the priority of reducing parking fees in a particular city where only one government body is concerned and transaction costs are negligible, due to the cost amelioration mentioned before, over creating continuous side street infrastructure across multiple cities, which requires complex inter-governmental cooperation and road improvement costs.

The actual design of the incentive program will also depend on various other factors including geographic location, consumer preferences, political willingness and levels of financial backing. This is illustrated in the results of commuters from the Los Angeles region who indicated a preference toward a mixture of own path on and away from existing side-streets whereas commuters from the San Francisco region indicated that the most important attributes in their purchasing decision were the price of the vehicle and a 100% reduction in parking fees.[59] Therefore, the incentive programs recommended in

[58] This is the estimated total market share of the Nanocar if it was the only vehicle on the market that has its unique characteristics (i.e. being able to take advantage of the incentives). In reality, however, many automakers are expected to capitalize on this potential market and develop competing vehicles. If this occurs, a separate simulated market must be created to determine the choice probability of a respondent purchasing the Nanocar over another similar vehicle and another entirely different vehicle on the market. Therefore, the value given should be thought of as an estimated market share of the ultra-compact vehicle class rather than specifically for the Nanocar.

[59] The reasons for this variation in purchasing preferences may be due to the fact that many people in the San Francisco region commute to work using mass transportation and therefore do not take infrastructure changes into account.

the previous section should only be considered as general designs that should be modified in order to match the conditions of a specific region.

Returning to the concept of collaboration among various levels of government, as well as private stakeholders, it is clear that to implement any type of incentive, political support and financial backing is required. When considering infrastructure changes (including modification of parking lot designs), the political stakeholders that would potentially be involved are the U.S. Department of Transportation (USDOT), the Federal Highway Administration (FHWA), the California Department of Transportation (CALTRANS), county planning agencies, local municipalities, the Department of Motor Vehicles (DMV), the American Association of State Highway and Transportation Officials (AASHTO), the National Highway Traffic Safety Administration (NHTSA), the California Air Resources Board (ARB), local air quality management districts (AQMDs), and private developers. For example, side-street infrastructure would generally be controlled by local agencies, while highway infrastructure would be maintained by CALTRANS. Parking lots come under the jurisdiction of municipal governments (for municipal parking lots), private developers (for privately-owned parking lots) and county planning agencies since final approval of new construction plans will be administered by this authority. Codified guidelines for the Nanocar and for the new types of side-street and highway infrastructure, as well as parking spaces would have to be established by the DMV, NHTSA, AASHTO, county planners and local municipalities. Finally, in order to construct roadway additions and modifications, funding would have to come from the DMV, CALTRANS, FHWA and the USDOT, as is current practice, which ultimately translates to taxpayer money. The funds required for parking lot modifications, subsidizing parking fee reductions and building Nanocar fueling stations could potentially come from CARB, local AQMDs, and county planning agencies that have been allocated a portion of county taxes.

The costs of any incentive program will vary considerably depending on the incentive used and the location that the program will be implemented. In terms of infrastructure modifications, the following equation is a simplified representation of what the total costs could look like.

$$C = L + M + W + D + A$$

The above equation shows that the costs (C) equal the sum of land costs (L), raw material costs (M), labor costs (W), design costs (D), and any additional costs (A) that may be incurred during the project. Additional costs may include costs such as consulting fees and legal fees. It is difficult to estimate what the total cost of an addition in side-street or highway infrastructure could be, due to the wide range of land costs across California. However, rough estimates indicate that that a mile of roadway for the Nanocar without land costs will roughly be $3.6 million. This is $200,000 lower than what it would cost to add a mile of roadway designed for standard vehicles on the road today.

It is important to note that there are areas where cost savings can be achieved for infrastructure additions. For example, if additional infrastructure is to be constructed as an elevated highway or side-street, or if the land for the roadway is already owned by CALTRANS (i.e. the State), land costs are eliminated.

Parking advantages and refueling advantages will also incur costs, albeit not as large as the total for infrastructure costs. As described in Section 4.4.1, a 25% or greater reduction in parking fees can be achieved without reducing revenues for the parking lot operators due to increase in parking space occupancy resulting from the unique size of the Nanocar. Therefore, the costs that will be incurred for creating preferential parking spaces by the parking lot operators are labor costs associated with repainting the parking lines, and additional costs such as fees paid to the state or municipalities to apply for permit for changes in total lot capacity. Furthermore, if refueling advantages are to take place at parking lots, the lot operator will have to purchase and install the refueling equipment which will be an additional cost. It is important to note that these are the costs to lot operators, and there may also be costs incurred by the government to establish or modify various parking codes. A further discussion of costs is described in Appendix C.

Given these cost considerations, a further assessment of the validity of funding sources is necessary, since it implies significant financial investments. The Southern California Association of Governments (SCAG) 2001 Regional Transportation Plan (RTP) has committed long-term investments of $44 billion for transportation infrastructure improvement and modification projects so as to meet the growing population pressures and environmental degradation mentioned earlier in the paper.

Although the RTP has developed a number of strategic frameworks to meet their performance standards, the actual components of these frameworks are subject to change due to the iterative process in which new alternatives are developed. One such measure that can fit into the overall framework could be the Nanocar concept.[60] The RTP calls on a number of sources of funding from many government levels (local, State, and Federal) to meet nearly half of their proposed costs and since the Nanocar concept can be a part of future transportation plans, the funding needs for Nanocar improvements could be drawn from the same sources.

Traditionally, local sources of funding comes from sources such as the Transportation Development Act, county transportation sales taxes, transit fares, local agency funds (public and private), and miscellaneous funds such as transit advertisement. State sources of funding may come from the State Transportation Improvement Program, Regional Share, Interregional Share, State Transit Assistance, Transit Capital Improvements (Proposition 116), the State Highway Operations and Protection Plan, and the Governor's Traffic Congestion Relief Plan. In addition, Proposition 42, which recently

[60] The performance standards consist of improving mobility, environment, system reliability, safety, accessibility, and cost-effectiveness.

passed in California, may provide additional funding since all gasoline tax revenues are diverted to improve state roads. Finally, Federal sources of funding may come from the Department of Transportation's (DOT) Regional Surface Transportation Program, the DOT's Congestion Mitigation and Air Quality Improvement Program (AQIP), local assistance via regional transportation enhancements, the Transportation Equity Act of the 21$^{st}$ Century (TEA-21), Section 5307 of the Federal Transportation Administration Urban Apportionments, and the DOT's Infrastructure Finance and Innovation Act (TIFIA).

With the use of creative infrastructure changes that are compatible with the unique characteristics of the Nanocar, extensive costs to implement the incentive programs may be minimized. In addition, the required funding may be available through the various programs that are mentioned above. Furthermore, a more compelling reason for developing these programs is the monetary benefits that are gained through the increased productivity, reduced fuel waste, and improved health and air quality related to amelioration of the traffic congestion problem. Some estimates by the Texas Transportation Institute and the American Highway Users Alliance have indicated that these benefits would range from $500 to $1,000 per driver in California and across the U.S., which equates to annual benefits of up to $370 million for commuters, businesses and the general public (TTI 2001, American Highway Users Alliance 2000).

The various incentive programs discussed in Chapter 4 may be difficult to conceptualize, since infrastructure incentives have been looked at individually rather than as an integrated incentive program. In order to illustrate this better, a case study was developed. The case study in the next section analyzes the preferences of commuters in the greater Los Angeles region and therefore the incentive package is specifically aimed at this commuting subset.

# CHAPTER 7

## **NANOCAR**CASESTUDY

## 7.1 Introduction

This Case Study represents a hypothetical commute to work for Bob Green, who experiences the stressful commute through the Sepulveda Pass and its associated infrastructure every workday (Figure 7.1). This case study is presented here to help the reader conceptualize what the Nanocar and its associated incentives could look like, and what the potential benefits of such a concept could be for the commuter in an actual "real world" setting. In addition, the case study also outlines the various regulatory and private bodies that would have to cooperate in order to make this concept a reality.

The 405 freeway is one of the most congested freeways in the state of California.[61] Additionally, the 11.5-mile stretch of the 405 freeway between the 101 freeway and the highway 10 intersection is considered to be one of the most congested areas along the 405 freeway. This stretch of highway is commonly referred to as the Sepulveda Pass. Freeway structural conditions within the area consist of ten mix-flow lanes with an HOV lane running the length of the Sepulveda Pass in the southbound direction. Due to the heavy congestion problems in the area[62] many infrastructure plans have been proposed to help alleviate automobile flux stresses. The most prominent plan includes the additional construction of an HOV lane running the length of the Sepulveda Pass in the northbound direction.[63] However, due to the relatively moderate impact that already existing HOV lanes have on reducing the targeted congestion conditions in the past, a new lane is not expected to be a promising solution to reduce congestion and thus increase mobility in the area (Dahlgren 2001).

The introduction of the Nanocar into everyday commuting adds another option to the list of tools available to transportation planners and regulators for

**Figure 7.1**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[61] State of California, Department of Transportation, Traffic Operations Division, 2001

[62] The California Department of Transportation has reported an Average Daily Traffic (ADT) value for the Sepulveda Pass of 331,000 (California Department of Transportation, 2000, Transportation Congestion Relief Plan Project #39, District 7 Projects Description)

[63] California Department of Transportation, 2000, Transportation Congestion Relief Plan Project #39, District 7 Projects Description

dealing with increasing congestion patterns. An integrated transportation system designed to incorporate the Nanocar into modern infrastructure will ultimately decrease automobile congestion in the area of implementation and increase the productivity of those commuters who take advantage of the opportunity for Nanocar commuting. Additionally, its use as an alternative to the standard gasoline burning automobiles will promote better air quality conditions in the areas of incorporation.

### 7.2 The Scenario

In order to determine the purchasing preferences of Los Angeles commuters, a multinomial logit analysis was conducted for the responses of people that stated that they were commuters and lived in the greater Los Angeles region.[64] The results, shown in Table 7.2, indicated that among the incentives, own lane on highway with an associated 25% reduction in highway commute time, a mix of own lane on and away from side-streets with an associated 25% reduction in commute time, own lane away from side-streets with an associated 50% reduction in commute time, a 50% reduction in parking fees, and preferential parking at work remained significant. The utility factors indicated that the highway infrastructure incentive had the highest positive utility among all significant attributes.

[64] Greater Los Angeles region includes Los Angeles, Orange and Riverside Counties.

**Table 7.2**

| MNL Results - LA Commuters Only | | |
|---|---|---|
| **Variable** | **Parameter Estimate** | **P-value** |
| HWOLO25 | 0.4205 | 0.2415 |
| HWOLO50 | 0.26001 | 0.5485 |
| HWOLA25 | 0.83935 | 0.0182* |
| HWOLA50 | 0.0332 | 0.937 |
| HWBOTH25 | -0.22844 | 0.5224 |
| HWBOTH50 | 0.30526 | 0.5244 |
| HWSAME | 0 | - |
| SSOLO25 | 0.45449 | 0.1992 |
| SSOLO50 | -0.09819 | 0.7941 |
| SSOLA25 | 0.23958 | 0.586 |
| SSOLA50 | 0.7956 | 0.0267* |
| SSBOTH25 | 0.74755 | 0.0397* |
| SSBOTH50 | 0.39448 | 0.2638 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.0000936 | <.0001*** |
| Tax Incentives | 0.0000598 | 0.5715 |
| Price of Gas | -0.56235 | 0.0086** |
| Parking Fee Reduction 25 | 0.28059 | 0.3851 |
| Parking Fee Reduction 50 | 0.75061 | 0.0203* |
| Parking Fee Reduction 75 | 0.13739 | 0.7129 |
| Parking Fee Reduction 100 | 0.04986 | 0.8822 |
| No Parking Fee Reductions | 0 | - |
| Preferential Parking at Stores | 0.51497 | 0.0698 |
| Preferential Parking at Work | 0.74959 | 0.005** |
| No Preferential Parking | 0 | - |
| Refueling ability at home | -0.19824 | 0.4552 |
| Refueling ability at work | 0.02472 | 0.621 |
| Refueling ability at home and work | 0.30817 | 0.2141 |
| Refueling at Fuel Stations | 0 | 0.846 |
| 25% Annual Fuel Reductions | -0.04844 | 0.5957 |
| 50% Annual Fuel Reductions | 0.13266 | 0.3632 |
| No Annual Fuel Reductions | 0 | - |

From these results, the following incentives were chosen for implementation in the Case Study area:

1. Own lane away from highway with an associated 25% reduction in commute time
2. A mix of own lane on and away from side-streets with an associated 25% reduction in commute time
3. Preferential parking at work
4. A 50% reduction in parking fees in privately owned and municipal parking lots for Nanocars.

### 7.3 The Commute

Bob Green is a typical daily commuter who faces the strenuous commute to and from his workplace at M/S Database Marketing in Westwood, California. Every weekday morning he wakes up at 6:05 a.m. and leaves his house at 7:05 a.m. so he can get to work by 8:00 a.m. to start his busy workday. Bob who has always been unhappy with his commuting situation looked for a better way of life by making the choice to purchase the Nanocar. Now that Bob is the proud new owner of the Nanocar, he is excited to travel on the new Nanocar infrastructure that has been integrated on all major routes of his everyday morning commute. In additions, he is happy to take advantage of preferential parking benefits in the parking garage adjacent to his office building.

Since Bob's purchased the Nanocar, he now wakes up at 6:20 a.m., well rested and ready to tackle his busy workday. He gets ready in his regular one-hour timeframe, which includes a quick breakfast and browse over the morning paper. When he finally leaves his house at 7:20 a.m. he feels good knowing that he will have plenty of time to make it to work as usual by 8:00 a.m. He jumps into his Nanocar and travels on traditional standard side-streets to Devonshire St. where he is permitted to access the *Nanolane*, which has been added to the existing side street, taking him to the 405 freeway entrance (Appendix D). The new freeway entrance has been split into two sections including one for standard automobiles and one for Nanocars. This setup relieved him because he could join the highway safely without interacting with larger vehicles.

Once on the southbound 405 freeway, Bob Green enjoys the quick commute on a completely segregated *Nanolane* that turns into a *Nanopass* which rises approximately 15 feet above the slow lane just after the 101-freeway intersection and continues through the Sepulveda Pass (Appendix E). He exits at E. Wilshire Blvd. onto another *Nanolane* that at times is directly adjacent to standard side streets while at other times is completely segregated. Ending his morning commute he enters the first level of the multistoried parking structure where he enjoys the benefits of Nanocar preferential parking. All the Nanocar parking spaces are located in close proximity to the elevator with the majority being placed on the first level, the most easily accessible level of the parking structure. This implies that he virtually never has any problems finding a space compared to the parking space "hunt" he faced during his pre-Nanocar days. Additionally, the monthly fees for parking in the structure have been reduced by 50% as an added benefit for having an overall smaller vehicle footprint.

His morning commute, as outlined in Table 7.3a, used to take approximately 52 minutes in everyday congested driving conditions. As shown in the table, his commute time with the Nanocar only takes approximately 37 minutes, a 15 minute reduction.

**Table 7.3a: Bob Green's Commute to Work**

| Bob Green's Commute to Work | Aggregate Miles | Standard Commute Time | Nanocar Commute Time | Aggregate Time Reduction |
|---|---|---|---|---|
| ***Start:*** 17500 Minnehaha St. | *0* | 5 sec | 5 sec | ***0*** |
| Right on Encino Ave. | 0.17 miles | 1 min 20 sec | 1 min 20 sec | ***0*** |
| Left on Devonshire St. | 2.60 miles | 6 min 40 sec | 5 min 24 sec | ***1 min 16 sec*** |
| S. 405 Freeway toward Santa Monica | 17.33 miles | 40 min 0 sec | 30 min 24 sec | ***9 min 36 sec*** |
| E. Wilshire Blvd. | 18.25 miles | 46 min 55 sec | 35 min 35 sec | ***11 min 10 sec*** |
| ***Finish:*** Westwood Place adjacent to Parking Structure, 10866 Wilshire Blvd. | N/A | 51 min 55 sec | 36 min 35 sec | ***15 min 20 sec*** |

Figure 7.3 is a graphical representation showing the difference between Bob Green's old traditional commute to work against his new Nanocar-modified commute. Now, with the Nanocar Bob reduces his commute time the most on the highway as well as his walk from his car to Wilshire Place where he works.

**Figure 7.3: Bob Green's Commute to Work**

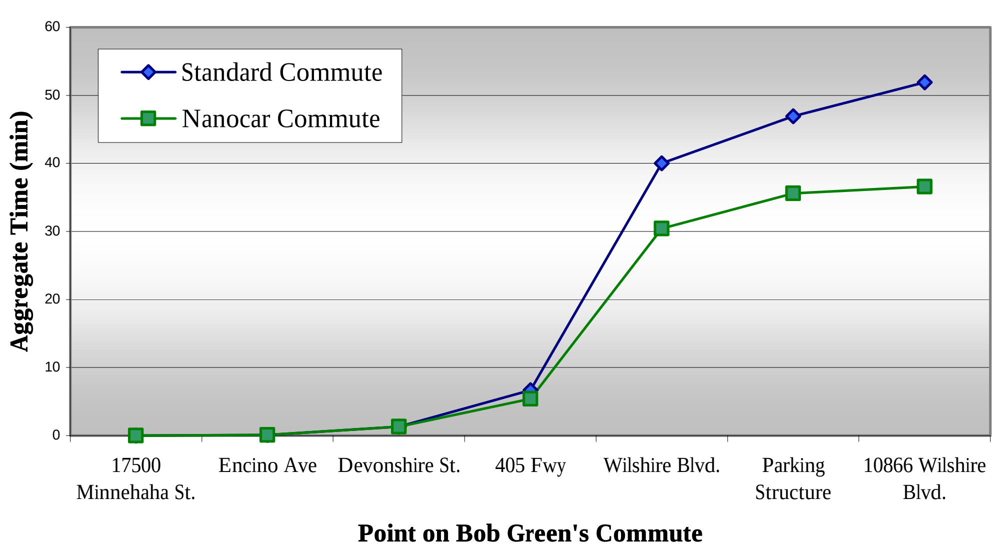

Table 7.3b - Decision Maker Support for Incentives

| Incentive | Responsible Decision Maker |
|---|---|
| Own Path Away from Side-Street | CalTrans, City Planners, Developers |
| Own Lane Away from Highway | CalTrans, City Planners, Developers |
| Preferential Parking at Work | Real Estate Developers, Municipalities |

Although Bob Green has reduced his commute time by approximately 15 minutes and reduced his monthly parking fees, he also enjoys the feeling of knowing he is taking a proactive stand for the future, showing awareness of the impending congestion and environmental problems that exist in metropolitan America. In addition, Bob has eased the congestion problem for the other drivers who travel on his old standard automobile commute path by removing one automobile from the congested streets. It should not go unrecognized that Bob is not the only contributor to these drastic societal improvements. The transportation planners and regulators, as outlined in Table 7.3b, who recognized the value in the new infrastructure and had foresight to implement these revolutionary ideas, are the individuals who make these benefits a reality. It is important to understand that the increased standard of living which Bob now experiences with the use of a Nanocar can also be experienced by so many other commuters who are unhappy with congested driving conditions.

# CHAPTER 8

# CONCLUSIONS

## 8.1 Conclusions

Mobility and associated air quality issues continue to be a major component of the planning objectives of States and Counties. Their primary objectives are to reduce congestion and improve air quality, while promoting economic growth. As vehicle populations in metropolitan areas continue to grow, it becomes increasingly important to develop integrated solutions for managing transportation demand. In order to address these issues, several States including California have developed Regional Transportation Plans that contain Transportation Demand Measures and technology-based Transportation Control Measures. For States in non-attainment for criteria pollutants, such as nitrogen oxides and carbon monoxide, these plans form part of the federally mandated State Implementation Plans, designed to meet the health-based National Ambient Air Quality Standards. Furthermore, states have developed vehicle-based regulations with hopes to increase the volume of environmentally friendly vehicles on the road. However, the trouble with these two separate types of solutions to the mobility and air quality problems are two-fold; first, they are not developed with each other in mind; and second, they are not based on consumer preferences. The Nanocar concept attempts to resolve both of these issues by integrating land-planning and vehicle based solutions into one idea. This one idea is based on consumer preferences.

The underlying research questions being addressed were 1) Is there a market for ultra compact environmentally friendly vehicles such as the Nanocar? 2) What transportation and policy incentives (attributes) are necessary for consumers to purchase the Nanocar? 3) Do current programs in California that aim to increase the purchase likelihood of environmentally friendly vehicles or reduce congestion observe consumer preferences? 4) At what point (if any) are consumers willing to trade-off automobile size for these incentives? and 5) Are there any quantifiable air quality benefits resulting from the gradual introduction of the Nanocar?

Our survey research indicated that given the appropriate package of incentives, there is a market for an ultra-compact, environmentally friendly vehicle such as the Nanocar. In other words, consumers are willing to purchase the vehicle if incentives that increase their convenience are included. This was shown in the survey results where 78% of the respondents indicated that they would purchase the vehicle given a certain set of monetary and non-monetary incentives. Evidence of this was further shown in Section 6.5, where the potential market size of the ultra-compact vehicle such as the Nanocar was shown to be significantly large. In terms of the specific attributes of the vehicle, the incentives that consumers regard as important, and whether current programs in California are effective in promoting environmentally friendly vehicles, the following were conclusions were made:

1. Price will be the main determinant to whether or not the vehicle is purchased, but other monetary and non-monetary incentives will increase the purchase likelihood.
2. The most value is gained from parking advantages and specific highway and side-street infrastructure changes, while annual fuel cost reductions do not influence the decision to purchase.

3. Tax incentives are not likely to have a great impact on whether or not the Nanocar is purchased as compared to other incentives.
4. Fuel savings, tax breaks and refueling advantages at home are incentives that reward the consumers who purchase the Nanocar rather than significant factors that are included in the consumer's purchasing decision.

The case study and air quality analysis showed that the introduction of the Nanocar serves as a practical transportation option that has the potential to decrease congestion and improve air quality in metropolitan areas such as Los Angeles. The infrastructure options for the Nanocar illustrated in the case study also serve as examples of how the implementation process can be achieved and how the commuter will experience the changes.

Finally, the recommendations presented in this report need to be reiterated since they are the main part of the Nanocar concept that require the most effort from all stakeholders involved. In terms of broad recommendations, three concepts must be kept in mind; collaboration, timing and good faith marketing. These concepts are integrated within each other since a higher degree of collaboration between regulators, the private sector and non-governmental organizations will lead to improved timing in implementing the required incentives to create a market for the ultra-compact Nanocar and also lead to better understanding of each party's objectives, thus allowing a stronger marketing program to be developed to educate the consumer.

The ideal incentive program(s) should be area specific depending on the characteristics that are desired by the local commuting population, as well as the relevant decision makers. Therefore, it is important to analyze a specific region's consumer commuting preferences to determine the attributes that this specific regional population regards as important and to determine the political feasibility of these attributes before developing an incentive program. Examples of practical incentives programs were shown in the recommendation sections where two programs, shopping-based and workplace-based programs, increased the purchasing likelihood of the Nanocar by five fold from the baseline scenario without any associated incentives.

Space requirements, economics, and safety are also important factors that must be addressed when developing these programs. Nonetheless, a properly integrated Nanocar infrastructure will provide a transportation solution that makes environmental and economical sense; funding is available through current funding sources for creative transportation solutions and the unique characteristics of the Nanocar naturally reduces implementation costs for specific incentives (e.g. infrastructure changes and preferential parking). Furthermore, utilizing the Nanocar option in correlation with other transportation tools such as mass transportation, vehicle sharing, and regulatory incentives, allows for a more efficient way of meeting the mobility needs of expanding urban populations. Finally, it is important to note that the development of the Nanocar and its associated infrastructure is not the panacea for metropolitan America's congestion and air quality problems, rather it is one method that can compliment future Transportation Demand Strategies to create more convenient transportation conditions.

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**APPENDICES:**

**The following pages contain the appendices for Chapters 1 ~ 8**

## APPENDIX A:
## APPENDICES FOR CHAPTER 2 - *SURVEY ANALYSIS: OBSERVING CONSUMER PREFERENCES*

### Appendix A-1: 1st Focus Group Questionnaire:

1. What mode of transportation do you most frequently use for work?
2. What mode of transportation do you most frequently use for non-commuting use?
3. How long is your commute?
4. What do you enjoy most about driving?
5. What do you enjoy least about driving?
6. Please tell us what you see as inconveniences? Check all that apply. If more than one, please rank with 1 being the lowest.
    a. Parking at work
    b. Parking at shops/stores
    c. Congestion on highways
    d. Congestion on surface streets
    e. Air pollution
    f. Registration fees
    g. Gas prices
7. Are there any other inconveniences that you face?
8. What could possible solutions be to the inconveniences mentioned above?

**Background Questions:**

1. What is your age?
2. What is your gender? Male / Female
3. What is your zip code?
4. What is your income bracket?
    a.) 0-29,999
    b.) 30,000-59,999
    c.) 60,000-100,000
    d.) 100,000 +
4. What is your nationality?
5. How many people live in your household?
6. If you have children, how many and of what age?

## Appendix A-2: Summarized Results of 1st Focus Group Questionnaire

| Primary mode of transporat to get to and from work | Total |
|---|---|
| mass transportation | 14 |
| bike | 2 |
| car | 74 |
| other | 6 |
| vanpool | 1 |
| Primary mode for private use | |
| mass transportation | 1 |
| walk | 1 |
| bike | 3 |
| car | 84 |
| other | 4 |
| | |
| **One-way commute (time)** | |
| Under 15 minutes | 30 |
| 16 to 30 | 25 |
| 31 to 45 | 11 |
| 46 to 59 | 7 |
| 60 to 90 | 15 |
| no reply | 5 |
| | |
| **Demographics** | |
| **Age** | |
| 0-18 | 0 |
| 19-25 | 10 |
| 26-35 | 7 |
| 36-45 | 11 |
| 46-55 | 4 |
| 56-60 | 2 |
| 60+ | 0 |
| | |
| **Income Bracket** | |
| 0-24999 | 5 |
| 25000-39999 | 7 |
| 40000-74999 | 10 |
| 75000-99999 | 3 |
| 100000 + | 20 |
| | |
| 0-29,999 | 10 |
| 30,000-59,999 | 15 |
| 60,000-100,000 | 19 |
| | |
| **Number of People in Household** | |
| 1 | 14 |
| 2 | 29 |
| 3 | 24 |
| 4 | 16 |
| 5 | 6 |
| more than 5 | 1 |
| | |
| **Top 3 Enjoyable Aspects of Commuting** | |
| 1 | Listen to music |
| 2 | flexibility, freedom, independence |
| 3 | privacy |
| | |
| **Top 3 Lease Enjoyable Aspects of Commuting** | |
| 1 | traffic congestion |
| 2 | other drivers, bad drivers |
| 3 | pollution |
| | |
| **Inconveniences Noted Most Often (in order of times mentioned)** | congestion on highways |
| | congestion on surface streets |
| | gas prices |
| | air pollution |
| | resgistration fees |
| | parking at shops/stores |
| | parking at work |

## Appendix A-3: Survey Attributes and Corresponding Levels of Each Attribute

| Attribute | Level | |
|---|---|---|
| Highway Infrastructure | 0 | no additional highway infrastructure (0% highway time reduction) |
| reduction of highway commute time | 1 | own lane on highway (25% reduction) |
| | 2 | own lane on highway (50% reduction) |
| | 3 | own lane away from the highway (25% reduction) |
| | 4 | own lane away from the highway (50% reduction) |
| | 5 | combination of a separate lane on and apart from traditional highways (25% reduction) |
| | 6 | combination of a separate lane on and apart from traditional highways (50% reduction) |
| Peripheral Street Infrastructure | 0 | no additional peripheral street infrastructure (0% reduction) |
| | 1 | own lane on existing peripheral streets (25% reduction) |
| | 2 | own lane on existing peripheral streets (50% reduction) |
| | 3 | own lane not on existing peripheral streets (25% reduction) |
| | 4 | own lane not on existing peripheral streets (50% reduction) |
| | 5 | combination of a separate lane that is at times either on existing streets or on it's own road (25%) |
| | 6 | combination of a separate lane that is at times either on existing streets or on it's own road (50%) |
| Parking Advantages | 0 | no additional parking advantages |
| | 1 | guaranteed preferential parking at work |
| | 2 | guaranteed preferential parking at stores/shops |
| Parking Fee Reduction | 0 | No reduction |
| | 1 | 25% reduction |
| | 2 | 50% reduction |
| | 3 | 75% reduction |
| | 4 | 100% reduction |
| Gas Price | 0 | $1.50 |
| | 1 | $1.75 |
| | 2 | $2.00 |
| | 3 | $2.25 |
| | 4 | $2.50 |
| Tax incentives | 0 | No tax incentive |
| | 1 | $500 |
| | 2 | $1,000 |
| | 3 | $1,500 |
| | 4 | $2,000 |
| | 5 | $2,500 |
| | 6 | $3,000 |
| Price of Car | 0 | $8,000 |
| | 1 | $10,000 |
| | 2 | $12,000 |
| | 3 | $14,000 |
| | 4 | $16,000 |
| | 5 | $18,000 |
| | 6 | $20,000 |
| Refueling advantages | 0 | ability to refuel at fuel station only |
| | 1 | ability to refuel at work and fuel stations |
| | 2 | ability to refuel at home and fuel station |
| | 3 | ability to refuel at home, work, and fuel station |
| Cost of Refueling | 0 | No change in annual fuel cost |
| due to fuel efficiency | 1 | Annual fuel cost reduced by 25% |
| | 2 | Annual fuel cost reduced by 50% |

## Appendix A-4: Definition of Attributes and Associated Levels as Presented to the Survey Respondent

**1.) Highway Infrastructure Additions and Reduction in Commute Time:**
This attribute describes additional infrastructure that will be built on or next to highways in order to reduce commute times by the amount specified inside the parentheses. The roads will serve the same function as highways in that they will be high-speed commuting roads. The terms in the specific scenarios are defined below.
Own-Lane Highway: This is a Nanocar only lane, similar to a car-pool lane, that will become an additional lane on existing highways.
Own-Lane Away from Highway**:** This is a Nanocar only lane, which will run along the same route as the highway, but will have its own dedicated on-ramps, off-ramps and barriers. It could be in the form of a designated elevated highway.
Combination of Both**:** This is a scenario where in some areas there will be Nanocar only lanes on highways while in others there will be Nanocar-only lanes away from highways.

**2.) Side Street Infrastructure Additions and Reduction in Commute Time:**
This attribute describes additional infrastructure that will be built on side streets (e.g. off the highway) that will accommodate the Nanocar and reduce commute times by the amount specified in the parentheses. The terms in the specific scenarios are defined below.
Own Lane on Existing Side Streets**:** This is a Nanocar only lane that will be built next to existing side streets.
Own Lane NOT on existing Side Streets**:** This is a Nanocar only lane that will be built away from existing side streets. An example would be a street that will be placed in areas that normal-sized vehicles would have trouble accessing.
Combination of Both**:** This is a scenario where in some areas there will be Nanocar-only lanes next to existing side streets while in others there are designated Nanocar-only lanes away from existing side streets.
Note: The attributes of "highway infrastructure" and "side street infrastructure" have corresponding commute time reductions because this is the main result of such changes.

**3.) Parking Advantages:**
This attribute describes situations where there will be convenient parking spaces set aside for Nanocar-type vehicles. The terms in the specific scenarios are defined below:
Preferential Parking at Work**:** This is a scenario where Nanocar owners will have convenient parking spaces allocated for them at work. For instance, on corporate campuses where parking may be troublesome, a program to designate Nanocar parking spaces in close proximity to specified work places will be implemented.
Preferential Parking at Stores/Shops**:** This is a scenario where Nanocar owners will have convenient parking spaces allocated for them at shopping centers and malls. For example, convenient parking spaces located next to handicap parking spots will be designated, "Nanocar Only".

**4.) Parking Fee Reduction:**
This attribute refers to new policies that would be implemented to reduce parking fees by the amount specified in the specific scenario. For instance, a scenario may be where the hourly parking fees for municipal (or privately owned) parking lots are reduced if the vehicle being parked is a Nanocar. Another example would be where annual parking permit fees at universities or residential neighborhoods are reduced for Nanocar-type vehicles.

**5.) Price of Gas:**
This attribute refers to the price of gasoline that a respondent would see at gas stations when thinking of buying their next car. The Nanocar may not run on gasoline, or it might use gasoline more efficiently. Reductions in annual fuel costs from buying the Nanocar can be found in the incentive, "Annual Fuel Cost Reductions from Fuel Efficiency".

**6.) Tax Incentives:**
This attribute refers to income and registration tax rebates that are associated with the purchase of a Nanocar. This is similar to the existing tax rebates allowed for purchasing electric and hybrid vehicles (up to $3000). The amount specified in the scenario is the amount that can be claimed as a tax rebate when filing income taxes.

**7.) Price of Vehicle:**
This is the manufacturer's suggested retail price (MSRP) of the Nanocar. Keep in mind that the price displayed is before any tax rebates or discounts offered by dealerships.

**8.) Refueling Advantages:**
This attribute refers to the locations where one can refuel the Nanocar. In some scenarios, it may be possible to refuel the Nanocar at local gas stations or new gas stations established specifically for Nanocar fueling. There may also be opportunities, in addition to fuel stations, to refuel the Nanocar while it is parked at home, at work, or possibly both.

**9.) Annual Fuel Cost Reductions from Fuel Efficiency:**
This refers to the annual savings that one would get from refueling one’s vehicle if you bought a Nanocar. For example, if you spent $1000 a year to refuel your current car and you could buy a Nanocar that would reduce your refueling costs by 50%, your annual refueling cost would be $500.

## Appendix A-5: Choice Theory

*(Adapted from Qualitative Choice Analysis - Train, 1993)*

The decision maker can be described by $n$ and the set of alternatives that the decision maker can choose from as $J_n$. This can be thought of as the choice set and is subscripted by $n$ to represent the fact that different decision makers might face differing sets of alternatives. In addition, the alternatives that a decision maker faces differ in their characteristics. Some of the alternatives are observed and some are not. The observed characteristics of alternative $i$, as faced by decision maker $n$, can be labeled as $z_{in}$, for all $i$ in $J_n$.

The choice made by a decision maker depends on the characteristics of each of the alternatives in the choice set. It is expected that different decision makers can make different choices when facing the same alternative because the value that each decision maker puts on each characteristic is different. The observed characteristics of the decision maker can be noted as $s_n$. Therefore, the probability that the decision maker $n$ chooses alternative $i$ ($P_{in}$) from set $J_n$ depends on the observed characteristics of alternative $i$ compared with all other alternatives and on the observed characteristics of the decision maker. The parametric function of the general form:

$$\mathrm{P_{in}} = f(z_{in}, z_{jn} \text{ for all j in } \mathrm{J_n} \text{ and } \mathrm{j} \neq \mathrm{i}, \mathrm{s_n}, B) \qquad \text{Equation 1}$$

where, f is the function that relates the observed data to the choice probability. This function is specified up to some vector of parameters $B$. The general description of stated choice models is characterized by this equation. In other words, all stated choice models have this general form; the specific models within stated choice theory are derived by specifying $f$.

## Appendix A-6: Random Utility Maximization Theory and Extreme Value Distribution

### Appendix A-6a: Random Utility Maximization

By combining the general specification of stated choice models to utility theory, three benefits clearly arise. The first is that a clear meaning of the choice probability emerges. Until utility theory is applied, the meaning of the choice probability, $P_{in}$ is not clear. The second is that utility theory offers a context for deriving various forms of *f*. As mentioned before, different stated choice models take shape because of variations in *f*, which is allowed by the theoretical underpinnings set in utility theory. Third, the literature on stated choice models uses terms that only have meaning in the context of utility theory. The analysis, therefore, is based on these three fundamental concepts.

Stated choice models can be derived from utility theory by making a precise distinction between the behavior of the decision maker and the analysis of the researcher. In making the choice described in Appendix A-5, the decision maker derives a certain level of relative happiness or "utility." In fact, each alternative would give the decision maker a certain level of utility, with some being higher or lower than others. The utility derived from alterative *i* in $J_n$ can be labeled as $U_{in}$, and similarly for each other alternative in $J_n$. The utility depends on a number of factors including the characteristics of the alterative and the characteristics of the decision maker. All of the relevant characteristics of alternative *i*, as faced by person *n*, can be labeled $x_{in}$. All of the relevant characteristics of person *n* can be labeled as $r_n$. Therefore, $x_{in}$ and $r_n$ should contain all relevant characteristics and the utility function that follows from these factors is:

Equation 2

$$U_{in} = U(x_{in}, r_n) \text{ for all i in } J_n$$

where, U is a function. This equation essentially states that the utility that one gets from a decision is based upon the utility of the factors that go into making the decision.

The decision maker will choose the alternative where he or she derives the greatest utility. This can be denoted as:

$$U_{in} > U_{jn} \text{ for all j in } J_n, j \neq i.$$

When equation 2 is substituted, *n* chooses *i* in $J_n$ if and only if:

Equation 3

$$U(x_{in}, r_n) > U(x_{jn}, r_n), \text{ for all } j \text{ in } J_n, j \neq i.$$

This equation is a final step in how a decision maker determines his or her choice. Ultimately, the decision maker chooses the alternative that provides the greatest utility.

Unfortunately, the researcher does not observe all of the relevant factors that are involved in the decision making process and therefore cannot exactly know the utility function. The elements of the original utility equation must be subdivided into what the researcher observes and what the researcher does not observe. Therefore, the characteristics of the alternative ($z_{in}$) and the characteristics of the decision maker are divided into observed and unobserved characteristics. $U(x_{in},r_n)$ can be then broken down for each *i* in $J_n$ into two sub-functions, one that is observed by the researcher and one that is unknown by the researcher. The known sub-function which is to be estimated up to a vector *B* and is labeled $V(z_{in},s_n,B)$. The unknown sub-function can be thought of as an error term with the label $e_{in}$. The utility equation then becomes:

$$U_{in} = U(x_{in}, r_n) = V(z_{in}, s_n, B) + e_{in} \qquad \text{Equation 4}$$

The error term is assumed to be random and varying across decision makers. The researcher, therefore, does not entirely know a decision maker's total choice utility. However, the researcher does know a good deal about the observed characteristics and is able to make an educated guess as to the decision maker's choice.

To make this educated guess, some assumptions need to be made about the value of the error term. The role that the error term plays is best seen in the choice probabilities. As can be reasoned from Equation 4, two different respondents may have varying utilities regarding the same alternative, which contains the same observed values because of the unobserved error term. Train (1993) expresses this point succinctly by stating, ". . . even though the observed part of utility is the same for all decision makers in the group, different decision makers would choose different alternatives depending on the values of the unobserved components of their utility." With this in mind, the probabilities of an alternative being chosen, say alternative *i*, form a group of respondents given that error values may differ. Equation 3 can be transformed into a probability formula:

$$P_{in}=\text{Prob}(U_{in}>U_{jn}, \text{ for all } j \text{ in } J_n, j \neq I). \qquad \text{Equation 5}$$

Where, $P_{in}$ is the probability that alternative *i* is chosen by decision maker *n*. Equation 4 can now be substituted with $V_{in}$ denoting $V(z_{in}, s_n, B)$:

$$P_{in}=\text{Prob}(V_{in}+e_{in}>V_{jn}+e_{jn}, \text{ for all } j \text{ in } J_n, j \neq I). \qquad \text{Equation 6}$$

This can be rearranged to:

$$P_{in}=\text{Prob}(e_{jn}-e_{in}< V_{in}-V_{jn}, \text{ for all } j \text{ in } J_n, j \neq I). \qquad \text{Equation 7}$$

Equation 7 is an important one that requires further explanation. The researcher observes the right hand side of the equation ($V_{in}$- $V_{jn}$) and the left hand side is unknown to the researcher ($e_{jn}$- $e_{in}$). Therefore, the equation simply states that the probability that an alternative is chosen depends on the probability that the random variable $e_{jn}$- $e_{in}$ is below the known value $V_{in}$- $V_{jn}$. This cumulative distribution holds for each random variable.

A decision maker will choose alternative *i* if his or her total utility, both observed and unobserved, is greater than the rest in the choice set ($V_{in} + e_{in} > V_{jn} + e_{jn}$). In addition, if the observed utilities are the same, alternative *i* will still be chosen if $e_{in}$ is greater than $e_{jn}$. However, if the observed utility of *i* is greater than j, and $e_{jn}$ is greater than $e_{in}$, *i* will still be chosen if the difference in the error term is not greater than the difference in the observed utility value. In other words, alternative *i* will not be chosen if $e_{jn}$ is greater than $e_{in}$ such that the difference is greater than $V_{in}$-$V_{jn}$.

What needs to be known, therefore, is how to deal with the unobserved, error values. All stated choice models specify different distributions for the unknown component of utility. As Train (1993) states, "Different stated choice models are obtained by specifying different distributions for the *e*'s, giving rise to different functional forms for the choice probabilities. For the purposes of this study, it is assumed that the unobserved characteristics, $e_{in}$, are independently and identically distributed (IID) in accordance with the extreme value distribution. With this distribution for the unobserved characteristics of utility, the probability that a decision maker will choose alternative *i* is:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in J_n} e^{V_{jn}}}, \text{for all i in } J_n \qquad \text{Equation 8}$$

The derivation of Equation 8, along with the formula for extreme value distribution is provided in, Appendix A-6b. Since the distribution of the unobserved components are assumed to have zero mean, the observed components are then the expected or average utility. The extreme value distribution, mentioned above, allows the assumption of zero mean for the unobserved component of utility. This means that although the values are unknown, their effect is negligible. Therefore, this assumption allows the known components, the exact details that the group is testing for, to be representative of the entire utility as a whole.

A byproduct of the IID Assumption is the assumption of Independence from Irrelevant Alternatives (IIA). This assumption follows from the IID assumption and implies that the ratio of the choice probability for any two or more alternatives is unaffected by the addition or deletion of an alternative. This can also be thought of as having the random components ($e_{in}$) being uncorrelated between choices and having the same variance.

## Appendix A-6b: Extreme Value Distribution

*This section is taken directly from Train (1993)*

It was stated that the utility of alternative *i* is decomposed into observed and unobserved parts $U_{in} = V_{in} + e_{in}$ and each $e_{in}$ is independently and identically distributed in accordance with the extreme value distribution, then the choice probability has the logit form

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in J_n} e^{V_{jn}}}, \text{ for all i in } J_n$$

This statement is demonstrated as follows.

Under the **extreme value distribution**, the density function for each $e_{in}$ is

$$\exp(-e_{in}) \bullet \exp(-e^{-e_{in}}),$$

with a cumulative distribution of

$$\exp(-e^{-e_{in}}).$$

The probability that alternative *i* is chosen is

$$P_{in} = \text{Prob}(V_{in} + e_{in} > V_{jn} + e_{jn}, \text{ for all j in } J_n, \ j \neq i)$$

Rearranging terms within the parentheses, we can write

$$P_{in} = \text{Prob}(e_{jn} < e_{in} + V_{in} - V_{jn}, \text{ for all j in } J_n, \ j \neq i). \qquad \text{Equation 9}$$

Suppose, for the moment, that $e_{in}$ takes a particular value, say, s. The probability that alternative I is chosen is then the probability that each $e_{jn}$ is less than $s + V_{in} - V_{jn}$, respectively, for all j in $J_n$, $j \neq i$. The probability that $e_{in}+s$ and, simultaneously, that $e_{jn} <$ $s + V_{in} - V_{jn}$,, for all j in $J_n$, $j \neq i$, is the density of $e_{in}$ evaluated at s times the cumulative distribution for each $e_{jn}$ except $e_{in}$ evaluated at < $s + V_{in} - V_{jn}$,. For the extreme value distribution, this is

$$e^{-s} \exp(-e^{-s}) \prod_{\substack{j \in J_n \\ j \neq i}} \exp(-e^{-(s+V_{in}-V_{jn})}).$$

Since $V_{in} - V_{in} = 0$, this expression can be rewritten as

$$e^{-s} \prod_{j \in J_n} \exp(-e^{-(s+V_{in}-V_{jn})}). \qquad \text{Equation 10}$$

The random variable $e_{in}$ need not equal s, however; it can take any value within its range. The right hand side of equation A is, therefore, the sum of expression B over all possible values of $s$. That is, since $e_{in}$ is continuous, equation A becomes

$$P_{in} = \int_{s=-\infty}^{\infty} e^{-s} \prod \exp(-e^{-(s+V_{in}-V_{jn})}) ds$$

Our task in deriving the choice probabilities is to evaluate this integral. Collecting terms in the exponent $e$,

$$P_{in} = \int_{s=-\infty}^{\infty} e^{-s} \exp\left[-\sum_{j\in J_n} e^{-(s+V_{in}-V_{jn})}\right] ds$$

$$= \int_{s=-\infty}^{\infty} e^{-s} \exp\left[-e^{-s}\sum_{j\in J_n} e^{-(V_{in}-V_{jn})}\right] ds$$

Let $e^{-s}=t$. Then $-e^{-s}ds=dt$ and $ds=-(dt/t)$. Note that as s approaches infinity, $t$ approaches zero, and as $s$ approaches negative infinity, t becomes infinitely large. Using these new terms,

$$P_{in} = \int_{s=-\infty}^{\infty} t \exp\left[-t \bullet \sum_{j\in J_n} e^{-(V_{in}-V_{jn})}\right](-dt/t)$$

$$= \int_{s=-\infty}^{\infty} \exp\left[-t \bullet \sum_{j\in J_n} e^{-(V_{in}-V_{jn})}\right] dt$$

$$= \left.\frac{\exp\left\{-t \bullet \sum_{j\in J_n} e^{-(V_{in}-V_{jn})}\right\}}{-\sum_{j\in J_n} e^{-(V_{in}-V_{jn})}}\right|_0^{\infty}$$

$$= \frac{1}{-\sum_{j\in J_n} e^{-(V_{in}-V_{jn})}} = \frac{e^{V_{in}}}{\sum_{j\in J_n} e^{V_{jn}}}$$

## Appendix A-7: Design Efficiency

*(Modified primarily from Kuhfeld et. al 1994)*

There are three main types of efficiency that one can use to evaluate the goodness of a model: A-efficiency, D-efficiency, and G-efficiency. These efficiency criteria evaluate the goodness of a model or design matrix. The design matrix can be defined by ($N_D xp$) and can be labeled X. $N_D$ is simply the number of "runs" or possible choices out of the full factorial. Remember that for the Nanocar survey there are 2,160,900 different possible "runs." The determination of the efficiency therefore, is based on what is called an information matrix, X'X. The variance-covariance matrix of the intercept of attribute estimates in a least-squares analysis (i.e. linear regression) is proportional to the inverse of the information matrix, X'X. As mentioned previously, high efficiency will have a "small" variance matrix and the eigenvalues of X'X gives the measure of its size. It is the interpretation and use of eigenvalues from which the different criteria of efficiency is derived. *A-efficiency* is a function of the arithmetic mean of the eigenvalues and *D-efficiency* is a function of the geometric mean of the eigenvalues. *G-efficiency* is based on the maximum standard error for prediction over the candidate set. *D-efficiency* was chosen as the most appropriate efficiency criterion because it is the standard approach to this type of situation. It is important to note that this efficiency criterion is for linear models. Although the Nanocar survey employs a nonlinear model, it is assumed as it has been by others (Kuhfeld et al 2001) that an efficiency model created for a linear model works just as well for nonlinear models.

<u>Optimal Design Selection and the Modified Federov Algorithm</u>

To have the ADX program reduce the full factorial to a subset that the researchers could work with, the researchers had to determine the amount of runs. The researchers decided to have the program reduce the 2,160,900 runs to 40 runs using ADX's optimization program. The researchers deliberately chose for the full factorial to be narrowed down to 40 scenarios because it was felt that this number was more manageable while maintain statistical efficacy. The program uses the PROC OPTEX procedure to make this reduction. PROC OPTEX works by having the computer randomly choose a design from the candidate set using the modified Federov algorithm. The efficiency of the candidate set is then evaluated according to the efficiency criterion chosen, in this case D-efficiency. The points that are in the current design being evaluated are considered for removal and the points not in the design are considered for inclusion by the algorithm. The program replaced one design point with another not currently in the design in order to increase efficiency. This process continues until efficiency does not increase further. The process is repeated again with a new random design.[65]

[65] Only main effects were taken into account. Second, third and higher order polynomial interactions were not considered for the optimal design.

As an example of how this works, consider a candidate set with *n* points, say 100, and a design with *m* points, say 5. Each iteration of the algorithm considers all pairs of *n* x *m* swaps (100*5), or 500 possible replacements for each iteration. Therefore, each design point (each of the 5) is removed and the effect of replacing it by each point of the candidate set *n* (all 100 points) is evaluated. Candidates are swapped in and design points are swapped out whenever efficiency improves. The process continues until all *n* x *m* swaps occur (500 swaps), but nothing changes (Kuhfeld et al. 2001).

The modified Federov algorithm is preferred over other algorithms because although it is computationally more complex it derives more efficient responses (Cook et al. 1980). In addition, today's computer technology allows feasible computation time for complex algorithms like the modified Federov algorithm. For these reasons, it was chosen as the method to select the specific design points of the survey. An analogy of how PROC OPTEX works is given below:

(Taken from Kuhfeld, Warren. Multinomial Logit, Discrete Choice Modeling, January 2001.)

> *To envision how PROC OPTEX works, imagine a bunch of blindfolded kangaroos hopping around, looking for the top of Mt. Everest. The search for an efficient design is like a kangaroo jumping around until it reaches a place where it can only go down. We want it to find the top of Mt. Everest, but we would be happy if it found K2, which is almost as high as Everest. We could also make do with other Himalayan peaks or even with Mt. McKinley. However, local optima such as underwater mountain peaks and the highest point in Nebraska are not good answers. Using a full-factorial design as a candidate set is like parachuting the kangaroos into random places on the planet. Most will drown, freeze, or meet some other unpleasant fate, but occasionally, a kangaroo will find the top of a mountain. Since the kangaroos are being parachuted over the entire planet, some kangaroo will find Mt. Everest; give enough kangaroos and enough time. However, it may take a very long time. Using a minimum sized resolution III candidate set is like parachuting kangaroos into some mountain range. They will find a peak very quickly, but you do not know if it is Everest because you may have dropped them in the wrong mountain range. Using increasingly larger candidate sets is like parachuting the kangaroos into increasingly larger areas: a region, a country, continent, hemisphere, and planet. As the size of the candidate set increases, the chance that you will find the optimum or a very good local optimum increases, however each search takes longer and has a lower probability of success, so more searches may be necessary.*

## Appendix A-8: Pretest Survey and Comments:

### Appendix A-8a: Pretest Survey

# Welcome

This survey is being conducted by graduate students at the University of California, Santa Barbara (UCSB).

In the following survey, you will be asked to answer a few questions about the mode of transportation you use currently and the choices you make or will be making when you buy a car.

The information from this survey will only be used for research at UCSB. All personal information will be held confidential and will not be distributed or used for any other purposes than this study.

You must be over the age of 18 to participate in this survey. For every completed survey, $0.50 will be donated to the American Red Cross Disaster Relief Fund. One survey per person, multiple survey entries will void a person's survey.

American Red Cross

Yes, I am over 18 and want to take the survey

No, I do not wish to take this survey

## Background

According to the 2000 U.S. Census, Southern California's (Los Angeles, Orange, Riverside, San Bernardino, and Santa Barbara county) population is 15,959,795. The Southern California Association of Governments predicts that by 2020, Southern California will gain at least 5.7 million more people, an increase of 36%. This is the approximately equivalent to two more Orange Counties. The following are the expected populations and percentage increases for specific counties in 2020:

- Los Angeles County- 12,249,088, an increase of 29%
- Orange County- 3,221,602, an increase of 14%
- Riverside County- 2,815,987, an increase of 82%
- San Bernardino County- 2,830,050, an increase of 66%
- Santa Barbara County- 552,800, an increase of 36%

With this population increase, there are expected to be 4 million new jobs created. More growth is expected in far suburbs and drive-alone commuting is expected to continue as the preferred mode of transportation for workers. Traffic conditions are predicted to worsen. The Southern California Association of Governments predicts that

- **Traffic will grow by more than 48%**.
- **Traffic delays will more than double and travel speeds will slow to 20 mph**.
- **Average commute times will increase by at least 13 minutes.**

These studies only speak for **highway traffic** conditions and do not cover the expected increase in side-street traffic and non-highway urban congestion.

**Think of what your primary commute is today, be it to work or to the grocery store. In particular, think of how many people are in the car with you, how long it takes to get where you are going, and the ease of getting there.**

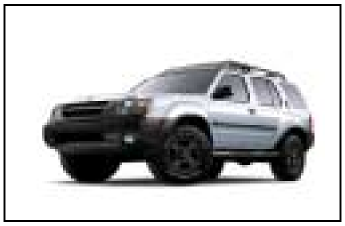
Please imagine your primary commute under these predicted conditions and whether it would be affected or not. Remember these conditions when filling out the survey --------- > NEXT

## The Question

According to the California Department of Motor Vehicle, there are 14 classes of passenger vehicles (two-seaters, sub-compacts, compacts, small wagons, mid-size cars, mid-size wagons, large cars, minivans, large vans, compact pickups, standard pickups, small SUVs, medium SUVs, and large SUVs). See diagrams below for some examples of some of the classes.

Compact- Dodge Neon
Length: 14.5 ft
Width: 5.62 ft
Height: 4.67 ft
Weight: 2635 1lbs
Cargo Volume: 13.1 cu. ft.

Mid-Size: Volkswagen Passat
Length: 15.4 ft.
Width: 5.7 ft
Height: 5.3 ft
Weight: 3452 lbs
Cargo Volume: 15 cu. ft.



SUV: Nissan Xterra
Length: 14.8 ft.
Width: 5.9 ft.
Height: 6.1 ft.
Weight: 3794 lbs
Cargo Volume: 44.5 cu ft. (rear seats up)

**Imagine** that there is a new car on the market; let's call it a **Nanocar**. This car is smaller than any of the above-mentioned classes of vehicles and is tailored for those trips where only one or sometimes two people are involved, i.e. commuting to work or the grocery stores. This car can be an addition to, or replacement, of, your currently owned vehicle(s)

The following are some details about the car:

- Its dimensions are Length: 10.5ft., Width: 4ft., Height: 4.5ft., Weight 2000 lbs
- Maximum storage capacity of 4 cu. ft. This is enough for 6 bags of groceries.
- The car is a 2-seater with seats positioned front-back instead of side-to-side.
- It is environmentally friendly with very low or no emissions (Ignore the fuel source. Assume that the ease of refueling is no less convenient as it is today.)
- For the purposes of this survey, the **Nanocar** meets and surpasses all state and federal safety and crash tests. As an example, the **Nanocar** would receive the highest frontal offset crash test rating of "good" by the Insurance Institute for Highway Safety. It also would receive the highest rating of 5 stars for both frontal and side impact by the National Highway Traffic Safety Administration.
- For the purposes of this survey, the **Nanocar** has the same appeal and amenities (i.e. sound system, air conditioning, power windows, etc.) as your next best option if you were to buy a new car.

----- > Next

Put yourself, at your current age, in the year 2020 faced with the population and traffic increases mentioned on the previous pages. Now imagine, that along with this new small car, there are incentives that go along with this car that might make buying it more attractive.

On the following page, there will be a grid with 4 different incentive scenarios that are associated with the **Nanocar**.

**Remember**:

- This car meets all safety standards and tests set by the government and consumer agencies. It receives the highest ratings by both the Insurance Institute for Highway Safety and the National Highway Traffic Safety Administration.
- There are little or no emissions associated with this vehicle.
- This car is smaller, in width and length, than any other car you have probably seen.

We are asking you to value the size of the car against other incentives that go along with the car. For the purpose of the survey, the car has the same look, appeal, and amenities as your next best option.

<u>The question that you are asked to answer is</u>:

When you are looking to buy your next car **realistically**, under which scenario, if any, would you be **most likely** to purchase the **Nanocar?**

------- > Next

**Click on highlighted underlined terms for an explanation**

| INCENTIVE | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| Highway Infrastructure Additions | Own lane on highway, 50% reduction in commute time | Own lane on highway, 25% reduction in commute time | No change in highway infrastructure Same commute time | Both own lane on highway and own lane away from highway, 25% reduction in commute time | I would not buy the **Nanocar** under any circumstance |
| Side-Street Infrastructure Additions | Own lane on highway, 50% reduction in commute time | Own lane away from highway 25% reduction in commute time | Own lane on highway, 25% reduction in commute time | Own lane on highway, 25% reduction in commute time | |
| Parking Advantages | Preferential parking at shops/stores | Preferential parking at work | No preferential parking | No preferential parking | |
| Parking Fee Reductions | 25% reduction in annual parking permit fee | No reduction | No reduction | 25% reduction in annual parking permit fee | |
| Meter Fee Reduction | Free metered parking | No reduction | Free metered parking | Free metered parking | |
| Tax Incentives | $500 tax break | $1,000 tax break | $3000 tax break | $1500 tax break | |
| Refueling Advantages | No refueling advantages over other cars | No refueling advantages over other cars | Refueling ability at fuel stations, home, and work | Refueling ability at fuel stations and at home | |
| Annual Fuel Cost Reductions | 50 % reduction in annual refueling costs | No change in annual fuel costs | 50% reduction in annual fuel costs | No change in annual refueling costs | |
| Price of Vehicle | $14,000 | $14,000 | $20,000 | $10,000 | |
| I WOULD MOST LIKELY BUY THE NANOCAR UNDER THIS SCENARIO (Check only one box) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Official Use Only | #01 | #016 | #48 | #72 | |

**The Question Again:**

When you are looking to buy your next car **realistically**, under which scenario, if any, would you be **most likely** to purchase the **Nanocar?**

# Background Information

1. Do you own or lease your current vehicle(s)?
____ Yes, I own my own car.
____ Yes, I lease my own car.
____ No, I do not own or lease my own car.

2. If you own or lease your vehicle, how many do you own and/or lease?
___ 1
___ 2
___ 3
___ 4 +

3. If you bought the Nanocar, you would use it as a
___ Primary Vehicle
___ Supplementary Vehicle

4. If you bought your vehicle, how often do you buy new vehicles?
___ Every year
___ Every 2-3 years
___ Every 4-5 years
___ More than 5 years
___ N/A

5. What mode of transportation do you use to commute to work?
___ Car
___ Mass transit (bus, rail, etc.)
___ Bike
___ Foot
___ Other
___ N/A, I do not have a commute to work

6. What mode of transportation do you use to run errands and other activities?
___ Car
___ Mass transit (bus, rail, etc.)
___ Bike
___ Foot
___Other
___ N/A, I do not run errands and other activities

7. Do you do any of the following on your primary commute on a regular basis?
___ Drop off spouse at work
___ Drop off children at school/day-care
___ Pick up breakfast/coffee
___ Go to gym
___ Other
___ None

8. How long is your primary commute, one-way?
___ 0-15 minutes
___ 16-30 minutes
___ 31-45 minutes
___ 46-60 minutes
___ 60 minutes +
___ N/A

9. How far is your primary commute, one way?
___ 0-10 miles
___ 11-20 miles
___ 20-30 miles
___ 30-40 miles
___ 40-50 miles
___ 50 +
___ N/A

10. Do you carpool to work?
___ Yes, every day
___ Sometimes (3-4 times a week)
___ Occasionally (1-2 times a week)
___ Never

If you do carpool, how many are in your carpool _______

11. Do you or anyone in your household currently conduct market research?
____ Yes
____ No

12. What area of work are you in?
____ Private Industry
____ Local/State/Federal government
____ Not for Profit organization
____ Academia
____ Student
____ Retired
____ N/A

13. Are you a member of or do you make donations to an environmental organization (i.e. Greenpeace, NRDC, Sierra Club, CalPIRG, etc.)?
___ Yes
___ No

14. What is your age range?
___ 18-29
___ 30-39
___ 40-49
___ 50-59
___ 60 or more

15. What is your household income?
___ Less than $20,000
___ $20,000-$39,999
___ $40,000-$59,999
___ $60,000-$80,000
___ $80,000-$100,000
___ More than $100,000

Please enter your Zip code in the box provided

Thank you very much for participating in this survey

## Appendix A-8b: Pre-Test Comments

The main comment that respondents had regarding the survey was that the scenario matrix contained excessive information for the respondent to digest. However, after realizing the task in front of them, the respondents acknowledged that the matrix could be worked through. To address this issue of excessive information, the researcher would have to eliminate one or more of the attributes or split up the matrix to multiple pages. In reducing the number of attributes, the group would have to compromise on some of the integral issues of the project. To split the scenarios up over a number of pages was deemed ineffective because the respondent would not be able to look at all of the scenarios at the same time. The respondents may then forget some key information regarding one scenario and choose another scenario when the chosen scenario did not truly maximize their utility. For these reasons the scenario matrices were left unchanged since after further thought all of the respondents said they were able to understand the matrix and make a decision.

<u>Respondent #1</u>

- The matrix was filled with too much information for one respondent to take in.

<u>Respondent #2</u>

- The concept of having to think twenty years from now and being the same age was difficult to grasp.
- The background question regarding past or current experience in the marketing field was also confusing. They were not clear if school experienced (say a project for their marketing class) counted or not.

<u>Respondent #3</u>

- Question of checking multiple boxes in the demographics section.

<u>Respondent #4</u>

- Little trouble understanding the scenario page, lots of information to go through. Overall, no problems

<u>Respondent #5</u>

- Scenario matrix has a good deal of information, but still able to work through

<u>Respondents #6,#7,#8,#9:</u>

No comments relating to the structure or comprehensibility of the survey.

### Appendix A-9: Email Invitation to Potential Respondents

Subject: Take a survey and help NY!!

Thank you for taking the time to open this e-mail!

The below link will take you to a short survey conducted by University of California graduate students. For every survey that is completed, $0.50 will be donated to the Twin Towers Fund, which goes directly to helping the victims and families of the World Trade Center tragedy.

http://research.survey.ucsb.edu/nanocar

In case you're wondering, we are graduate students studying at the University of California Santa Barbara (UCSB) and the above site is where you will be able to get more information on our transportation research project. Please feel free to contact us at ucsb_survey@bren.ucsb.edu if you have any questions or concerns about the survey or our research.

Thank you again for reading this message and we hope to get your response soon. Remember, the survey will not only help us but also help the victims of the September 11th tragedy.

Sincerely,
UCSB-Nanocar Group

p.s. Please feel free to send this to your friends and colleagues in California that may be interested in taking the survey and donating to the Twin Towers Fund.

**Appendix A-10: Online Survey**

## Welcome

This survey is being conducted by graduate students at the University of California, Santa Barbara (UCSB)

In the following 5 to 10 minute survey, you will be asked to answer a few questions about the mode of transportation you use currently and the choices you make or will be making when you buy a car.

The information from this survey will only be used for research at UCSB. All personal information will be held confidential and will not be distributed or used for any other purposes other than this study.

You must be over the age of 18 to participate in this survey. **For every completed survey, $0.50 will be donated to the Twin Towers Fund, which will provide assistance to the victims and families of the World Trade Center Disaster**. One survey per person, multiple survey entries will void a person's survey.

UCSB

**Take me to the Survey!**

ucsb
Social Science Survey Center
Benton Survey Research Lab

## Background

According to the 2000 U.S. Census, Southern California's (Los Angeles, Orange, Riverside, San Bernardino, and Santa Barbara Counties) population is 15,959,795. The Southern California Association of Governments predicts that by 2020, Southern California will gain at least 5.7 million more people, an increase of 36%. This is approximately equivalent to two more Orange Counties! The following are the expected populations and percentage increases for specific counties in 2020.

- Los Angeles County - 12,249,088, an increase of 29%
- Orange County - 3,221,602, an increase of 14%
- Riverside County - 2,815,987, an increase of 82%
- San Bernardino County - 2,830,050, an increase of 66%
- Santa Barbara Country - 552,800, an increase of 36%

With this increase in population, 4 million more jobs are expected to be created. More growth is expected in far suburbs and drive-alone commuting is expected to continue as the preferred mode of transportation for workers. If this is the case, traffic conditions will worsen. The Southern California Association of Governments predicts that:

- **Traffic will grow by more than 48%**
- **Traffic delays will more than double and travel speeds will slow to 20mph**
- **Average commute times will increase by at least 13 minutes**

These studies only speak for **highway traffic** conditions and **do not** cover the expected increase in side-street traffic and non-highway urban congestion.

**Think of what your primary commute is today, be it to work or to the grocery store. In particular, think of how many people are in the car with you, how long it takes to get where you are going, and the ease of getting there.**

Please imagine your primary commute under these predicted conditions and whether it would be affected or not. Remember these conditions when filling out the survey.

NEXT PAGE

# The Question

According to the California Department of Motor Vehicles, there are 14 categories of passenger vehicles on the road today. Examples of vehicles in several categories are shown below:

Compact: Dodge Neon
Length: 14.5 ft.
Width: 5.62 ft.
Height: 4.67 ft.
Weight: 2635 lbs
Cargo Volume: 13.1 cu. ft.

Midsize: Volkswagen Passat
Length: 15.4 ft.
Width: 5.7 ft.
Height: 5.3 ft.
Weight: 3452 lbs
Cargo Volume: 15 cu. ft.

SUV: Nissan X-Terra
Length: 14.8 ft.
Width: 5.9 ft.
Height: 6.1 ft.
Weight: 3794 lbs
Cargo Volume: 44.5 cu. ft. (rear seats up)

Imagine that there is a new car on the market; let's call it a **Nanocar**. This car is smaller than any of the above mentioned categories of vehicles and is tailored for those trips where only one or sometimes two people are involved; i.e. commuting to work or the grocery store. This car can be an addition to, or a replacement of the vehicle(s) that you currently own.

The following are known about the **Nanocar**:

- **Its dimensions are Length: 10.5ft., Width: 4ft., Height: 4.5ft., Weight: 2000lbs.**
- **Maximum storage capacity of 4 cubic feet.** This is enough for 6 bags of groceries.
- **The car is a 2-seater** with seats positioned front-back instead of side-to-side.
- It is environmentally-friendly with **very low emissions or zero emissions** (Note: Ignore the fuel source. Assume that the time taken to start and "refuel" the vehicle is the exactly the same as conventional vehicles on the road today).
- For the purposes of this survey, the **Nanocar meets and surpasses all state and federal safety and crash tests.** As an example, the Nanocar would receive the highest frontal offset crash test rating of "good" by the Insurance Institute for Highway Safety. It also would receive the highest rating of 5 stars for both frontal and side impact by the National Highway Traffic Safety Administration.
- For the purposes of this survey, the **Nanocar has the same appeal and amenities** (i.e. sound system, air conditioning, power windows, etc.) as your **next best option** if you were buying a new car.

NEXT PAGE

# The Question (continued...)

Put yourself at your current age in the year 2020, faced with the population and traffic increases mentioned on the previous pages. Now imagine, that along with this new small car, there are **incentives** that go along with this car that might make buying it more attractive.

On the following page, there will be a grid with 4 different incentive scenarios that are associated with the **Nanocar.**

**Remember:**

- This car meets all safety standards and tests set by the government and consumer agencies. It receives the highest ratings by both the Insurance Institute for Highway Safety and the National Highway Traffic Safety Administration.
- There are little or no emissions associated with this vehicle
- This car is smaller in width and length, than any other vehicle you have probably seen

We are asking you to value the size of the car against other incentives that go along with the car. For the purposes of this survey, the **Nanocar** has the same look, appeal, and amenities as your next best option when buying your next car.

**The question that you are asked to answer is:**

**When you are looking to buy your next car, realistically, under which scenario, if any, would you be most likely to purchase the Nanocar?**

NEXT PAGE

**Select one of the scenarios below: Click on underlined terms for further definitions**

| Incentive | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| Highway Infrastructure Additions | No change in highway infrastructure. Same commute time | Own lane on highway, 50% reduction in commute time | Own lane on highway, 50% reduction in commute time | Both own lane on highway and own lane away from highway; 25% reduction in commute time | I would not buy the Nanocar under any circumstance |
| Side-Street Infrastructure Additions | No change in side-street infrastructure. Same commute time | Own lane not on existing peripheral streets. 25% reduction in commute time | Own lane on existing peripheral streets. 25% reduction in commute time | Both own lane on existing peripheral streets and own lane not on existing peripheral streets. 25% reduction in commute time | |
| Parking Advantages | No parking advantages | Preferential parking at work | Preferential parking at stores | Preferential parking at work | |
| Parking Fee Reductions | No reduction | 50% reduction in annual parking permit fee | No reduction | 50% reduction in annual parking permit fee | |
| Tax Incentives | No tax break | No tax break | $1,000 tax break | $3,000 tax break | |
| Price of Gas | $1.50 | $1.50 | $2.50 | $2.50 | |
| Refueling Advantages | Refueling ability at fuel stations, at home, and at work | Refueling ability at fuel stations, at home, and at work | Refueling ability at fuel stations and at work | Refueling ability at fuel stations | |
| Annual Fuel Cost Reductions from Fuel Efficiency | No change in annual refueling costs | 50% reduction in annual fuel costs | No change in annual refueling costs | 25% reduction in annual fuel costs | |
| Price of Vehicle | $8,000 | $12,000 | $16,000 | $16,000 | |
| **S.** I would most likely buy the Nanocar under this scenario | A | B | C | D | E |

Next

**When you are looking to buy your next car, realistically, under which scenario, if any, would you be most likely to purchase the Nanocar?**

# Background Information

**1.** Do you currently own or lease your current vehicle(s)?

- ☐ I own my own car
- ☐ I lease my own car
- ☐ I do not own or lease a car

**2.** What is the total number of vehicles you own or lease?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 or more

**3.** How often do you buy or lease a new vehicle?

- ☐ Every year or less
- ☐ Every 2-3 years
- ☐ Every 4-5 years
- ☐ More than 5 years

What is the make and model of the vehicle that you drive most often?
**4A.**

Make [ ]

**4B.**
Model [ ]

**5.**Approximately, how many miles do you drive a year?

- Less than 10,000 miles
- 10,000-12,000 miles
- 12,000-15,000 miles
- 15,000-18,000 miles
- More than 18,000 miles

**6.** If you bought the Nanocar, you would use it as a...

- ...primary vehicle
- ...secondary vehicle

**7.** What mode of transportation do you normally use to run errands and other activities (such as going to the grocery store)?

- Car
- Mass transit (bus, rail, etc.)
- Bike
- Foot
- Other
- I do not run errand or do other activities

**8.** What mode of transportation do you normally use to commute to work?

- Car
- Mass transit (bus, rail, etc.)
- Bike
- Foot
- Other
- I do not have to commute to work

**9.** Which of the following do you do on your primary commute on a regular basis (check all that apply)

- ☐ Drop off spouse at work
- ☐ Drop off children at school/day-care
- ☐ Pick up breakfast/coffee
- ☐ Go to gym
- ☐ Other
- ☐ None

**10.** How long is your primary commute, one-way?

- ☐ 0-15 minutes
- ☐ 16-30 minutes
- ☐ 31-45 minutes
- ☐ 46-60 minutes
- ☐ 60 minutes or more

**11.** How far is your primary commute, one way?

- ☐ 0-10 miles
- ☐ 11-20 miles
- ☐ 21-30 miles
- ☐ 31-40 miles
- ☐ 41-50 miles
- ☐ 51 miles or more

**12.** Do you carpool to work?

- ☐ Yes, every day
- ☐ Yes, Sometimes (3-4 times a week)
- ☐ Yes, occasionally (1-2 times a week)
- ☐ No, never

**13.** How many people are in your carpool?

Total people in carpool: ______

**14.** What is your highest level of completed education?

- ☐ High School Diploma
- ☐ Some college
- ☐ College
- ☐ Some graduate School
- ☐ Professional Degree (M.D., M.B.A., J.D.)
- ☐ Masters Degree
- ☐ Ph.D.

**15.** Do you or anyone in your household currently conduct market research?

- ☐ Yes
- ☐ No

**16.** What field of work are you in?

- ☐ Automotive
- ☐ Finance
- ☐ Marketing/Sales
- ☐ Medical/Healthcare

- Education/Research
- Manufacturing (other than Automotive)
- Consulting
- Legal
- Student
- Administrative
- Engineering
- Other

**17.** Are you a member of or do you make donations to an environmental organization (i.e. Greenpeace, NRDC, Sierra Club, CalPIRG, etc.)?

- Yes
- No

**18.** What is your Zip Code?

Zip Code: [ ]

**19.** To help ensure the integrity of the survey results, please enter your email address below:

e-mail: [ ]

Submit Survey

## Appendix A-11: Internet Groups Utilized During Survey Administration

| Yahoo! Groups | Google Groups |
|---|---|
| Ace_club | Sci.environment |
| Grouphug | Sci.environment.waste |
| High-tech-stammtisch | Alt.California.illegals |
| PacificSurfliner | LA.jobs |
| Sombay | LA.transportation |
| SPA4Council | LA.news |
| WildGrapa | LA.general |
| BATN | AOL.neighboorhood.ca |
| CUSES | AOL.neighboorhood.ca.jobs |
| Estartupsolutions | Sac.singles |

## Appendix A-12 Binary Coding and Multinomial Logit in SAS

*(Modified from Kuhfeld 2000)*

Before the multinomial logit model could be run, the database had to be arranged in the format that the SAS Software required. The data entries for the first two survey respondents are shown below. For conciseness, only four attributes are shown; highway infrastructure modifications, side-street infrastructure modifications, cost (i.e. the price of the vehicle) and tax incentives. In the actual database, all nine attributes were included.

| Subj | Set | c | HWLC05 | HWLC10 | HWLA05 | HWLA10 | HWOTH05 | HWOTH10 | HWSAME | SSLC05 | SSLC10 | SSLA05 | SSLA10 | SSOTH05 | SSOTH10 | SSSAME | Cost | Taxinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 800 | 0 |
| 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1300 | 0 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1600 | 100 |
| 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1600 | 300 |
| 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 800 | 0 |
| 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1300 | 0 |
| 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1600 | 100 |
| 2 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1600 | 300 |
| 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

The variable "Subj" indicates the subject number of the specific matrix set. Since each respondent was presented with five scenarios (i.e. four Nanocar packages and one "no buy" scenario), there are five datalines for each respondent. "Set" represents which survey matrix the respondent saw. "c" is the choice variable in the database; a value of "1" was inputted for the survey that was chosen. Otherwise a value of "2" was inputted. Therefore in the above scenario, Subj=1, Set=1 and a response value of "1" in the "c" column of the third line implies that the first respondent who saw the first matrix chose the third package over the four other packages presented. In the actual database, there were ten "sets" since ten different matrices were created.

The specific attributes associated with a Nanocar package were then entered. For continuous variables, such as cost and tax incentives, the actual value was inputted directly into the database. However, categorical variables require different treatment. SAS instructs that each level of the attributes have a column of their own and that a binary coding be utilized to represent whether or not a package included a specific level of an attribute. For example, in the first package of set one, the value of "1" under "HWSAME" and "SSSAME" implies that for this package, no changes would be made to highway and side street infrastructure. This is the status quo scenario and therefore no additional utility would be gained from these two variables if the respondent chose to "buy" this scenario. Again, in the actual database all nine attributes and their associated levels were included.

After arranging the database, the file was exported into SAS. The following code was then used to run a multinomial logit analysis on the database.

**Example of SAS Code:**

```
proc phreg data=allrespondents outest=betas brief;
title 'Multinomial Logit Model for Nanocar Survey – All Respondents';
model c*c(2) = HWOLO25 HWOLO50 HWOLA25 HWOLA50 HWBOTH25 HWBOTH50 HWSAME SSOLO25
SSOLO50 SSOLA25 SSOLA50 SSBOTH25 SSBOTH50 SSSAME Cost TaxInc GasCost PF25 PF50
PF75 PF100 PFNONE RFH RFW RFALL RFS AF25 AF50 AFNONE ZFStores ZFWork ZFNONE /
ties=breslow;
strata subj set;
run;
```

The **data=** option specifies the input data set, which in this example is "allrespondents." The **outest=** option requests an output data set called BETAS which includes parameter estimates of the survey attributes. The statement **strata** specifies that each combination of the variables SET and SUBJ forms a set from which a choice was made. Each term in the likelihood function is a stratum. There is one term or stratum per choice set per subject, and each is composed of information about the chosen and all the unchosen alternatives.

On the left side of the **model** statement, the variables that indicate which alternatives were chosen and unchosen are specified. While this could be two different variables, one variable C was used to provide both pieces of information. The response variable C has values 1 (chosen or first choice) and 2 (unchosen or subsequent choices). The first **c** of the **c*c(2)**on the **model** statement specifies that C indicates which alternative was chosen. The second **c** specifies that C indicates which alternatives were not chosen, and **(2)** means that observations with values of 2 were not chosen. When C is set up with 1 = choice and 2 = unchosen, always specify **c*c (2)** on the left of the equal sign on the **model** statement. The attribute variables are specified after the equal sign. In the above scenario, 32 different levels of nine attributes are specified. Finally the **ties=breslow** after the slash explicitly specifies the likelihood function for the multinomial logit model. The model was then run to obtain the parameter estimates.

## APPENDIX B:
## APPENDICES FOR CHAPTER 3 – *RESULTS OF SURVEY RESPONSES*

### Appendix B-1: In-Depth Discussion of Descriptive Statistics

### General Demographics

In terms of age distribution, the general trend for survey respondents to be younger than the overall California population may be a result of the survey distribution method (Figure B-1a). Since the survey was administered via e-mail and the Internet, it was only available to those who had access to it and were comfortable with using Internet browser programs. Although the Internet population is broadening to all ages, younger generations are thought to be more Internet and e-mail "savvy." This hypothesis seems to fit with the results of the survey age demographics. It must be noted however, that the ages where one's earning potential (i.e. purchasing power) is greatest is heavily represented in the survey. In addition, the general trend of age distributions of the survey respondents closely resembles those of the California census (Figure B-1b). The income distribution of the respondents showed similar results.

Next, the respondents' tendency towards owning a vehicle and using the Nanocar as a primary vehicle has several implications. First, it is interesting that only 11% stated that they neither own nor lease a vehicle (Figure B-1i) while 22% stated that they did not have a commute. This indicates that there is a discrepancy in the way the respondents viewed the definition of a primary commute. In addition, the results also indicate that vehicles seem to be viewed as commodities from which consumers derive value from ownership.

This fact raises some questions regarding how consumers see themselves using the Nanocar and how they define their primary vehicle (Figure B-1j). For those respondents that stated that the Nanocar would be used as their primary vehicle, it may be safe to assume that they see themselves commuting in the Nanocar. The transportation and/or monetary incentives were therefore, enough so as to either trade in their only car for the Nanocar or keep their current car and relegate it to "secondary" status. For those consumers that stated that they would use the Nanocar as their secondary vehicle, it becomes slightly more difficult to interpret their perceived use of the Nanocar. One plausible assumption is that the respondents may be stating that they view the Nanocar as an addition to their current vehicle set, and therefore will use it for commuting to work (its intended purpose), yet not label it as their primary vehicle.

The respondents were asked to identify their field of work, highest level of education, and whether they donate to or are members of an environmental organization. These demographics are important because high frequencies in some of the categories may require a higher degree of interpretational caution than would otherwise be necessary. The distribution of the 891 respondents as to professional field reveals little information due to the high percentage of people that identified themselves as working outside one of the established fields (Figure B-1c). More revealing is the educational level of respondents. Most of the respondents had at least attended college. The "some college" category may be over-represented because the distribution scheme included targeting college students across California. In addition, 46% of the respondents had graduated from college and 22% had advanced degrees. Figure B-1d shows the distribution of highest education level amongst the respondents. This high level of education may mean that the respondents are more informed or better educated about environmental and urban congestion issues than others and recognize the overall benefits of the Nanocar. However, a high degree of education may affect one's purchase choice because a respondent may factor such concepts such as the technical and political feasibility of specific incentives.

Finally, a majority of respondents did not donate to nor were not members of an environmental organization (80%). This information is important to the survey because a large percentage of respondents who were affiliated with environmental organizations may skew the results and may prefer to buy the Nanocar due to its inherent "greenness" regardless of their own personal commuting and transportation preferences. Figure B-1e shows that this is not the case.

**Transportation Demographics**

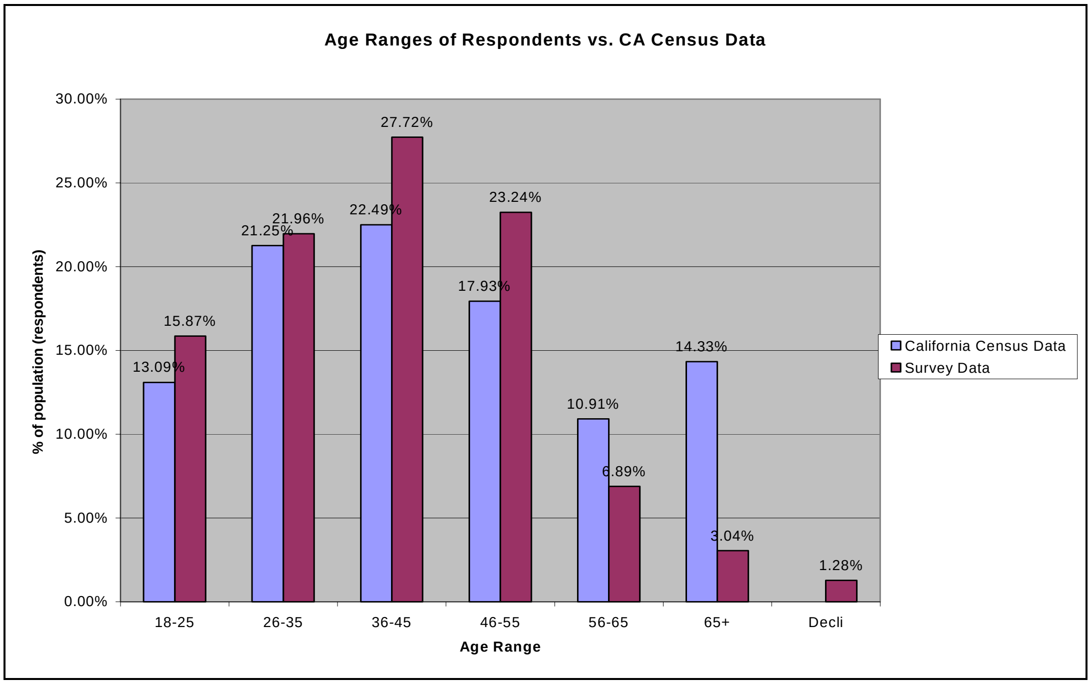
Although the overall commute time trend for respondents is comparable with the commute times for the general state population, the fact that there are a high percentage of respondents with low commute times may lead to results that deviate from what would be expected (Figure B-1g). One may anticipate that those respondents with longer commute times may find the Nanocar more attractive due to the commute time reductions associated with the Nanocar and those with lower commute times finding the Nanocar less attractive. Though this fact needs to be kept in mind when analyzing the data, it must be remembered that consumers may choose to purchase the Nanocar for a number of reasons, commute time reductions being one of them. In addition, it is also interesting to note how respondent commute times match their commute distance; 71% of respondents have commute times of less than 30 minutes and nearly 73% of respondents have commutes less than 20 miles (Figure B-1k). An obvious, general correlation between the two data sets shows that commutes of lower distances to travel, less than 20 miles, will arrive at their destination faster, in less than 30 minutes, than those of longer distances. This, however, does not take into account whether commutes have been extended due to increased congestion. Equally as important, the data shows that 27% of commuting respondents live more than 20 miles from work and 28% of commuting respondents have commutes of more than 31 minutes. This is consistent with the trend in the mid-to-late 20$^{th}$ century for people to live in suburbs that extend farther and farther from metropolitan centers, making their commutes longer (Oregon Dept. of Planning and Land Conservation, 1992). There is a slight percentage difference in commute time and distance where a few respondents (around 2%) live less than 20 miles from work yet their commute takes longer than 30 minutes.

In terms of the respondents' stops during their primary commute to work, 16% (135 people) drop off a child at school or day care and 5.5% (47 people) drop off their spouse at work (Figure B-1l). This is important because one's mode of transportation must accommodate their commuting needs and preferences; single seat automobiles would not be able to accommodate these particular needs.

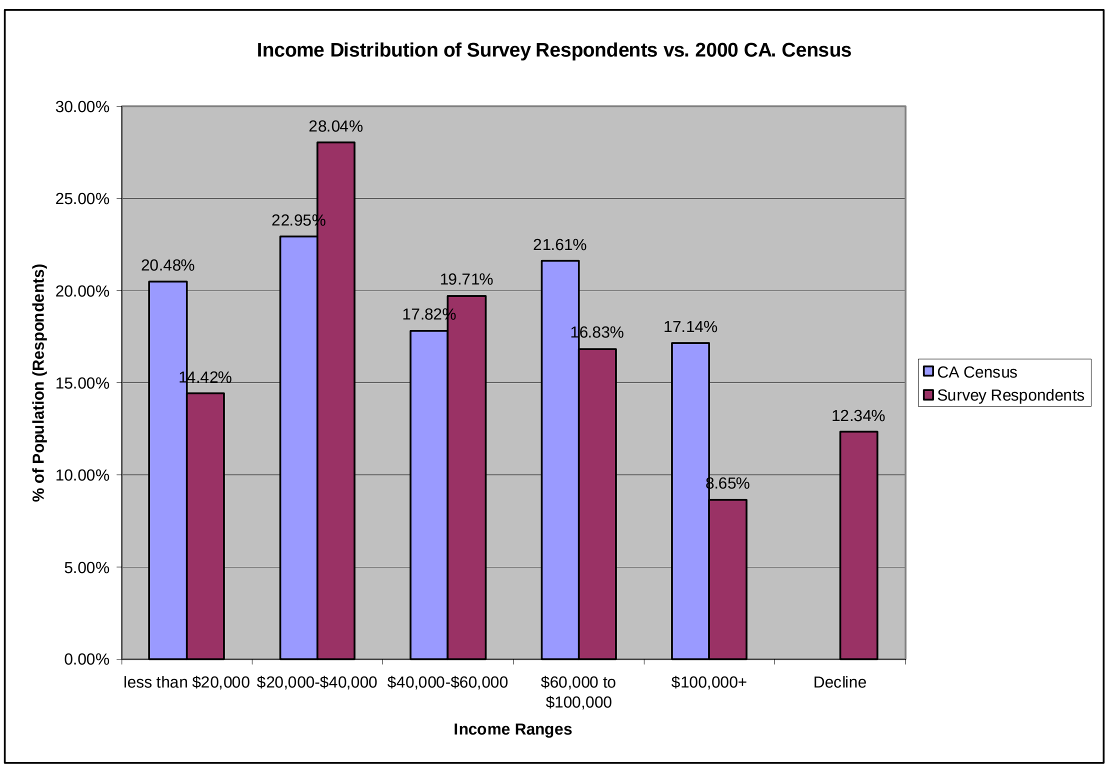
Respondents were also asked to reveal how many miles they drive per year. Most of the respondents drove less than 10,000 miles per year and percentages decreased as miles driven per year increased. This trend continues until there is a slight rise in the percentage of respondents who drive more than 18,000 miles per year. Figure B-1m shows this relationship. Again, only 11% (99 people) reported that they do not own a car, yet 22% (199 people) reported that they did not have a commute.

The make and model of survey respondents' current vehicle(s) was also obtained. The make and model information was compiled into general car company categories. As Figure B-1n shows, there is a distinct trend for respondents to drive mass produced vehicles. This is expected because many of these mass-produced vehicles have lower price tags and high advertising expenditures. When examined further, the distribution of vehicles is mainly centered on the "Big 3" of the automotive industry; General Motors, Ford and DaimlerChrysler. The major Japanese automotive companies, including Toyota, Honda and Nissan, were also major components of the distribution.

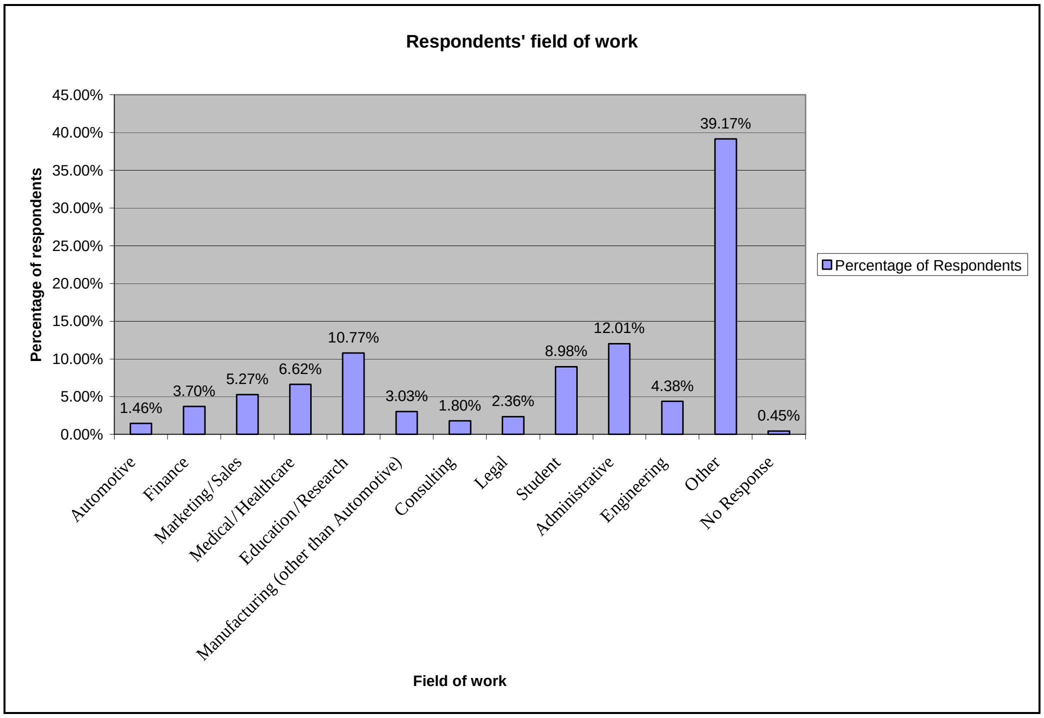
## Appendix B-1a: Age Distribution of Survey Respondents vs. 2000 CA Census Data



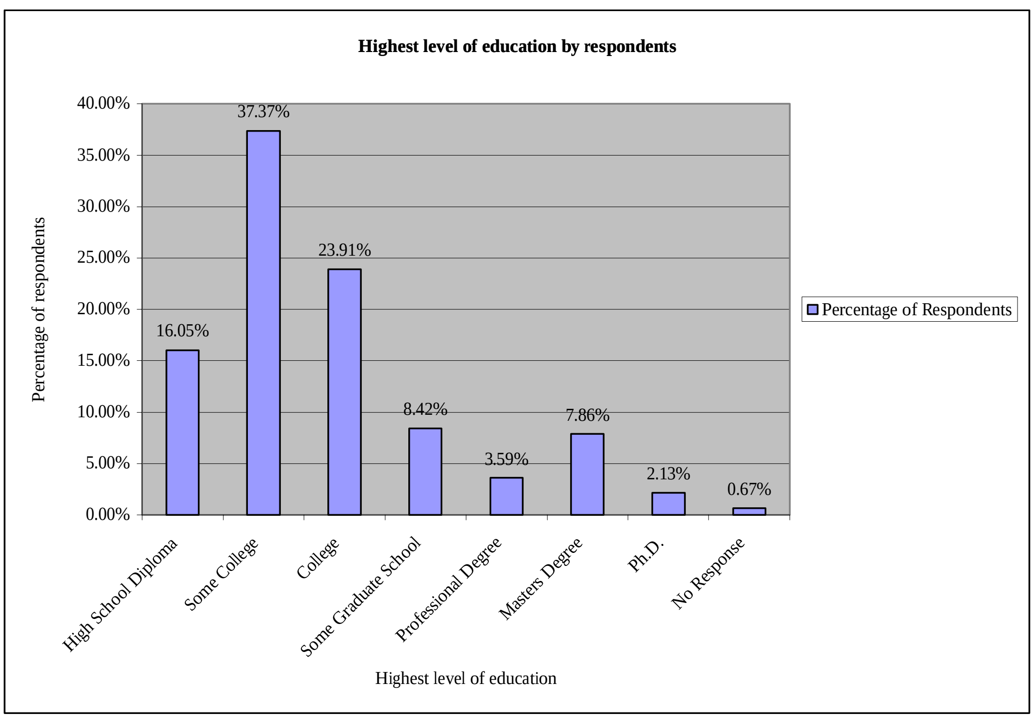

## Appendix B-1b: Income Distribution of Survey Respondents vs. 2000 CA Census Data



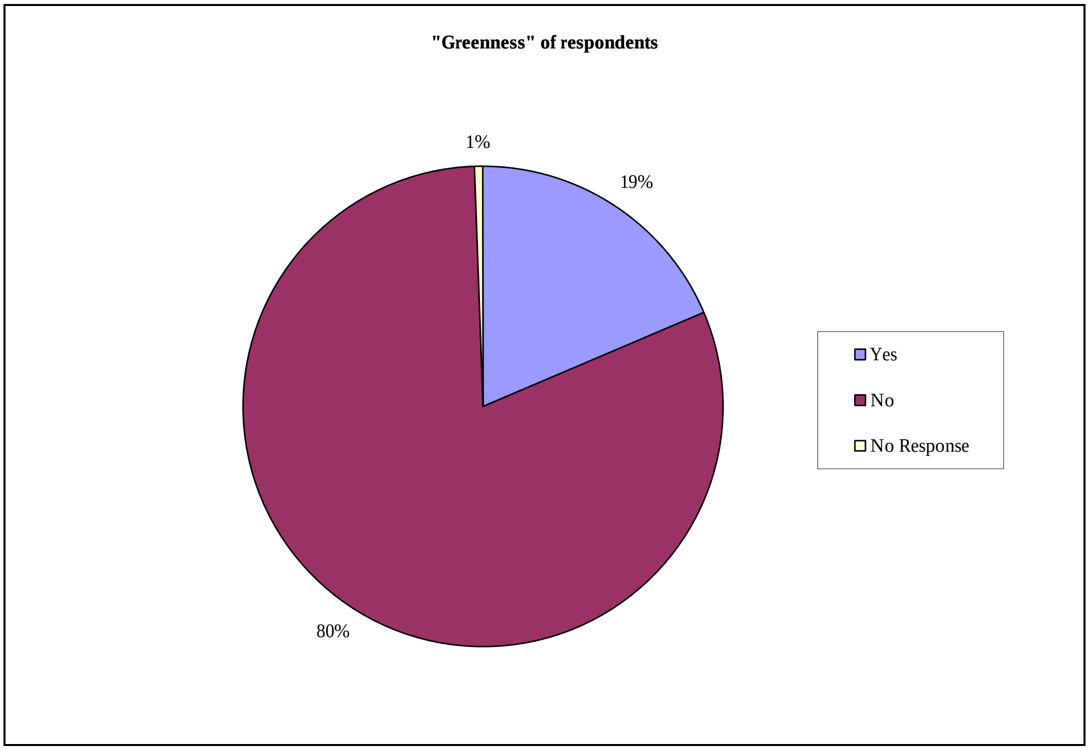
## Appendix B-1c: Respondents' Field of Work



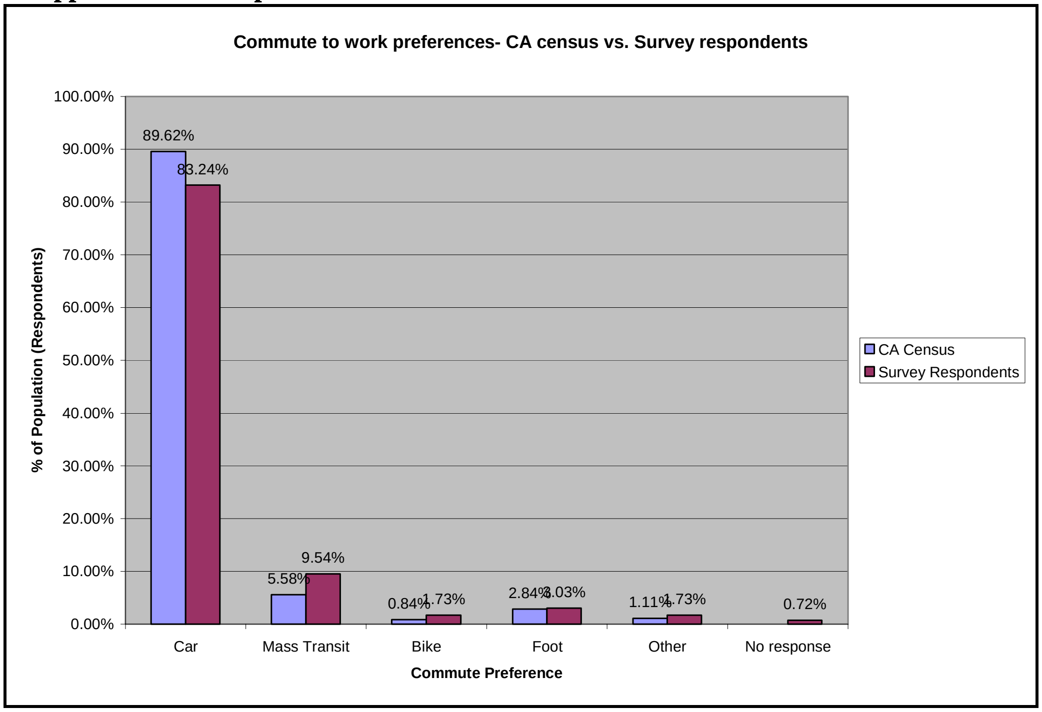

## Appendix B-1d: Education Level of Respondents



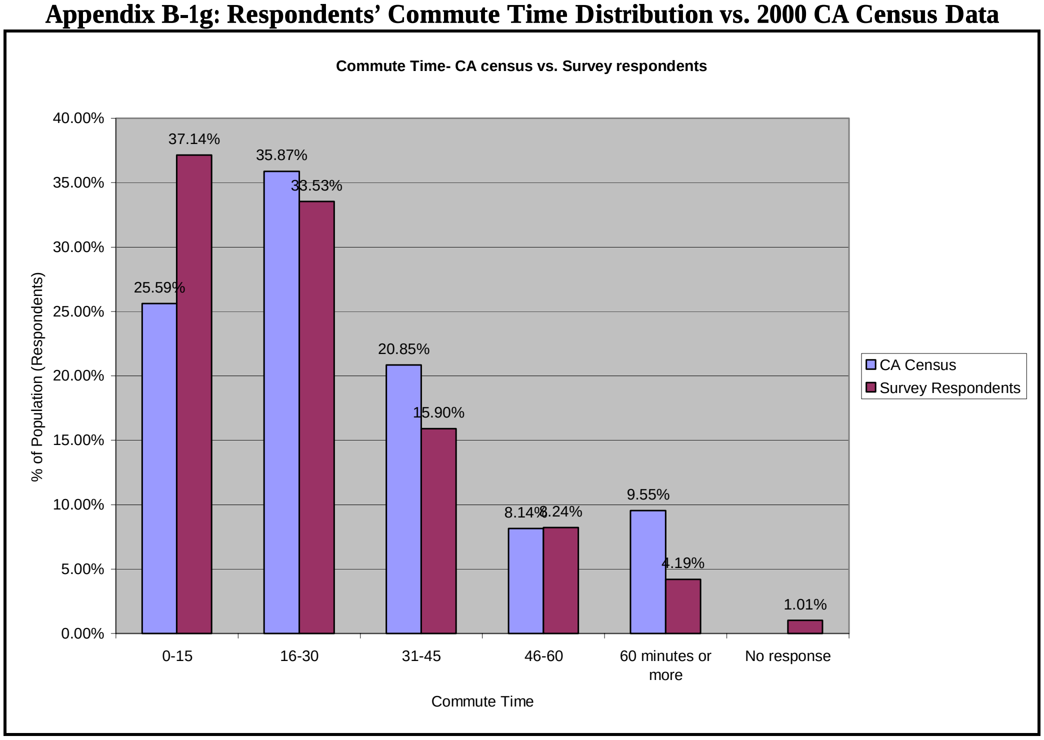
**Appendix B-1e: Environmental Affiliations of Respondents (Are you a member of do you donate to an environmental organization?)**



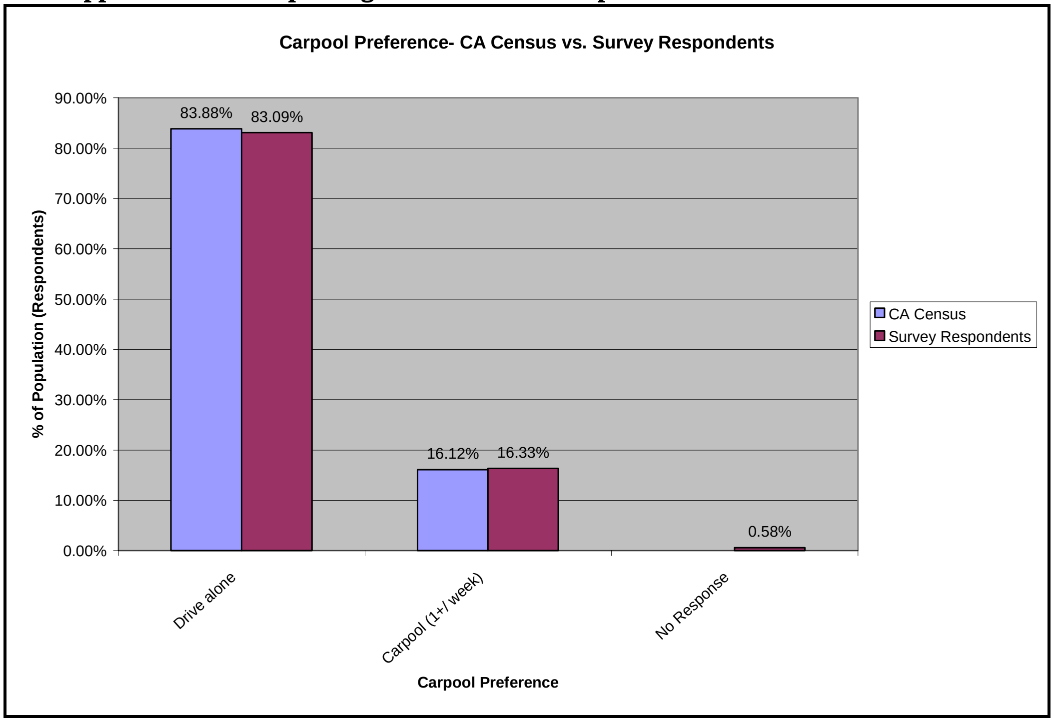
## Appendix B-1f: Respondents' Commute to Work Preferences vs. 2000 CA Census Data



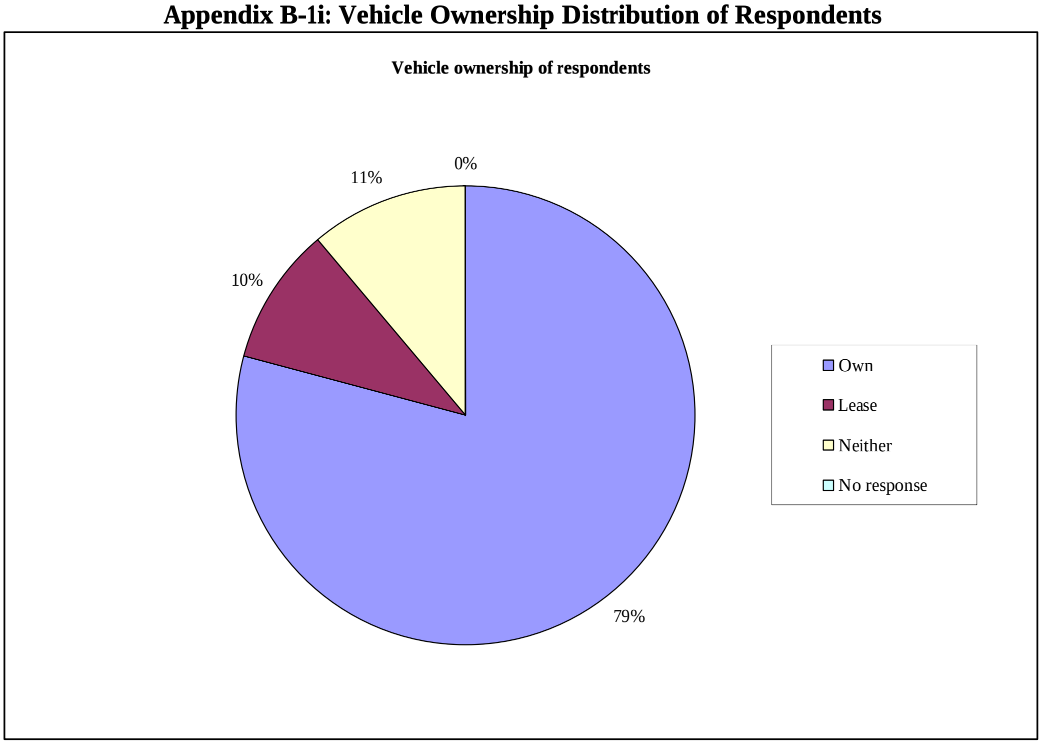

## Appendix B-1g: Respondents' Commute Time Distribution vs. 2000 CA Census Data



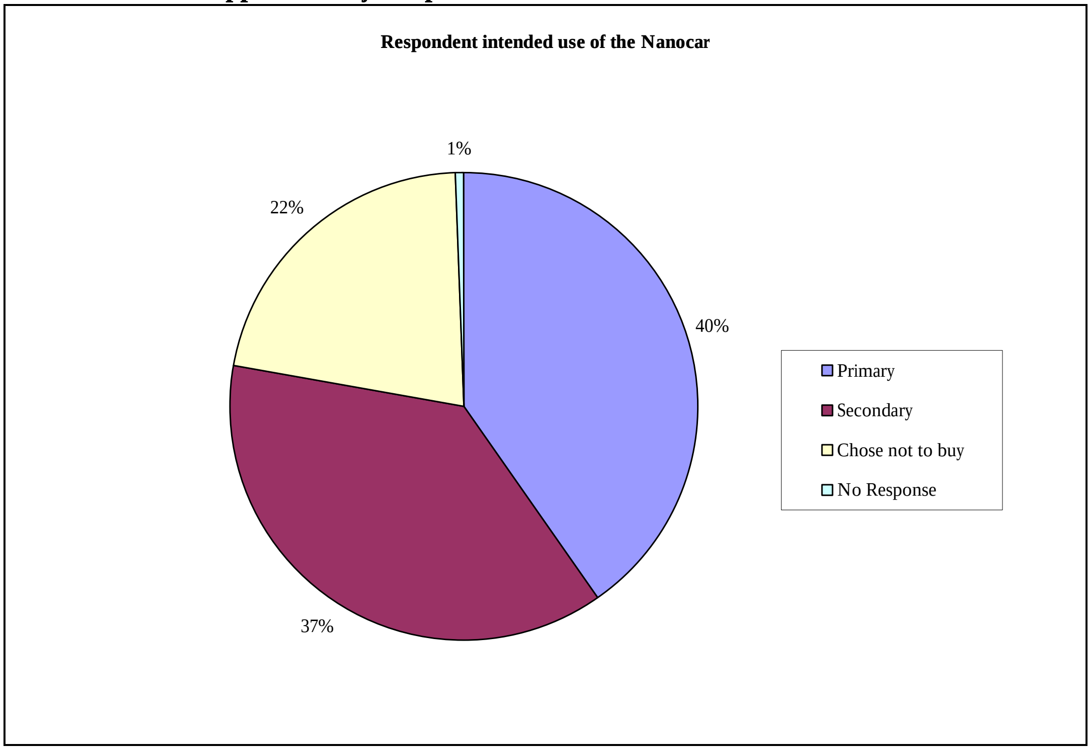
## Appendix B-1h: Carpooling Distribution of Respondents vs. 2000 CA Census Data



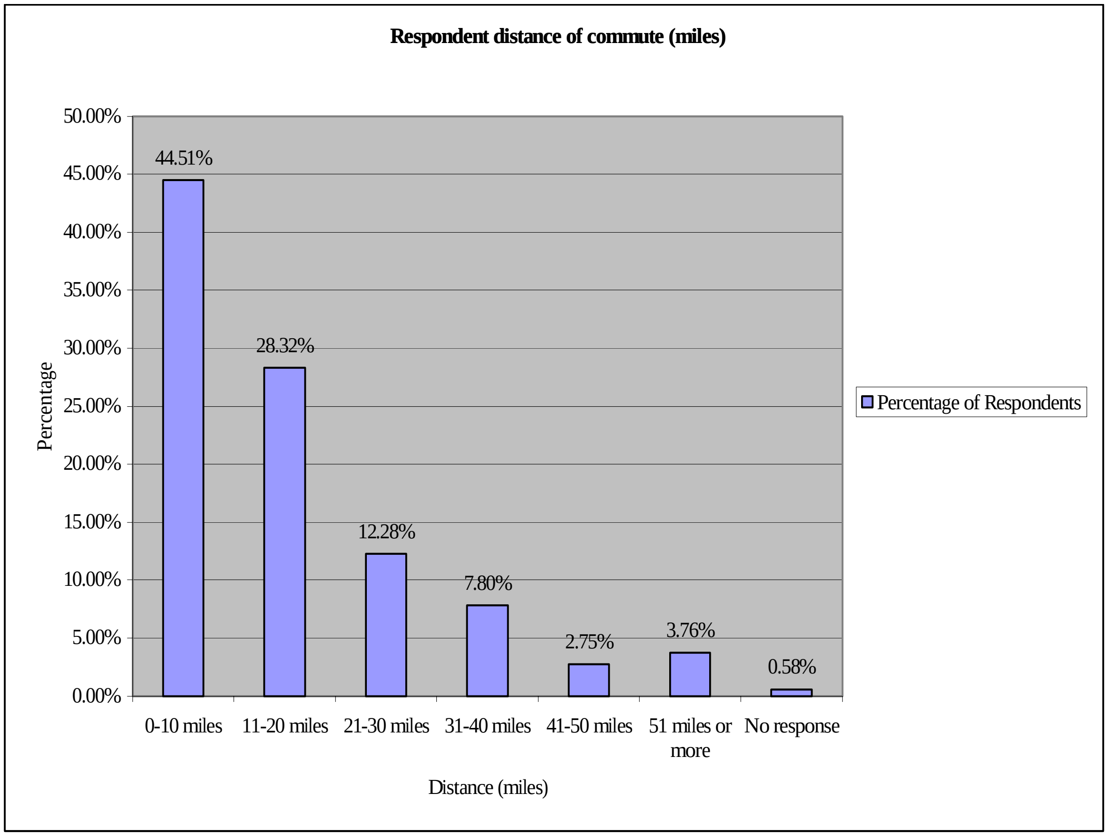

## Appendix B-1i: Vehicle Ownership Distribution of Respondents



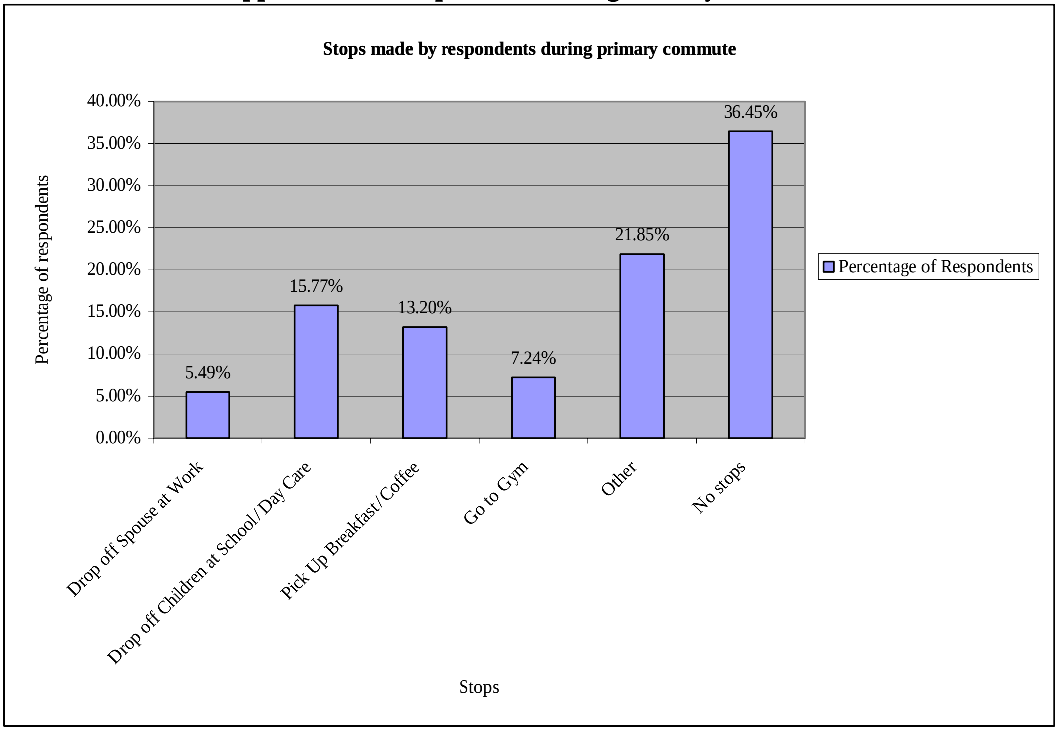
**Appendix B-1j: Respondents' Intended Use of The Nanocar**



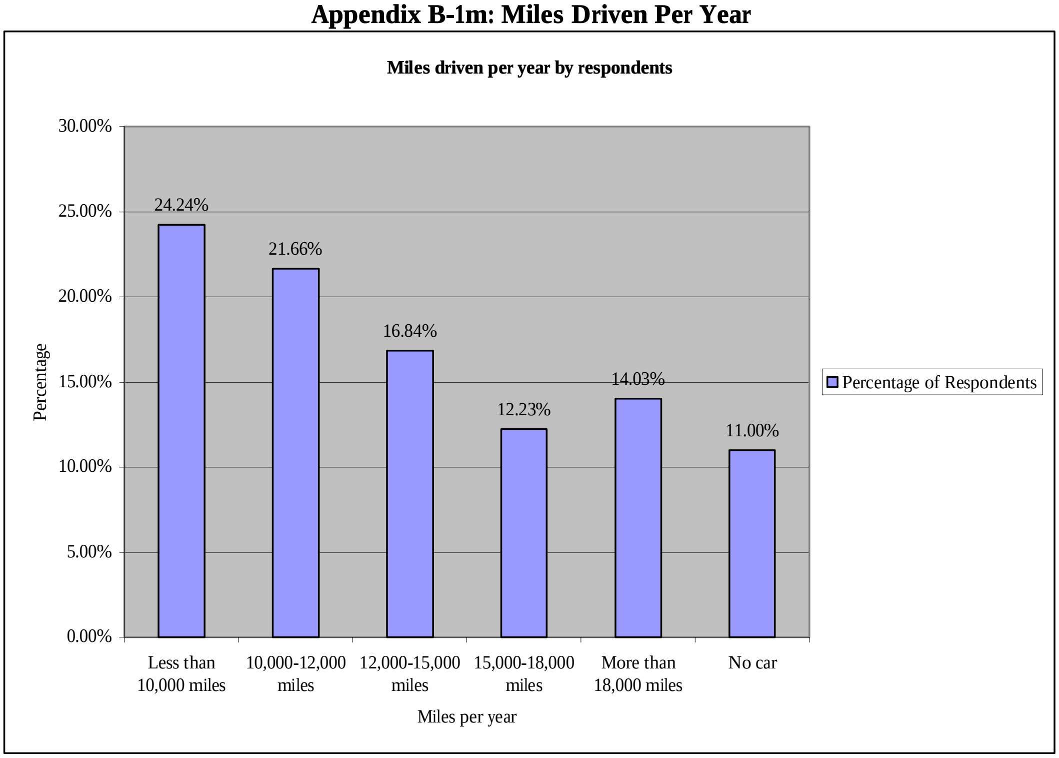
**Appendix B-1k: Distance Distribution for Respondents' Primary Commute**



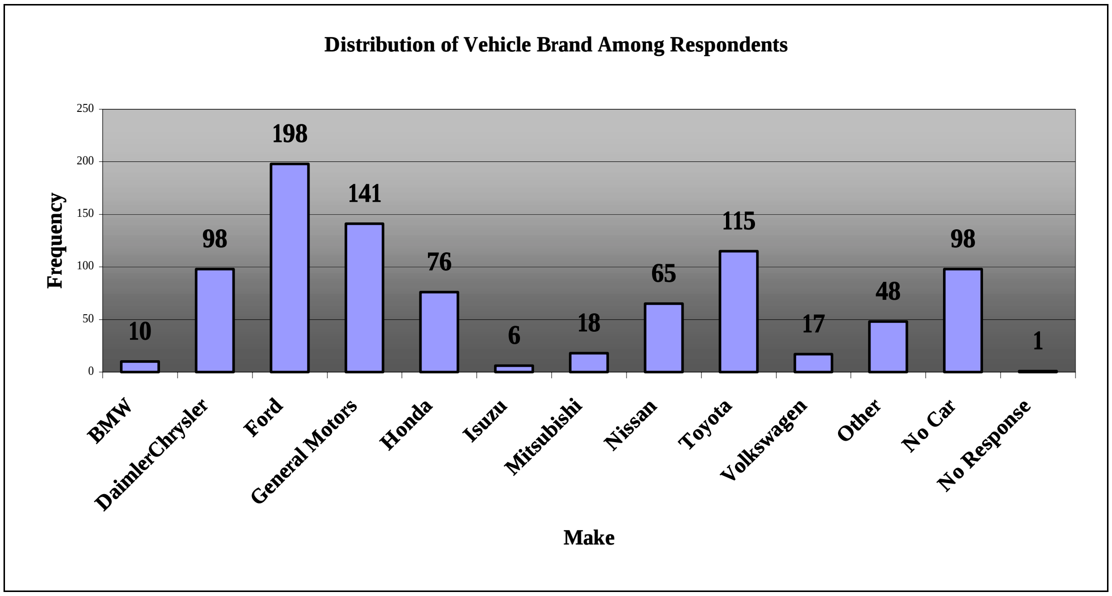
## Appendix B-1l: Stops Made During Primary Commute




## Appendix B-1m: Miles Driven Per Year



## Appendix B-1n: Make of Respondent-Owned/Leased Vehicles



## Appendix B-2: Results of Demographic Logit Analysis

| Logit Results- Demographic Information | | | | |
|---|---|---|---|---|
| | | **Value** | **Std. Error** | **t-value** |
| | (Intercept) | 0.27281694 | 0.9429693 | 0.2893169 |
| **Length Variables** | No Commute | -0.09724928 | 0.911797 | -0.1066567 |
| | < 15 minutes | 0.31092133 | 0.9125357 | 0.3407224 |
| | 16-30 minutes | 0.33380576 | 0.9119774 | 0.3660242 |
| | 30-45 minutes | 1.10063392 | 0.9506283 | 1.1577963 |
| | 46-60 minutes | 0.55970462 | 0.9676657 | 0.578407 |
| | 60+ minutes | 0.32174864 | 1.0177391 | 0.3161406 |
| | No Answer | NA | NA | NA |
| **Age Variables** | 18-25 | 0.40092154 | 0.4281533 | 0.9363972 |
| | 26-35 | -0.3325155 | 0.3552834 | -0.9359163 |
| | 36-45 | -0.31947714 | 0.3432954 | -0.9306188 |
| | 46-55 | -0.51847411 | 0.3473809 | -1.4925233 |
| | 56-65 | -0.64723671 | 0.4466318 | -1.4491504 |
| | 65+ | -0.96052582 | 0.5913955 | -1.6241682 |
| | No Answer | NA | NA | NA |
| **Income Variables** | < $20,000 | 0.6501204 | 0.3822323 | 1.7008516 |
| | $20,000-$39,999 | 0.79528251 | 0.3325636 | 2.39137 |
| | $40,000-$59,999 | 0.89819457 | 0.3589185 | 2.5025025 |
| | $60,000-$79,999 | 0.61823463 | 0.4100861 | 1.5075728 |
| | $80,000-$99,999 | 0.38060455 | 0.4514052 | 0.8431549 |
| | $100,000+ | 1.86807942 | 0.5844144 | 3.1964982 |
| | No Answer | NA | NA | NA |
| **Location Variables** | San Diego | 0.61855607 | 0.6105878 | 1.0130502 |
| | Los Angeles | 0.53271034 | 0.5599115 | 0.9514188 |
| | Santa Barbara/Ventura | 0.33033269 | 0.6765625 | 0.4882515 |
| | South | 0.84068715 | 0.6206991 | 1.3544198 |
| | S.F/Bay Area | 0.33185788 | 0.5809109 | 0.5712715 |
| | Sacramento | 0.26952715 | 0.622013 | 0.4333143 |
| | Mid-North | 0.33884809 | 0.5747645 | 0.5895425 |

Notes:

1. Significance is determined to be 1.96 (t-value) for 95% of confidence level
2. Values labeled as N/A are considered structural zero's

Additional Geographic Location Description:

1. South: Areas in Southern California not associated with the named regions
2. Mid-North: Areas in Mid-Northern California not associated with the named regions

## Appendix B-3: Multinomial Logit Results for Non-Commuters

**Appendix B-3a**

**MNL Results - Non Commuters**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HWOLO25 | 0.38495 | 0.3308 |
| HWOLO50 | -0.87564 | 0.1296 |
| HWOLA25 | -0.26656 | 0.5485 |
| HWOLA50 | -0.14663 | 0.7551 |
| HWBOTH25 | -0.0543 | 0.8834 |
| HWBOTH50 | -0.21989 | 0.6691 |
| HWSAME | 0 | - |
| SSOLO25 | 0.29935 | 0.5116 |
| SSOLO50 | -0.35045 | 0.4255 |
| SSOLA25 | 0.16057 | 0.7866 |
| SSOLA50 | 0.61723 | 0.1725 |
| SSBOTH25 | -0.02442 | 0.9585 |
| SSBOTH50 | 0.14125 | 0.7166 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.0001269 | <. 0001* |
| Tax Incentives | 0.0001686 | 0.1585 |
| Price of Gas | -0.29454 | 0.1851 |
| Parking Fee Reduction 25 | 0.08583 | 0.823 |
| Parking Fee Reduction 50 | 0.77796 | 0.0328* |
| Parking Fee Reduction 75 | -0.10042 | 0.8161 |
| Parking Fee Reduction 100 | 0.60675 | 0.1272 |
| No Parking Fee Reductions | 0 | - |
| Refueling ability at home | -0.2888 | 0.3656 |
| Refueling ability at work | 0.13197 | 0.6915 |
| Refueling ability at home and work | 0.2665 | 0.3905 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.13591 | 0.667 |
| 50% Annual Fuel Reductions | 0.26581 | 0.3632 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 1.02861 | 0.0035** |
| Preferential Parking at Work | 0.94698 | 0.0022** |
| No Preferential Parking | 0 | - |

**Appendix B-3b**

**MNL Results - Non Commuters With Infrastructure Groupings**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HWOLO | 0.02212 | 0.9497 |
| HWOLA | -0.33494 | 0.3544 |
| HWBOTH | -0.10922 | 0.7375 |
| HWSAME | 0 | - |
| SSOLO | -0.14183 | 0.6673 |
| SSOLA | 0.0887 | 0.7967 |
| SSBOTH | -0.07009 | 0.8219 |
| SSSAME | | - |
| Price of Vehicle | -0.0001096 | <. 0001*** |
| Tax Incentives | 0.0002067 | - |
| Price of Gas | -0.20647 | 0.3113 |
| Parking Fee Reduction 25 | 0.17604 | 0.6149 |
| Parking Fee Reduction 50 | 0.58872 | 0.086 |
| Parking Fee Reduction 75 | 0.15052 | 0.6501 |
| Parking Fee Reduction 100 | 0.30059 | 0.401 |
| No Parking Fee Reductions | 0 | - |
| Refueling ability at home | -0.28273 | 0.3377 |
| Refueling ability at work | -0.04528 | 0.8681 |
| Refueling ability at home and work | 0.10909 | 0.6965 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | 0.07995 | 0.7189 |
| 50% Annual Fuel Reductions | 0.27581 | 0.3075 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.72863 | 0.0132* |
| Preferential Parking at Work | 0.83668 | 0.0028** |
| No Preferential Parking | 0 | - |

**Appendix B-3c**

**MNL Results - Non Commuters With Commute Time Groupings**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HW25 | 0.0811 | 0.7979 |
| HW50 | -0.13513 | 0.694 |
| HWSAME | 0 | |
| SS25 | -0.21891 | 0.5062 |
| SS50 | 0.00947 | 0.9741 |
| SSSAME | 0 | - |
| Price of Vehicle | -0.0001107 | <. 0001*** |
| Tax Incentives | 0.0001853 | 0.0978 |
| Price of Gas | -0.31296 | 0.1318 |
| Parking Fee Reduction 25 | 0.21581 | 0.5324 |
| Parking Fee Reduction 50 | 0.64875 | 0.0598 |
| Parking Fee Reduction 75 | 0.03049 | 0.9333 |
| Parking Fee Reduction 100 | 0.51947 | 0.1268 |
| No Parking Fee Reductions | 0 | - |
| Refueling ability at home | -0.30296 | 0.2834 |
| Refueling ability at work | -0.1153 | 0.6871 |
| Refueling ability at home and work | 0.04773 | 0.8674 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | 0.02407 | 0.9267 |
| 50% Annual Fuel Reductions | 0.31428 | 0.2515 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.80811 | 0.0083** |
| Preferential Parking at Work | 0.92127 | 0.001*** |
| No Preferential Parking | 0 | - |

## Appendix B-4: Multinomial Logit Results for Net Cost Variable

**Appendix B-4a**

**MNL Results - Commuters with Net Cost Variable**

| Variable | Parameter Estimate | P-value |
|---|---|---|
| HWOLO25 | 0.54019 | 0.0123* |
| HWOLO50 | -0.13035 | 0.6423 |
| HWOLA25 | 0.51339 | 0.0232* |
| HWOLA50 | 0.13961 | 0.5924 |
| HWBOTH25 | -0.13432 | 0.5293 |
| HWBOTH50 | -0.00181 | 0.9954 |
| HWSAME | 0 | - |
| SSOLO25 | 0.07744 | 0.7022 |
| SSOLO50 | -0.49322 | 0.0292* |
| SSOLA25 | 0.28437 | 0.3278 |
| SSOLA50 | 0.62723 | 0.0023** |
| SSBOTH25 | 0.29316 | 0.1471 |
| SSBOTH50 | 0.46702 | 0.0259* |
| SSSAME | 0 | - |
| Net Cost | -0.0000985 | <.0001*** |
| Price of Gas | -0.51828 | <.0001*** |
| Parking Fee Reduction 25 | 0.48855 | 0.0053** |
| Parking Fee Reduction 50 | 0.97031 | <.0001*** |
| Parking Fee Reduction 75 | 0.32065 | 0.1522 |
| Parking Fee Reduction 100 | 0.81692 | <.0001*** |
| No Parking Fee Reductions | 0 | - |
| Refueling ability at home | -0.30765 | 0.0619 |
| Refueling ability at work | 0.34662 | 0.0241* |
| Refueling ability at home and work | 0.05047 | 0.743 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.32716 | 0.0273* |
| 50% Annual Fuel Reductions | 0.1009 | 0.5094 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 0.87348 | <.0001*** |
| Preferential Parking at Work | 0.70169 | <.0001*** |
| No Preferential Parking | 0 | - |

**Appendix B-4b**

| MNL Results - Non Commuters with Net Cost Variable | | |
|---|---|---|
| **Variable** | **Parameter Estimate** | **P-value** |
| HWOLO25 | 0.39993 | 0.311 |
| HWOLO50 | -0.89368 | 0.1237 |
| HWOLA25 | -0.24784 | 0.5744 |
| HWOLA50 | -0.14155 | 0.7636 |
| HWBOTH25 | -0.03646 | 0.9213 |
| HWBOTH50 | -0.19947 | 0.6963 |
| HWSAME | 0 | - |
| SSOLO25 | 0.33655 | 0.4492 |
| SSOLO50 | -0.32581 | 0.4533 |
| SSOLA25 | 0.18491 | 0.7541 |
| SSOLA50 | 0.65903 | 0.1333 |
| SSBOTH25 | 0.02308 | 0.959 |
| SSBOTH50 | 0.16572 | 0.6652 |
| SSSAME | 0 | - |
| Net Cost | -0.0001279 | <.0001*** |
| Price of Gas | -0.28192 | 0.1979 |
| Parking Fee Reduction 25 | 0.13105 | 0.7175 |
| Parking Fee Reduction 50 | 0.81702 | 0.0189* |
| Parking Fee Reduction 75 | -0.08543 | 0.8425 |
| Parking Fee Reduction 100 | 0.6447 | 0.0909 |
| No Parking Fee Reductions | 0 | - |
| Refueling ability at home | -0.26838 | 0.3924 |
| Refueling ability at work | 0.14775 | 0.6543 |
| Refueling ability at home and work | 0.26199 | 0.3986 |
| Refueling at Fuel Stations | 0 | - |
| 25% Annual Fuel Reductions | -0.16373 | 0.5924 |
| 50% Annual Fuel Reductions | 0.2495 | 0.3867 |
| No Annual Fuel Reductions | 0 | - |
| Preferential Parking at Stores | 1.041 | 0.003** |
| Preferential Parking at Work | 0.96022 | 0.0018** |
| No Preferential Parking | 0 | - |

# APPENDIX C
# APPENDICES FOR CHAPTER 5 - *AIR QUALITY ANALYSIS*

## Appendix C-1: In-Depth Analysis of Air Quality

### Background Information

California has had the longest history of air quality regulation. This is primarily the result of a large densely packed population combined with high average commute distances. In 1946, the extent of air pollution in the Los Angeles region was acknowledged by the state and furthermore, throughout the county, with the establishment of the nation's first air pollution control district (Kamieniecki and Ferall, 1991) and is the only state with Congressional authority to endorse stricter rules than the EPA does for vehicles and fuels (Hall 2001). In the 1970's, it was common to have 100 or more Stage 1 smog alerts in the Los Angeles Basin, and even today the American Lung Association's report (2001) on state air pollution places San Bernardino as having the largest number of "high ozone days in the unhealthy ranges" in the entire United States. Although tremendous improvements have been made in the last 30 years from Federal motor vehicle codes and adoption of clean air technologies, as of October 2000 the California Air Resources Board (ARB) declared that 95% of all Californians live in non-attainment areas that do not meet health-based Federal or State air quality standards.

### Current Regulations

The rising trend of poor air quality in the United States has resulted in the need for national and regional regulators to take a closer look at the problem. Regulations that have been created in hopes of bettering current air quality conditions include the Clean Air Act of 1970 and its amendments, which have been responsible for the implementation of the Low Emission Vehicle (LEV) Program and the Zero Emission Vehicle (ZEV) Mandate. The passage of the Clean Air Act by Congress in 1970 is considered to be one of the pioneer environmental policies in the United States. Although originally very controversial, the act gained substantial support through evidence that showed a high proportion of pollutant emission into the atmosphere as a direct consequence of mobile-source pollutants. Estimates have indicated that motor vehicles account for about 50% of all hydrocarbon and nitrogen oxide precursor pollutants, up to 90% of the carbon monoxide, and over half of the toxic air pollutants in the United States (Smith 1994). These are startling figures considering that the majority of constituents found in automobile emissions are toxic to the ecosystem and/or human health.

The 1970 Clean Air Act and the subsequent 1977 amendments directed the Environmental Protection Agency (EPA) to develop Primary and Secondary National Ambient Air Quality Standards (NAAQS) – see Table C-1a. Additionally, to address the need for a more proactive regional approach to the air quality problem, section 110 of the Act required states in non-attainment zones to develop implementation plans (State

Implementation Plans or SIPs), which have to be submitted to the enforcement arm of the Federal government (in this case the EPA) for approval by a specific date. The SIPs include maintenance and enforcement measures to reach the health-based NAAQS.

| **Table C-1a: National Ambient Air Quality Standards (NAAQS) For Mobile Source Related Emissions** | | | |
|---|---|---|---|
| POLLUTANT | STANDARD VALUE* | | STANDARD TYPE |
| Carbon Monoxide (CO) | | | |
| 8-hour Average | 9 ppm | (10 mg/m$^3$) | Primary |
| 1-hour Average | 35 ppm | (40 mg/m$^3$) | Primary |
| | | | |
| Nitrogen Dioxide ($NO_2$) | | | |
| Annual Arithmetic Mean | 0.053 ppm | (100 µg/m$^3$) | Primary & Secondary |
| | | | |
| Ozone ($O_3$) | | | |
| 1-hour Average | 0.12 ppm | (235 µg/m$^3$) | Primary & Secondary |
| 8-hour Average ** | 0.08 ppm | (157 µg/m$^3$) | Primary & Secondary |
| | | | |
| Particulate (PM 10) Particles with diameters of 10 micrometers or less | | | |
| Annual Arithmetic Mean | 50 µg/m$^3$ | | Primary & Secondary |
| 24-hour Average | 150 µg/m$^3$ | | Primary & Secondary |
| | | | |
| Particulate (PM 2.5) Particles with diameters of 2.5 micrometers or less | | | |
| Annual Arithmetic Mean ** | 15 µg/m$^3$ | | Primary & Secondary |
| 24-hour Average ** | 65 µg/m$^3$ | | Primary & Secondary |

These measures include regulation on mobile sources, such as automobile and diesel trucks, as well as stationary sources, such as electric utilities and manufacturing plants. Furthermore, Section 177 of the Clean Air Act allows individual states to retain the authority to adopt and enforce new vehicle standards as long as such standards are identical or surpass that of California and are adopted at least two years before a model year. SIPs are not single documents but rather a compilation of new and previously submitted plans, programs, district rules, State regulations and Federal controls. However in California, the majority of the SIPs are based on a core set of control strategies, fuel regulations and limits on consumer product emissions.

In California, the Air Quality Management Plan (AQMP) developed by the South Coast Air Quality Management District (SCAQMD), the Southern California Association of

Governments (SCAG) and the California Air Resources Board (ARB) was adopted in 1989 and made up a large portion of the revised SIP submitted for approval to the EPA. Furthermore, the initial AQMP included various steps proposed by the ARB to reduce the impact of mobile-source emissions on California's air quality.

The three-tiered plan consists of control measures that can be adopted in the short-term with current technologies (Tier I), more stringent control measures that use "on-the-horizon" technologies that have a reasonable chance of being developed in the short-term (Tier II), and control measures that require major technological breakthroughs to occur in a twenty-year time span (Tier III). As part of both the Tier II and Tier III control measures, the California LEV Program was adopted in 1990. The program set fleetwide automobile emissions standards for new vehicles sold in California and commencing in 1994, the standards grew increasingly stringent each year. In addition, the LEV program established five new vehicle standards: Transitional LEV (TLEV), LEV, Ultra LEV (ULEV), Super-Ultra LEV (SULEV) and ZEV.

The ZEV mandate (subsequently changed to the ZEV program in 2000) has been the most controversial and contested section of the overall LEV program. In its original form, the mandate, which was inspired by trends in battery electric vehicle technology, required at least two percent of vehicles sales of the seven largest automakers in California to be ZEVs in 1998, increasing to 10% by 2003. The ZEV mandate has been modified extensively since 1990 for various reasons including the lack of a large-scale breakthrough in battery technology, major criticism from automakers, and the growing number of alternative technologies that would fall under the category of ZEV. In its current state, the less stringent version of the original ZEV mandate maintains its original target of 10% in 2003, but allows automakers to use multiplier credits for ZEVs in the early stages (i.e. receiving 4 credits for every one "Pure ZEV" on the market between 2001-2002, and 1.25 credits for every one "Pure ZEV" in 2003-2005). In addition, partial zero emission vehicles (PZEV), such as gasoline-electric hybrid vehicles, and advanced technology PZEV (ATPZEV), such as methanol reformer fuel-cell vehicles, can also be counted as part of the ten percent ZEV requirements. Therefore, in its current state only two percent of the vehicles must be ZEVs in 2003 while the other eight percent can be comprised of credits received from PZEVs, ATPZEVs and SULEVs. Table C-1b presents the modified ZEV percentage requirements for the seven largest automakers, which were officially adopted in January 2001.

**Table C-1b: Future ZEV Percentage Requirements for the Seven Largest Automakers (January 2001)**

| Model Years | Minimum ZEV Requirement |
|---|---|
| 2003 through 2008 | 10% |
| 2009 through 2011 | 11% |
| 2012 through 2014 | 12% |
| 2015 through 2017 | 14% |
| 2018 and subsequent | 16% |

Even though 95% of Californians still live in areas that are not in compliance with either State or Federal NAAQS, the actual quality of the air has seen vast improvements in the past 30 years. For example, emissions of all the major pollutants associated with on-road motor vehicles such as Carbon Monoxide (CO), Nitrogen Oxides ($NO_x$), and Reactive Organic Gases (ROG), which are all precursors to ground-level ozone, have shown a decreasing trend in the South Coast Air Basin (SCAB). In addition, recent results from air quality models have led the California Air Resources Board to believe that existing stringent vehicle emission standards, the increased use of natural gas as the principal fuel for power plants and control rules that limit $NO_x$ emissions are the major factors behind this decrease, and further regulations on vehicle emissions will prolong this trend for years to come. Specifically, the ARB predicts that the ZEV program and the resultant increase in the proportion of lower-emission vehicles on the road will play a major role in continuing improvements to California's air quality. However, given the increasing population and growing vehicle commute times that have been the result of urban sprawl, the overall benefit of such programs will be dramatically overshadowed.

## Gasoline Combustion, Air Quality and Health Effects

The process of combusting gasoline with the intent of transforming chemical energy into mechanical energy produces very toxic byproducts that are released as exhaust. As mentioned before, these exhaust constituents include hydrocarbons, nitrogen oxides, carbon monoxide, and carbon dioxide. Each of the identified automobile exhaust constituents has been correlated with the causation of either environmental and/or human risks.

## Hydrocarbons

Hydrocarbon emissions are released when fuel molecules in the engine do not burn or burn only partially. Although the degree of combustion completeness varies depending on the engine, all engines release hydrocarbons. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. This relationship is depicted in the following equation:

$$NO_x + \lambda \text{ (ultraviolet radiation)} \rightarrow N + O$$
$$O + O_2 + M \rightarrow O_3 + M$$

Where, *M* is a hydrocarbon molecule.

Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. It is the most widespread and intractable urban air pollution problem. A number of exhaust hydrocarbons have also been determined to have carcinogenic properties.

### Nitrogen Oxides

Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as $NO_x$. Additionally, nitrogen oxides contribute to the formation of acid rain which, when reaching high enough concentrations, defaces structures and degrades local ecologic conditions. About half of all $NO_x$ emissions released in the United States are from mobile sources (USEPA 1994).

### Carbon Monoxide

Carbon monoxide (CO) is a product of incomplete combustion and occurs when carbon in the fuel is only partially oxidized rather than fully oxidized to carbon dioxide ($CO_2$). Carbon monoxide is highly toxic when inhaled reducing the flow of oxygen in the bloodstream. It is a particularly serious threat to persons with heart disease. Transportation sources account for over 75% of the total U.S. carbon monoxide emissions (USEPA 1994).

### Carbon Dioxide

In recent years, the EPA has started to view carbon dioxide, a product of "perfect" combustion, as a pollution concern. Carbon dioxide does not directly impair human health, but it is a "greenhouse gas" that traps the earth's long wave radiation and contributes to the potential for global warming. Although its ability to absorb the long wave spectrum is not great compared to other greenhouse gases such as perfluorocarbons, hydrofluorocarbons and sulfur hexafluoride, its presence in the atmosphere causes great impacts due to the enormous volumes that are annually released.

## Appendix C-2: Primary Data Sources

| Data Type | Primary Data Sources |
|---|---|
| Populations | DMV, DOF |
| Vehicle Miles Traveled | CALTRANS, TDMs, ARB |
| Vehicle Starts | U.S. EPA, ARB |
| Ambient Temperatures | NWS, ARB, Districts, DWR |
| VMT by Speed Distribution | CALTRANS, TDMs |
| Soak Distribution | U.S. EPA, ARB |
| Activity Distribution | U.S. EPA, ARB |

## Appendix C-3: Vehicle Classes Modeled in EMFAC2001

Key:

| CLASS# | Class | Tech Groups | Vehicle Class (spelled out) |
|---|---|---|---|
| 1 | LDA | NCAT, CAT, DSL | Light-Duty Autos |
| 2 | LDT | NCAT, CAT, DSL | Light-Duty Trucks |
| 3 | MDT | NCAT, CAT, DSL | Medium-Duty Trucks |
| 4 | LHGT | NCAT, CAT, DSL | Light-Heavy Gas Trucks |
| 5 | LHDT | DSL | Light-Heavy Diesel Trucks |
| 6 | MHGT | NCAT, CAT | Medium-Heavy Gas Trucks |
| 7 | MHDT | DSL | Medium-Heavy Diesel Trucks |
| 8 | HHDT | DSL | Heavy-Heavy Diesel Trucks |
| 9 | UBD | DSL | Urban Transit Buses |
| 10 | MCY | NCAT | Motorcycles |

## Appendix C-4: Baseline and Adjusted Sales

| Baseline | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV TLEV | LDV LEV | LDV ULEV | ALL ZEV | LDV ULEVII | LDV LEVII | LDV SULEV II | LDV PZEV | Tier2-3 120k | Tier2-4 120k | APTZEV placeholder | | | TOTAL % |
| Year | 22 | 23 | 24 | 25 | 28 | 29 | 30 | 31 | 32 | 33 | 37 | 176 | 177 | Sum |
| 2005 | 0 | 12 | 9 | 0.4 | 51.3 | 0 | 0 | 25.1 | 0 | 0 | 2.2 | 0 | 0 | 100 |
| 2006 | 0 | 0 | 0 | 0.5 | 40.5 | 23 | 0 | 33 | 0 | 0 | 3 | 0 | 0 | 100 |
| 2007 | 0 | 0 | 0 | 0.6 | 25 | 15 | 0 | 36.9 | 0 | 19.1 | 3.4 | 0 | 0 | 100 |
| 2008 | 0 | 0 | 0 | 0.6 | 15 | 25 | 0 | 41 | 0 | 14.6 | 3.8 | 0 | 0 | 100 |
| 2009 | 0 | 0 | 0 | 0.9 | 4 | 6 | 0 | 44.9 | 29 | 10 | 5.2 | 0 | 0 | 100 |
| 2010 | 0 | 0 | 0 | 1 | 4 | 6 | 0 | 49 | 24.4 | 10 | 5.6 | 0 | 0 | 100 |
| 2011 | 1 | 0 | 0 | 0 | 4 | 6 | 0 | 53.1 | 19.8 | 10 | 6.1 | 0 | 0 | 100 |
| 2012 | 0 | 1.4 | 0 | 0 | 4 | 6 | 0 | 56.6 | 14.2 | 10 | 7.8 | 0 | 0 | 100 |
| 2013 | 0 | 0 | 0 | 1.4 | 4 | 6 | 0 | 56.6 | 14.2 | 10 | 7.8 | 0 | 0 | 100 |
| 2014 | 0 | 0 | 0 | 1.4 | 4 | 6 | 0 | 56.6 | 14.2 | 10 | 7.8 | 0 | 0 | 100 |
| 2015 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |
| 2016 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |
| 2017 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |
| 2018 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |
| 2019 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |
| 2020 | 0 | 0 | 0 | 1.9 | 4 | 6 | 0 | 56.7 | 11.1 | 10 | 10.3 | 0 | 0 | 100 |

| Adjusted (10% SULEV) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV TLEV | LDV LEV | LDV ULEV | ALL ZEV | LDV ULEVII | LDV LEVII | LDV SULEV II | LDV PZEV | Tier2-3 120k | Tier2-4 120k | APTZEV placeholder | | |
| Year | 22 | 23 | 24 | 25 | 28 | 29 | 30 | 31 | 32 | 33 | 37 | 176 | 177 |
| 2005 | 0 | 10.8 | 8.1 | 0.36 | 46.17 | 0 | 10 | 22.59 | 0 | 0 | 1.98 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0.45 | 36.45 | 20.7 | 10 | 29.7 | 0 | 0 | 2.7 | 0 | 0 |
| 2007 | 0 | 0 | 0 | 0.54 | 22.5 | 13.5 | 10 | 33.21 | 0 | 17.19 | 3.06 | 0 | 0 |
| 2008 | 0 | 0 | 0 | 0.54 | 13.5 | 22.5 | 10 | 36.9 | 0 | 13.14 | 3.42 | 0 | 0 |
| 2009 | 0 | 0 | 0 | 0.81 | 3.6 | 5.4 | 10 | 40.41 | 26.1 | 9 | 4.68 | 0 | 0 |
| 2010 | 0 | 0 | 0 | 0.9 | 3.6 | 5.4 | 10 | 44.1 | 21.96 | 9 | 5.04 | 0 | 0 |
| 2011 | 0.9 | 0 | 0 | 0 | 3.6 | 5.4 | 10 | 47.79 | 17.82 | 9 | 5.49 | 0 | 0 |
| 2012 | 0 | 1.26 | 0 | 0 | 3.6 | 5.4 | 10 | 50.94 | 12.78 | 9 | 7.02 | 0 | 0 |
| 2013 | 0 | 0 | 0 | 1.26 | 3.6 | 5.4 | 10 | 50.94 | 12.78 | 9 | 7.02 | 0 | 0 |
| 2014 | 0 | 0 | 0 | 1.26 | 3.6 | 5.4 | 10 | 50.94 | 12.78 | 9 | 7.02 | 0 | 0 |
| 2015 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |
| 2016 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |
| 2019 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |
| 2020 | 0 | 0 | 0 | 1.71 | 3.6 | 5.4 | 10 | 51.03 | 9.99 | 9 | 9.27 | 0 | 0 |

| Adjusted (20% SULEV) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LDV TLEV | LDV LEV | LDV ULEV | ALL ZEV | LDV ULEVII | LDV LEVII | LDV SULEV II | LDV PZEV | Tier2-3 120k | Tier2-4 120k | APTZEV placeholder | | |
| Year | 22 | 23 | 24 | 25 | 28 | 29 | 30 | 31 | 32 | 33 | 37 | 176 | 177 |
| 2005 | 0 | 9.6 | 7.2 | 0.32 | 41.04 | 0 | 20 | 20.08 | 0 | 0 | 1.76 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0.4 | 32.4 | 18.4 | 20 | 26.4 | 0 | 0 | 2.4 | 0 | 0 |
| 2007 | 0 | 0 | 0 | 0.48 | 20 | 12 | 20 | 29.52 | 0 | 15.28 | 2.72 | 0 | 0 |
| 2008 | 0 | 0 | 0 | 0.48 | 12 | 20 | 20 | 32.8 | 0 | 11.68 | 3.04 | 0 | 0 |
| 2009 | 0 | 0 | 0 | 0.72 | 3.2 | 4.8 | 20 | 35.92 | 23.2 | 8 | 4.16 | 0 | 0 |
| 2010 | 0 | 0 | 0 | 0.8 | 3.2 | 4.8 | 20 | 39.2 | 19.52 | 8 | 4.48 | 0 | 0 |
| 2011 | 0.8 | 0 | 0 | 0 | 3.2 | 4.8 | 20 | 42.48 | 15.84 | 8 | 4.88 | 0 | 0 |
| 2012 | 0 | 1.12 | 0 | 0 | 3.2 | 4.8 | 20 | 45.28 | 11.36 | 8 | 6.24 | 0 | 0 |
| 2013 | 0 | 0 | 0 | 1.12 | 3.2 | 4.8 | 20 | 45.28 | 11.36 | 8 | 6.24 | 0 | 0 |
| 2014 | 0 | 0 | 0 | 1.12 | 3.2 | 4.8 | 20 | 45.28 | 11.36 | 8 | 6.24 | 0 | 0 |
| 2015 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |
| 2016 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |
| 2019 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |
| 2020 | 0 | 0 | 0 | 1.52 | 3.2 | 4.8 | 20 | 45.36 | 8.88 | 8 | 8.24 | 0 | 0 |

## Appendix C-5: Emissions Analysis for the Baseline, 10% Nanocar Sales and 20% Nanocar Sales

| | **Baseline** | | | | **10% SULEV (Nanocar)** | | | | **20% SULEV (Nanocar)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total CO | | Total NOx | | Total CO | | Total NOx | | Total CO | | Total NOx | |
| YEAR | LDA TOTAL | ALL TOTAL | LDA TOTAL | ALL TOTAL | LDA TOTAL | ALL TOTAL | LDA TOTAL | ALL TOTAL | LDA TOTAL | ALL TOTAL | LDA TOTAL | ALL TOTAL |
| 1990 | 3537.61 | 6235 | 298.09 | 725.03 | 3537.61 | 6234.54 | 298.09 | 725.03 | 3537.61 | 6235 | 298.09 | 725.03 |
| 1992 | 3039.45 | 5293 | 269.75 | 658.15 | 3039.45 | 5292.74 | 269.75 | 658.15 | 3039.45 | 5293 | 269.75 | 658.15 |
| 1994 | 2734.2 | 4775 | 246.02 | 601.98 | 2734.2 | 4774.85 | 2734.2 | 601.98 | 2734.2 | 4775 | 2734.2 | 601.98 |
| 1996 | 2246.03 | 3976 | 197.47 | 520.34 | 2246.03 | 3975.5 | 197.47 | 520.34 | 2246.03 | 3976 | 197.47 | 520.34 |
| 1998 | 1957.39 | 3478 | 175.25 | 473.21 | 1957.39 | 3478.12 | 175.25 | 473.21 | 1957.39 | 3478 | 175.25 | 473.21 |
| 2000 | 1741.23 | 3097 | 158.59 | 467.29 | 1741.23 | 3097.36 | 158.59 | 467.29 | 1741.23 | 3097 | 158.59 | 467.29 |
| 2002 | 1407.93 | 2518 | 128.73 | 407.71 | 1407.93 | 2517.68 | 128.73 | 407.71 | 1407.93 | 2518 | 128.73 | 407.71 |
| 2004 | 1165.89 | 2109 | 103.08 | 351.63 | 1165.89 | 2108.71 | 103.08 | 351.63 | 1165.89 | 2109 | 103.08 | 351.63 |
| 2006 | 982.13 | 1806 | 85.66 | 311.41 | 981.91 | 1806.01 | 85.65 | 311.4 | 981.69 | 1806 | 85.63 | 311.39 |
| 2008 | 830.31 | 1558 | 71.63 | 272.88 | 829.79 | 1557.8 | 71.6 | 272.84 | 828.19 | 1556 | 71.48 | 272.72 |
| 2010 | 699.03 | 1335 | 59.28 | 234.38 | 697.57 | 1333.87 | 59.18 | 234.28 | 696.36 | 1333 | 59.1 | 234.19 |
| 2012 | 595.62 | 1155 | 48.24 | 194.26 | 594.1 | 1153.42 | 48.15 | 194.17 | 592.43 | 1152 | 48.05 | 194.07 |
| 2014 | 501.91 | 988 | 39.53 | 162.5 | 500.24 | 986.15 | 39.44 | 162.41 | 498.41 | 984 | 39.34 | 162.31 |
| 2016 | 426.18 | 850 | 32.87 | 137.27 | 424.45 | 848.04 | 32.79 | 137.18 | 422.54 | 846 | 32.69 | 137.09 |
| 2018 | 360.84 | 729 | 27.51 | 116.84 | 359.21 | 727.39 | 27.43 | 116.76 | 357.29 | 725 | 27.34 | 116.67 |
| 2020 | 206.37 | 415 | 13.91 | 73.04 | 205.01 | 413.72 | 13.84 | 72.98 | 202.17 | 410.88 | 13.74 | 72.87 |

**APPENDIX D:**
**APPENDIX FOR CHAPTER 6 – *RECOMMENDATIONS AND PRACTICAL APPLICATIONS***

### Appendix D-1: Nanocar Transportation Infrastructure

The integrated Nanocar system should ultimately be designed to maximize time, space, and monetary efficiencies. This system should be implemented in residential, commercial and business areas to take advantage of the characteristics that the Nanocar can offer. Presented below are the steps needed to effectively design and implement infrastructure changes given the current infrastructure, as well as some recommendations of how to approach these changes. Many of the ideas presented revolve around the redefinition of current transportation systems and related infrastructure to promote new land use strategies that will accommodate the use of smaller vehicles. Additionally, this section addresses the retrofitting of current infrastructure covering highways, side streets, private transportation networks, and parking avenues while keeping in mind that they must provide safety and utility to all.

**Land Use**
At a time when urban population density has become a serious problem, space has come to be a very important issue. The dependency of the average commuter on their vehicle has caused an automobile density problem. The number of vehicles on the road, combined with the amount of space that they occupy, has amounted to an unsustainable growth pattern. The average midsize vehicle is currently about 15.4 feet in length and 5.7 feet in width.[66] When this number is multiplied over the driving population, the result is an obvious finding; a significant amount of space is dedicated to the automobile. The use of a Nanocar would drastically reduce the amount of space taken up by automobiles. As shown in the example below, if all of the approximately 10.7 million Californians drive alone commuters in 2000[67] switched to a Nanocar, there would be significantly smaller amount of space that is attributed to the Nanocar versus the average midsize vehicle. This is due to the smaller size of the Nanocar with a length of approximately 10.5 feet and a width of approximately 4 feet.

Standard Commuter Vehicle:

$$\text{Total Area} = 15.4'\,\text{long} * 5.7'\,\text{wide} * 10.7\times10^{6}\,\text{people} = 9.4\times10^{8}\,\text{feet}^{2}$$

Nanocar:

$$\text{Total Area} = 10.5'\,\text{long} * 4'\,\text{wide} * 10.7\times10^{6}\,\text{people} = 4.5\times10^{8}\,\text{feet}^{2}$$

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[66] These dimensions are of an Volkswagen Passat
[67] U.S. Census, 2000.

Thus, if all drive alone commuters as noted by 2000 U.S. Census data switched to commuting with a Nanocar, the total open area created would be:

$$\text{Total Area} = \left(9.4\times10^{8}\ feet^{2}\right) - \left(4.5\times10^{8}\ feet^{2}\right) = 4.9\times10^{8}\ feet^{2}$$

To put this area into perspective, the average NFL football field is 57,596.4 ft.[2]. Thus, if all the 2000 drive alone commuters switched from driving an average commuter vehicle to driving a Nanocar the amount of space saved is equivalent to:

$$\text{Space Saved} = \frac{4.9\times10^{8}\ feet^{2}}{\left(\dfrac{5.8\times10^{4}\ feet^{2}}{FootballField}\right)} = 8.5\times10^{3}\, FootballFields\,!$$

By saving a fraction of the space implied by the above numbers there would be new or unutilized space that could be applied to other land-uses.[68] Furthermore, this number does not account for the amount of land that is saved by smaller-sized parking spaces needed for the Nanocar. The Nanocar could provide a partial solution to the vehicle density problem by creating more efficient land allocations for societal use.

As stated throughout this section, land space conservation is not the only benefit to the introduction of the Nanocar. In the case of residential land use strategies, the goal is to take advantage of the limited space. In order to do so, developers and city planners must move away from the suburban model[69] of development design towards an adapted form of the neoclassical model.[70] The problem with the suburban model is that it has been designed in a way that uses space inefficiently. It utilizes a small number of winding arterial avenues with short local diverting roads that end in cul-de-sacs or dead ends versus rectangular shaped blocks that allows for parallel routes as their street structuring. In so doing, the suburban model increases the area of land and the number of miles needed to travel from one point to another within the community. An example of how a Nanocar infrastructure can more effectively manage space in the context of the suburban model is the reduction of space required for cul-de-sacs due to the Nanocar's reduced wheelbase and thus, minimized turning radius. One of the reasons why the suburban model has been so popular is because they are visually appealing with many open spaces and low traffic diverting streets. However, the concentration of traffic is visible in arterial roads especially during peak commute times. An alternative to reducing the inefficient space created by the suburban model is to use dedicated paths. These

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[68] Note that in reality, the space savings associated with the Nanocar would be small individual parcels of land in urban communities rather than a large expanse shown in the calculation.
[69] Suburban model: Mainly characterized by being inclusive housing communities having one arterial road across the development with many small parallel streets. Mainly found in suburban residential areas, units in the community share playgrounds, pool area, and other amenities.
[70] Neoclassical model: Characterized by being independent units with no common areas or amenities. Mainly found in metropolitan cities and having a grid-like street layout.

paths can be used to connect arterial roads with the rest of the community development while at the same time relieving congestion. Congestion relief can also be achieved by having a centralized community where the commercial, civic, cultural and recreational activity areas are close together. This decreases the traffic flow that is mainly composed of automobile commuting and the amount of vehicle miles traveled per household. This could be complemented with a system of fully connected narrow streets that provide alternative routes to the outskirts of the city.

In the building phase of the transportation system, safety and utility must be heavily stressed. Although safety is not an issue with the Nanocar itself, infrastructure safety must be considered to minimize interactions with larger sized vehicles. The safety of these *Nano-paths* begins in the design stage where the following are studied; appropriate sight distances, curves, road deterioration, appropriate warning devices and speed assignation. In doing so, it will reduce the amount and severity of accidents. There is no one design that will commonly work for all cities and streets. Therefore, there must be a great deal of consideration given to the topography, meteorology transportation, existing land use, and characteristics of each city. This does not imply that the Nanocar transportation infrastructure is exclusive to cities. In fact, it can be incorporated in places ranging from metropolises to rural areas.

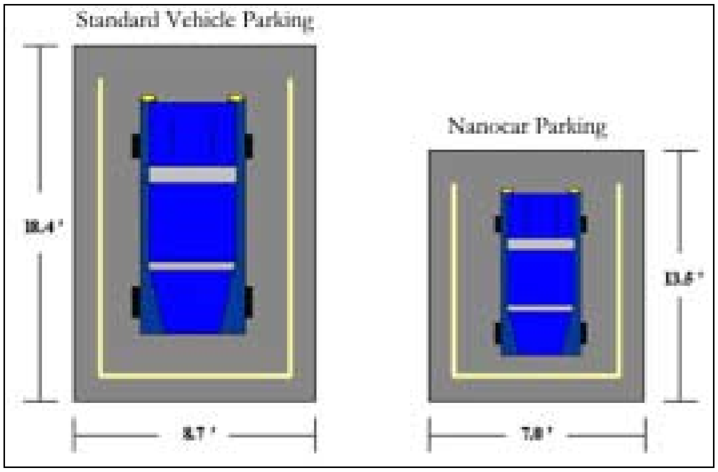
**Parking**

Traditional parking arrays could potentially be considered for the introduction of the Nanocar. Exclusive parking closer to shopping areas, workplace and at transit stations are envisioned for Nanocar drivers where Nanocar parking is clearly designated with the aid of signs. In some cases enforcement in these parking areas may need to take place to avoid its usage by non-authorized vehicles. An example of an incentive based parking scheme is where there is metered parking for standards car but complimentary parking for Nanocars.

Two types of parking are considered, on street parking and parking lots. The introduction of Nanocars has a positive effect on both. In the case of on street parking for the Nanocar, the number of vehicles that can be parallel parked on side streets increases and the width allocated on the road for parking decreases. Other efficiencies include increased capacity per parking lot and the ability of Nanocars to park at oddly shaped spaces that are currently not being used.

As intuition holds, the most beneficial aspect of Nanocar parking compared to standard car parking is the better allocation of land in the form of reduced space per vehicle. Due to the substantially smaller size of the Nanocar you can expect there to be a smaller land requirement to park an equal number of cars when compared to the standard vehicle. Standard vehicle dimensions are approximately 15.4’ by 5.7’. Nanocar vehicle dimensions are approximately 10.5’ by 4.0’. Since standard vehicle parking space is being compared to that needed for a Nanocar, it is assumed that the parking space dedicated for Nanocar use is restricted to vehicles with sizes that are equal to or less than that of a Nanocar.

**Figure D-1a: Nanocar Parking Spaces vs. Standard Car Parking Spaces**




The amount of space needed for any one vehicle to park is equal to that of its footprint with an approximately 1.5’ on each side of the vehicle’s perimeter. For example, a standard vehicle with dimensions 15.4’ by 5.7’ would require a parking space with dimensions equal to or greater than 18.4’ by 8.7’. Therefore the space required for a standard car to park would equal 160.08 $ft^2$ (18.4’ multiplied by 8.7’). Comparatively, the space allocated to the parking of a Nanocar is 94.5 $ft^2$. This relationship is visually depicted in Figure D-1a.

Multiple vehicle parking lot designs can become complex due the space required for vehicles to park and move around. The space required will be substantially decreased when considering parking for an equal amount of Nanocars versus standard cars. Therefore, it is important to realize that monetary savings for every parking space can be achieved through the integration of Nanocar parking spaces.

## Infrastructure Design

There are two primary considerations when looking at infrastructure design for the Nanocar. One consideration is the uniformity of design to create an efficient network. Another is the specific design of the Nanocar. It is critical to know the specifications of the vehicle such as its size dimensions and turning radius in order to calculate the design of its infrastructure. The development of new traffic control devices must also be considered for the new mix of standard car and Nanocar road networks. The preferred tool for traffic regulation is signals because they convey more information at one time, improving safety. Signs must be clear in transmitting the message that areas are designated for Nanocars only and should not be confused with standard vehicle signs. Most importantly, Federal Highway Administration must approve all signs that are developed specifically for the Nanocar. Some examples can be found in the Table D-1a below:

**Table D-1a: Examples of Traffic Devices**

| Scenario | Traffic Device |
|---|---|
| Arterial streets and urban expressways equipped with exclusive lanes | Devices stating that separate lane use is mandatory or warn of lane transitions |
| Dedicated network of pathway | Devices that regulate vehicle speeds and passing zones |
| Street or lot parking which provides preferential parking to Nanocars | Signs which guide Nanocars to preferential parking facilities or the regulate use of parking to Nanocars only |

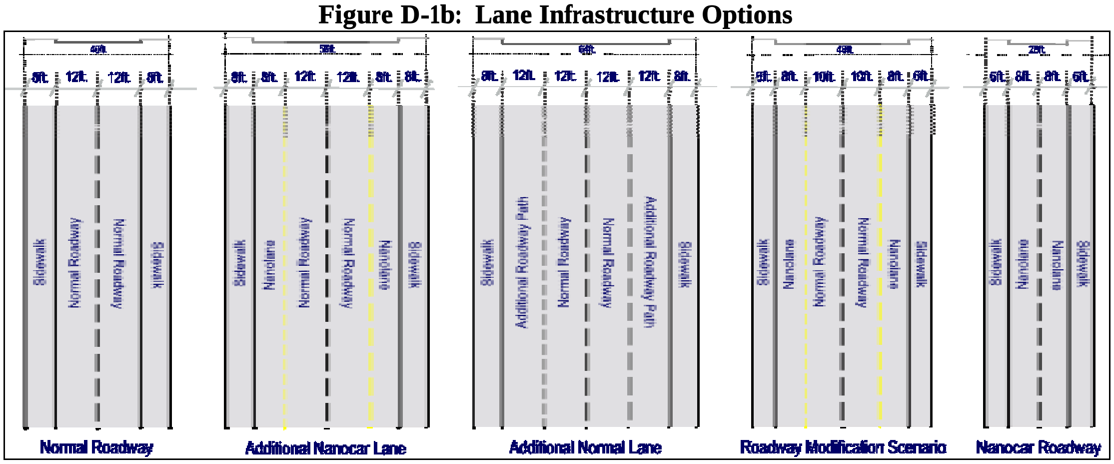
## Retrofitting

There are two categories in which current transportation systems can be retrofitted for Nanocar usage; major and minor modifications. The former includes a dedicated network of paths. This may be in the form of own lane adjacent to standard lane on high-speed roads and side streets, elevated lanes on freeways and major arterials, usage of road shoulders, and modified curbside parking for *Nano-lane* usage.

## Major Modifications

Dedicated network of paths for Nanocars could be one-way, two-way or even double lane, and have its own bicycle lane and sidewalk (Figure D-1b). It is important that easy access into or out of such a network exists for this Nano-infrastructure to be useful. Because much of the paths will pass through private properties and other secluded areas it would be aesthetically beneficial to blend it into the surrounding landscape. The advantages of this option are that the Nanocars can go where standard size cars cannot, they can incorporate side-street parking for Nanocars, and it includes the ability to connect various activity centers without using congested existing side streets. There are

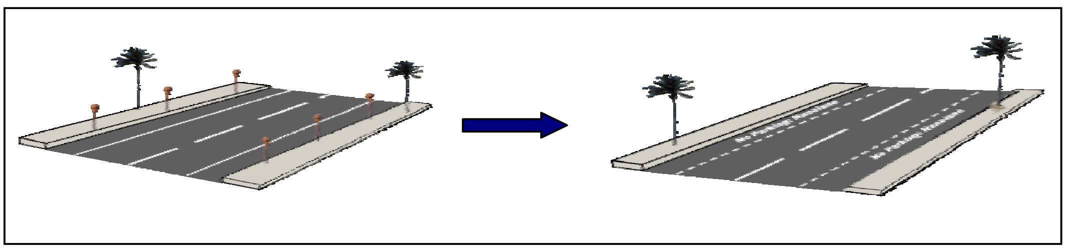
**Figure D-1b: Lane Infrastructure Options**




some aspects related to this option that must be given special consideration; a drainage system and traffic control devices must be incorporated into the network. These devices include but are not limited to, stop signs, warning of merging lanes, signs that regulate pedestrian, bicycle, and animal crossing, vehicle speeds, preferential parking among other warning signs. Also, in order to build these paths, the city may have to buy the necessary land from property owners in return for property tax credits or money. Finally, the paths must be built with the same quality of construction as standard roads. This includes civil engineering design, safety standards, and quality of materials. However, material costs are expected to be significantly less due to the lower load requirements of the road since Nanocars are lighter in weight.

Another possibility is for the Nanocar to have its own lane adjacent to standard lanes on high-speed roads and side streets.[71] The advantages of this possibility include the simplicity of achieving the separation of the Nanolane from the other lanes on the road. It can be as easy as re-striping the roads or modifying standard car side street parking to incorporate a Nanolane (Figure D-1c). More substantial lane separation techniques could include concrete walls, steel horizontal bars, and water filled barriers.[72] Especially in the case of high-speed roads, traffic signs can help minimize accidents.

**Figure D-1c: Side-Street Parking to Nanolane Retrofit**



Usage of road shoulders can increase the efficiency of land already in use. This infrastructure change can be costly. For example, this would require the relocation of street signs, telephone poles, trees, water drainage, and reinforcement of pavement. From a policy perspective, this infrastructure change could be in noncompliance with current regulations that prohibit road shoulder driving and therefore may require a rethinking of current regulations. The last major modification discussed is the alteration of curbside parking for Nanolane usage. The main difficulty would be dealing with the opposition from residents, business, and other community members who currently use that space for parallel parking and the revenue that is generated by those spaces.

### Minor Modifications

The most important advantages of reducing speed limits are that they entail minimal costs and increases safety. The main disadvantage that will be incurred is the increase in travel time, which in turn reduces production time and profitability.

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[71] This concept is similar to the high occupancy vehicle (HOV) lanes found on State highways where only certain types of vehicles with a specified number of passengers (typically 2) are allowed to use a particular lane to bypass the congestion of neighboring lanes

[72] Again, a proper drainage system must be considered for certain topographies as well as proper traffic control devices

**Costs**

First in terms of parking lots, it is a common trend among land planners to calculate its total price based on per parking space prices. For example, the city of Santa Barbara, California has a constant cost associated with a standard car parking space regardless of the number of spaces required. This cost includes all land and construction costs for the individual parking spaces themselves as well as the mobility space required for the vehicles. Santa Barbara planners have assigned a cost of $5,000 per standard vehicle parking space for the construction.[73]

The City of Santa Barbara transportation planners confirmed that the decrease in per vehicle parking space would be approximately equal to the difference in size between a standard vehicle and a Nanocar. Based on this information, since the Nanocar is approximately two times smaller, the cost of constructing a Nanocar parking space would be approximately $2,390.

As mentioned before the addition of a new *Nano-lane* is costly, albeit not as costly as the addition of a standard sized vehicle lane if additional pavement needs to be laid down. The major costs associated with this option are those required to purchase an adequate amount of land for the extra lane. Land costs can range from $35 to $75 per square foot in Santa Barbara depending on the location of the land.[74] In addition to these costs, lane construction costs range from approximately $300 per lineal foot to $400 per lineal foot (Gerth 2001).

Elevated lanes in freeways and major arterials increase in safety due to lack of interaction between Nanocars and standard cars as well as reduce traffic created by standard light and heavy-duty vehicles. However, the construction of elevated lanes can be costly and time intensive, and may be noncompliant with existing city ordinances. Despite the minimal requirement for additional land purchases the construction costs could increase from $150 to $200 per lineal foot of road made (Gerth 2001) Refer to Table D-1b for a summary of the costs for various infrastructure changes.

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[73] Gerth, G., Streets, Parking, and Transportation Operations Manager, City of Santa Barbara; November 2001, Personal Communication

[74] Prices that deviate from this value are expected for other counties

**Table D-1b: Cost Estimates for Current vs. Nanocar Infrastructure Addition**

| | | | | |
|---|---|---|---|---|
| | Standard ($/lineal ft.) | Nanocar ($/lineal ft.) | Total Cost for Standard 1 mile ($/mi.) | Total Cost for Nanocar 1 mile ($/mi) |
| | $ 368 | $ 349 | $ 1,944,730 | $ 1,840,978 |
| | Saved Without Land Cost ($/mi.) | | | |
| | $ 103,752 | | | |
| | Ave. Land Cost in Outlying Area ($/ft.2) | Ave. Land cost in Santa Barbara ($/ft.2) | TC for 1 mi. in Outlying Area ($/mi.) | TC for 1 mi. in Outlying Area ($/mi.) |
| | $ 35 | $ 75 | $ 816,786,432 | $ 515,473,728 |
| | TC for 1 mi. in Santa Barbara | TC for 1 mile in Santa Barbara | Saved ($/mi.) in Outlying Area | Saved ($/mi.) in Santa Barbara |
| **Existing Road Expansion** | **$ 1,750,256,640** | **$ 1,104,586,560** | **$ 301,312,704** | **$ 645,670,080** |
| | Stardard ($/ft.2) | Nanocar ($/ft.2) | TC for Standard 1 mille ($/mi.) | TC for Nanocar 1 mile ($/mi.) |
| | $ 166 | $ 166 | $ 42,071,040 | $ 28,047,360 |
| | Saved ($/mi.) | | | |
| **Elevated Road** | **$ 14,023,680** | | | |
| | Standard ($5,000/parking space, 88 ft.2) | Nancar ($2,386/parking space, 42 ft.2) | Saved ($/mi.) | |
| **Parking Lot** (50 spaces) | **$ 250,000** | **$ 119,318** | **$ 130,682** | |

Notes:

1. Land Costs and construction costs are priced for Santa Barbara County. These numbers should be exected to be substantially lower in other counties. However, it is acccurate information when considering proportionalities
2. For the elevated road example it is assumed that for both cars it will cost the same per square foot
3. It is assumed that there would be no additional cost for land when considering elevated roads because the land is assumed to have already been purchased
4. The dimensions of a Nanocar are 10.5' in length and 4' in width. The dimensions for standard cars are 15.4' in length by 5.7' in width
5. The $5,000 figure was provided by the City of Santa Barbara. It is assumed that cost per space for a Nanocar is approximately 48% that of a standard car due to the proportionality of the vechicles themselves

## Challenges

In a study conducted for Neighborhood Electric Vehicles (NEV), which is a similar to the Nanocar in size and purpose, the Institute of Transportation Studies at Davis emphasizes their view that an evolution period must elapse in order to tease out the designs that will provide the most effective transportation infrastructure (Kurani et al. 1999). It would be ideal to set up this new infrastructure in one metropolitan city to use as a model where the necessary modifications can be conducted. After the optimal design is selected, it can then be extrapolated to other cities both metropolitan and urban. However, correlating infrastructure change to safety can be a difficult task. Still the biggest barrier in the introduction of the Nanocar is the lack of supporting infrastructure.

Motor vehicle infrastructure does not currently accommodate a smaller car such as the Nanocar Most of the locations where the Nanocar could be used have a fully developed transportation system. In addition, public policies and laws may not be in place to support Nanocar infrastructure. The change in infrastructure will most likely face resistance from State agencies that are responsible for building and maintaining State highways and enforcing traffic State laws.

## Conclusion

The development of the Nanocar and its associated transportation infrastructure are not remote concepts. From the automakers perspective the industry is an ever-changing one particularly due to constant changes in consumer demand and regulatory requirements to increase vehicular safety and environmental performance. Many of the alternatives discussed in this section will require a branching out from traditional transportation systems. As evidence of this, some cities such as Palm Desert in California and Peachtree City in Georgia have already implemented a new infrastructure to accommodate alternatives to standard automobiles. With the support of the Air Quality Management District (AQMD), the city of Palm Desert has successfully been retrofitted for NEV use while the City of Peachtree tailored its current transportation system to allow the use of golf carts in their community transportation network.

Retrofitting the existing transportation system evenly throughout the participating cities and counties can be resource intensive. Some areas currently being used for street parking may have to be removed or relocated, and side streets may have to be altered to accommodate Nanocars. Furthermore, the size of the lanes used today may have to be narrowed, and speed allocations may need to be reconsidered.

This system must emphasize uniformity throughout cities and counties in order for the program to be successful in its implementation and operation on a wider scale. This can be achieved through multi-jurisdictional planning and cooperation. This includes collaboration to decide on universal traffic control devices, speeds, and codes. It is important that the proposed infrastructure not only strengthens the features of convenience but also safety.

Although there are costs associated with the introduction of the Nanocar infrastructure, they are far outweighed by its benefits if implemented on the right scale. These benefits include a reduction in congestion and commute times, which infer increased mobility for vehicle owners. To further increase its total benefits, least costs methods to retrofit existing infrastructure must be explored. Therefore, promoting public policies that will ease the development and introduction of the Nanocar infrastructure is necessary, considering that the market potential for this vehicle and its transportation network are greatly affected by these recommendations.

## APPENDIX E
## CASE STUDY APPENDIX

### Option 1: Nanolane Addition onto Existing Road

*Space Requirement*: 8' in each direction or 16' total
*Economics*[75]: Given all cost considerations (construction and land[76]), one mile of Nanocar highway is estimated to cost approximately $515 million.[77]
*Safety*: There are definite safety considerations associated with this option. The safety hazard increases with the increase in potential contact with standard sized vehicles as well as larger ones. The safety hazard decreases with the effective use of signs and/or dividing techniques such as large reflector turtles or low cement dividers.

### Option 2: Nanolane Retrofit of Existing Pavement

*Space Requirement*: No additional space required (there will be a decrease in the size of the shoulder or a decrease in the total number of car lanes).
*Economics*: Only minor costs will need to be considered for this option. The costs are associated with paint striping and any regulatory costs.
*Safety*: This option has the greatest safety hazard of the three. This is because there is no longer a large shoulder for emergency purposes and there is the same standard car/Nanocar interaction that existed for option one.

### Option 3: Nanopass

*Space Requirement:* The space needed to construct a Nanocar overpass is limited to that which is needed for the support columns. These can generally be constructed and erected in the divider separating northbound and southbound traffic. Therefore, there are no additional ground space considerations for this option. However, this option does reduce the amount of above ground space in the area.
*Economics*: It seems that this option would be the most costly of the three, but because there is no need to buy additional land the cost is significantly lower than that needed for Option 1. The only cost that must be considered is that which is required for construction. These costs are approximately $28 million for a mile of highway.[78]
*Safety:* This is by far the safest option of the three proposed. There is no potential interaction with standard or larger sized vehicles.

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75 It should be noted that land costs highly distort the total costs for Nanolane construction. In conditions where the adjacent property is already owned by the government, significant cost reductions would be expected.
76 The cost of land used in the calculation is based on Santa Barbara land prices.
77 Gerth, G., Streets, Parking, and Transportation Operations Manager, City of Santa Barbara; November 2001, Personal Communication
78 Gerth, G., Streets, Parking, and Transportation Operations Manager, City of Santa Barbara; November 2001, Personal Communication