AN APPROACH FOR DESIGNING A NEW TYPE OF TRANSPORTATION FOR

MEXICO CITY

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AN APPROACH FOR DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

Elisa Carmona

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of Master of Industrial Design

Auburn, Alabama
December 15, 2006

AN APPROACH FOR DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

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Date of Graduation

VITA

Elisa Carmona was born in Nuevo Laredo Tamaulipas, Mexico and relocated with her family to the United States at the age of five where her childhood interests included art and dance. At the age of six, Elisa began to practice these talents which led her in to the direction of art competitions and magnet programs such as the prestigious School for the Creative and Performing Arts located in Lexington, Kentucky. She continued her art studies in Lexington's Tates Creek High School until her junior year when her art work was displayed in her first gallery. Elisa completed her high school career in the year 2000 from Auburn Alabama's Auburn High School and then entered Auburn University college of Architecture, Design and Construction. While at Auburn she worked as a product designer with well known companies such as Brother International and Emerson Tool Company. Among many of her accomplishments as an undergraduate Elisa was awarded a research stipend from Auburn University's Competitive Undergraduate Research Fellowship in 2004, exhibited studio design work at the 2004 Consumer Electronics Show in Las Vegas, Nevada, and became a member of the Tau Sigma Delta Honor Society in 2005. She received a Bachelors of Industrial Design and entered Graduate School at Auburn University in August 2005. As a graduate student, Elisa became a graduate teaching assistant for an intensive summer design program, a CAD modeling course, and a professional portfolio graphics course where she was responsible in grading and

aiding students in 2006. She was also given the Auburn University Minority Student Recognition Award in the same year.

THESIS ABSTRACT

AN APPROACH FOR DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

Elisa Carmona

Master of Industrial Design, December 15, 2006
(B.I.D., Auburn University, 2005)

152 typed pages

Directed by Professor Tin-Man Lau

The metropolitan area of Mexico City is rapidly growing into the largest urbanized area of the world. This drastic growth in population began in the year of 1859, when "Mexico City's role as a center of industrialization and transportation attracted migrants from rural areas leading to its being the primary population center of Mexico" (Pick and Butler, 1997:30). Between 1950 and 1990, the largest increase in urbanization took place in Mexico City where "the gain in urban population was from 368,000 to a population of 8.3 million persons" (Pick and Butler, 1997:32).

In the world, there is not a large city whose residents do not complain about transportation problems. In Mexico City, the root of all traffic dilemmas relates to the fact that "transportation policy has been subject to sharp breaks in continuity associated with presidential cycles; has overly favored the better-off economic groups

who use private transport; and has wavered in its commitment towards what is considered the most appropriate form of public transport" (Ward, 1990:92).

As the culmination of my study and work here at Auburn University, I plan to create a set of guidelines which will aid in solving the numerous transportation problems in the largest, most crowded and problematic city on the globe – Mexico City. The current and severe problems that the inhabitants of this ancient city face are massive quantities of air pollution, the overcrowding of streets, and the continual rising costs of both public and private transportation.

Due to the fact that the solutions to these and other conditions that create these problems are in the hands of city officials and lawmakers, it is my opinion that the needed solutions lie in establishing new criteria for designing Mexico City's future automobiles. My thesis guidelines will communicate and instruct how to design vehicles which will approach and solve these problems and place the power back into the hands of the consumer.

ACKNOWLEDGEMENTS

I would like to extend my appreciation to the members of my thesis committee for all of their extensive input and aid in the completion of this publication. My gratitude also extends to all of the members of my family who currently reside in Mexico. This thesis is dedicated to Juan Jose Carmona, M.D. and Elisa Carmona, Sr.

Style manual or journal used	American Psychological Association
Computer software used	Adobe Illustrator
	Adobe Photoshop
	Microsoft Word
	Microsoft Excel

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CHAPTER ONE: INTRODUCTION

1.1 PROBLEM STATEMENT

As the culmination of my study and work here at Auburn University, I plan to design a set of guidelines for use in the redesign of a vehicle for the emerging consumer market in Mexico City. These guidelines will aid in solving the numerous transportation problems in this large, most crowded and problematic city in the world. All of these challenges can be met with thoughtful and prudent industrial design solutions. In utilizing strict methodology, I endeavor to introduce a new way of transportation for this troubled city. The guidelines which I will develop will be for an enclosed, electrically powered three-wheeled vehicle. Completely armed with power locks and windows, air conditioning, safety airbags and seatbelts, this vehicle will provide all of the comfort of a regular sized car for the capacity of three passengers.

The many inhabitants of Mexico City who are already capable of owning private vehicles will undoubtedly be able to afford this type of transportation. These guidelines will give those who own vehicles but cannot afford unleaded gasoline the opportunity of a new means of independent transportation.

1.2 NEED FOR STUDY

The objective of this thesis is to create a set of guidelines which will aid in solving the numerous transportation problems in the largest city on Earth, Mexico City.

Conducted research has revealed that Mexico City suffers from an ever-weakening infrastructure, leading to declining road conditions on some of the oldest streets in the world, massive pollution, rising costs of public transportation, and the constant hassle in moving from one place to another, particularly for commuters who work in the city but live on its fringes. Rather than attempting to solve Mexico's political or economic problems, one should establish new criteria for the design of the future of Mexico's automotive industry, focused entirely on alleviating these problems in the consumer market.

The transportation of the future will be smaller than the current automobile, seating only two to three passengers. This limited capacity addresses the fact that, most commuters are the heads of their households, who are the sole occupiers of cars designed to accommodate three to five people. These automobiles are also impractical for driving through Mexico City's ancient, narrow streets, many of which are in disrepair due to decades of neglect. In addition, recent innovations in fuel efficiency have rendered pollution a thing of the past and are simply waiting to be implemented into an effective automobile design by competent and capable hands. Lastly, in a city whose households each commit roughly ten percent of their yearly earnings to gasoline and public transportation, fuel efficiency means less spending on these commodities and more savings. More effective transportation on the whole eliminates the need for reliance on public transportation which is also contributing to the city's air pollution problem. There is an urgent and desperate need for research of this kind. Since the solutions to so many of the conditions that create problems lie in the hands of lawmakers and city officials, who often abuse their power or create inefficient regulation in Mexico City,

vehicles are needed which will circumvent these conditions altogether and shift the power to the consumer. It is not only necessary, it is possible, and this research will accomplish just that.

1.3 OBJECTIVES FOR STUDY

Plan for procedure and methodology:

Phase One - Identifying the problem.

1. Preliminary Analysis
    - -Problem Statement
    - -Need for Study
    - -Literature Review
2. Topic History
    - -A detailed overview of Mexico City in the following areas:
        - -Population, Urbanization, Transportation, Pollution, Styling and Design.
    - -A detailed overview of popular vehicles in Mexico City:
        - -Volkswagen Beetle, Nissan Sentra, etc.
    - -A detailed overview of small and electric vehicles:
        - -An analysis of electric, hybrid vehicles.
        - -Comparative vehicle analysis.

Phase Two- Conducting design research & developing the design guidelines.

1. Human Function
    - -Anthropometrics study
        - -Define the ergonomic percentiles of Latin America.
        - -Conduct human factors research for vehicle design.
        - -Develop a questionnaire - target market survey.
        - -Interaction Matrix – human and environmental elements.
2. Technical Function
    - -Exploded view
        - -Conduct research of the parts of electric/hybrid vehicles.
        - -Conduct research on how the engine and battery works.
3. Production Function
    - -Material and Process Analysis
        - -Conduct research on existing electric vehicle materials.
        - -Identifying the types of methods of production.

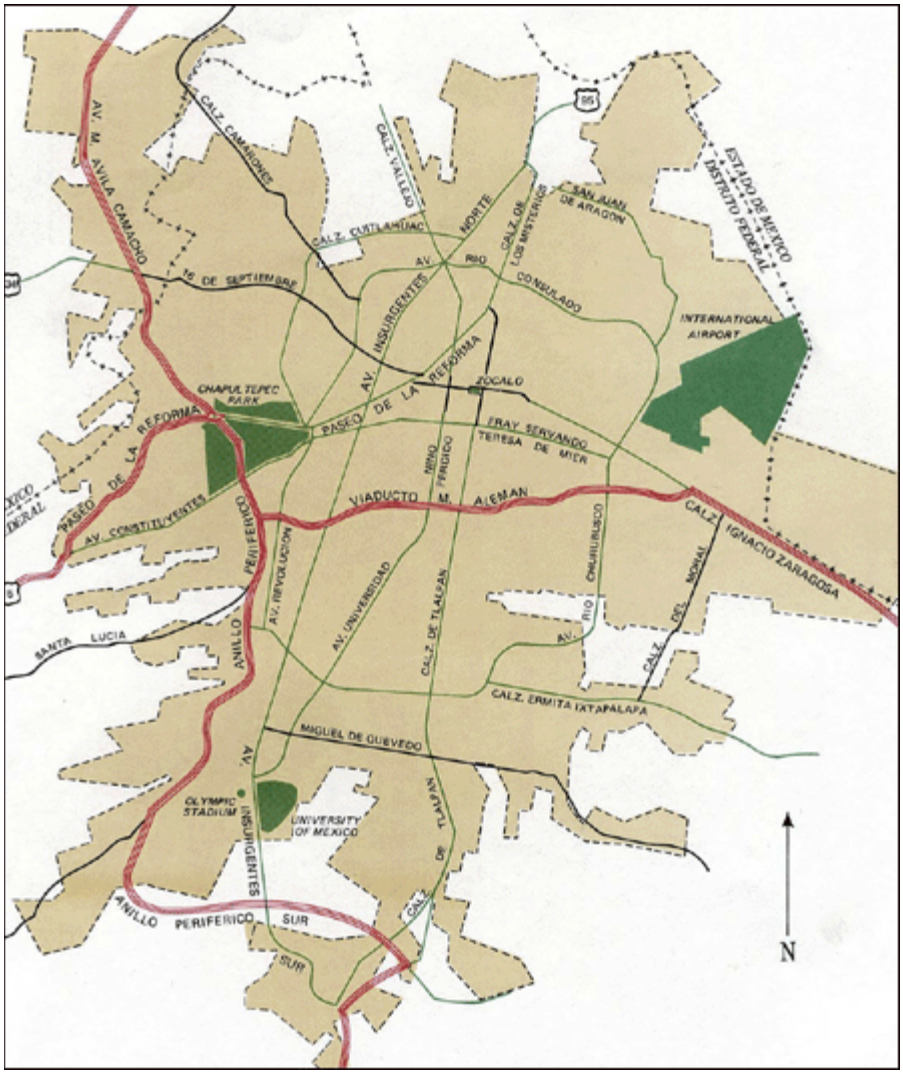
4. Styling/Design
   -Conduct research on current electric vehicles – styling trends.
   -Conduct research on design principles associated with current electric vehicles.
5. Design guidelines
   Using all of the research and methodology mentioned above, a formulated and structured set of guidelines will be written and the development of the final solution will be produced following these guidelines as an example.

Phase Three – Developing a design applying the new design guidelines.

1. Brainstorming
2. Tentative 2D solutions
   -Concept sketches
   -Compose marker renderings.
3. Product studies
   -Concept alternative sketches-best solutions.
4. Evaluation checklists – one for each concept.
5. Model variations-scaled
6. Most effective solution (pre-prototype)
   -Compose a related evaluation checklist.
7. Building the prototype
   -Develop construction drawings of the prototype (orthographic views).
   -Compose an evaluation checklist of final solution
   -Gather building sequence photos.
   -Gather photos of final solution.
8. Summary and Findings
   -Comprise all finished data and design process into a written thesis format (an ongoing progress during the project).

1.4 LITERATURE REVIEW

1.4.1 Identifying the urbanization and population of Mexico City



The Mexico City metropolitan area is rapidly emerging as one of the largest urbanized complexes on the globe. In the year 2000, Mexico City became the largest city in the World hosting the population of thirty million or more inhabitants (Ward, 1990: 29). This drastic growth in population began in 1859, when Mexico City became a center of industrialization and transportation attracting migrants from rural areas causing it to become the primary population center of Mexico (Pick and Butler, 1997: 30). During the

earlier fraction of this period, Mexico went to war with the United Sates over the territory of Texas. This struggle along with other conflicts concerning the United States of America ultimately finished with land and population transfers. The consequence reduced Mexican terrain by approximately fifty percent (Pick and Butler, 1997: 32). Urbanization in Mexico City developed shortly after when Mexican independence changed to a highly regionalized, weakly articulated urban system in which cities were consumers rather than producers (Kemper and Royce, 1979: 271).

The population and urban growth in Mexico during the twentieth century has been impressive. The increase of inhabitants between 1900 and 1970 was from 12.2 to 27 million. However, the urban populace augmented from 1.4 million to 22 million (Pick and Butler, 1997: 30). During this era "the decline in mortality rates, accompanied by continuing high fertility rates and increased life expectancy, accounted for the great population increase" (Pick and Butler, 1997: 31). Approximately half of the population in Mexico resided in large cities that held a population greater than 100,000. The largest cities in 1990 obtained 33 percent of the total inhabitants in Mexico where the greatest relative growth took place in the capital of the State of Mexico (Pick and Butler, 1997: 39). Between 1950 and 1990, the greatest increase in urbanization took place in Mexico City where the gain in urban population was from 368,000 to a population of 8.3 million inhabitants (Pick and Butler, 1997: 32).

Surrounded by volcanic mountains and majestic pyramids, the site of Mexico City has been impressive from the first settlements to the present day. It is important to note that Mexico City is not only the largest single urban area in the World but it is also one of the oldest. The Spanish *Conquistadores* built their grand city over the ruins of

Tenochtitlan, the capital of the Aztec Empire. This became the last stage of several periods of urban development. A few aspects that urbanization is associated with are literacy and higher levels of education, higher income, and vehicle ownership.

1.4.2 Identifying the transportation problems of Mexico City

There is probably not a large city on the globe where residents do not complain about traffic problems. In Mexico City, the root of all traffic dilemma relates to the fact that "transportation policy has been subject to sharp breaks in continuity associated with presidential cycles; has overly favored the better-off economic groups who use private transport; and has wavered in its commitment towards what is considered the most appropriate form of public transport" (Ward, 1990: 92). At the periphery of the metropolitan area, urban expansion is developing well-established *Pueblo* cores. These town centers have caused the expansion of the city and its functions have evolved to create a variety of spatially decentralized areas within the metropolitan area (Ward, 1990: 94). Because of this, the majority of Mexico City's population travels to the nearest local sub-center instead of remaining in the old historic core of the city.

These small locations of industrial development are scattered through most of the metropolitan area causing its main location to shift. According to a recent study conducted by researcher Peter Ward, "spatial distribution of service and industrial functions thus sets the pattern of daily journeys to work for many: just over fifty percent of all daily journeys undertaken" (Ward, 1990: 95). Trips to school follow with a thirty-five percent and shopping and recreational trips cover eight percent of all daily expeditions (Ward, 1990). Most of the inhabitants of Mexico City choose to make these trips by one of the most important means of public transportation, city and suburban

buses. However, the Metro has become increasingly important in recent years. “Given the poor standard of driving, the widespread existence of potholes, and the occasional uncovered manhole, few people risk riding on two wheels” (Ward, 1990: 95). These clustered industrial areas are well served with working-class districts. Nevertheless the 600,000 residents of Netzahualcoyotl in the east who travel to work spend a one to two hour one-way journey to northern factories (Ward, 1990: 96).

Though public transportation costs in Mexico City are affordable, it is the emotional and social costs of everyday travel that are more burdensome. Collectively with the loss of time for other activities and the overall augmentation of a working day, most people choose to travel in private cars. Although private car users do not suffer the physical discomforts that public transportation imposes on its users, distances are considerable from the more remote residential districts. During peak periods, traffic moves considerably slow even on the large orbital and interior urban freeways (Ward, 1990: 97). However, the average journey times for most of the population in Mexico City have not increased in recent years. This is because most of individuals’ needs are met within the broad area in which they live. Furthermore, their search for employment and accommodation tends to revolve around existing social networks and most people relate to one broad zone, or more usually to a single sector of the city (Ward, 1990: 97). In smaller areas within the city, people may have the need to travel across town through the city center. This group of people, which is about one-quarter of the daily workers of Mexico City, spends more than two hours traveling to and from their workplace (Ward, 1990: 97).

The establishment of major industrial centers in the northern area of the metropolitan area, along with the physical expansion of the city as a whole, caused the need of a transportation system that would allow workers to get to the factories. It was not until the creation of the Metro in 1968 and particularly, its expansion from 1977 onward that the direct state intervention in favor of collective systems of mass public transport really emerged (Ward, 1990: 102). However, though positive transportation planning and development has taken place in recent years, the private sector seems to be extremely favored by the state. Forty-five percent of they city's automobiles are registered in the metropolitan area of Mexico City (Mendoza, 1988). Private cars, taxis and collective taxis defined by the city as 'low-capacity' vehicles, carry under one third of the total daily journeys within the city. This proportion may not seem unreasonable, but it is to be noted that most of the city's population is poor. The large majority of Mexico City's inhabitants cannot afford these means of transportation and are excluded. However, for those who can afford a vehicle capital investment in road construction and improvements, relatively low fuel costs, low repair and service costs, non-punitive costs on car tax and circulation licenses, all encourage private car ownership and usage (Ward, 1990: 103).

1.4.3 Identifying the pollution problems of Mexico City

In spite of the enormous population, the city does not sprawl over anything as many other relatively large cities do. A relatively small proportion of Mexico City houses green spaces in the form of private backyards, gardens, or public parks. In 1978, the Federal District only had 2.3 meters squared of backyard space per resident, compared with the 16 meters squared that is considered normal by the World Health Organization

and the 9 meters squared recommended by the international standards (Guerva and Moreno, 1987: 20). Within the city, many opportunities were found for further increases on inefficiently used space: about nineteen percent of all plots considered vacant. Since the early 1980's, the planning policy of Mexico City has sought to convert vacant plots into active use (Ward, 1990:107). Most of the land that is available for future development is located almost entirely in the south of the city. However, this region has been identified as one which must be preserved as conservation and agricultural locations by growing ecological awareness state groups. These groups state that "the importance is highlighted in the need for reoxygenation of the highly polluted atmosphere in Mexico City" (Ward, 1990: 99).

"The main source of air pollution in most large cities is from industry and vehicles and Mexico City is no exception" (Pick and Butler, 1997: 202). About eighty-five percent of pollution comes from automobiles, mostly all of it from the disproportionate number of private cars (Ward, 1990). Half of the energy that is consumed in the city is by the 2.5 million vehicles that burn 40,000 barrels of diesel fuel and one million barrels of leaded gasoline each day. Every year 5,170,000 tons of contaminants are generated by vehicles, primarily carbon monoxide (Pick and Butler, 1997). Due to the city's high altitude, there is a consequent lack of oxygen. Automobile engines are therefore producing nearly twice as much carbon monoxide and hydrocarbon pollution as they would at lower altitudes (Pick and Butler, 1997: 203). There has been evidence since 1992 of the effects of use of unleaded gas. However, it was not by any means enough to improve the devastating air pollution statistics. Unless the use of unleaded gas increases dramatically, it also can be anticipated that the number of

transport vehicles in the region will continue to grow and air pollution will not abate without further use of unleaded gasoline and other emission controls (Pick and Butler, 1997: 203).

1.4.4 Identifying and summarizing the overall need for the study

All of the before mentioned challenges can be met with thoughtful and prudent industrial design solutions. In utilizing strict design methodology, I endeavor to introduce a new way of transportation to the consumer market of Mexico City that will alleviate and aid the problems of the city at their source. As previously discussed, many of the people who own private vehicles travel daily to work in distant factories alone. It would be prudent and convenient to drive in a vehicle that is easier to handle, park, maintain and not contribute to the continuous rising of air pollution of regular automobiles.

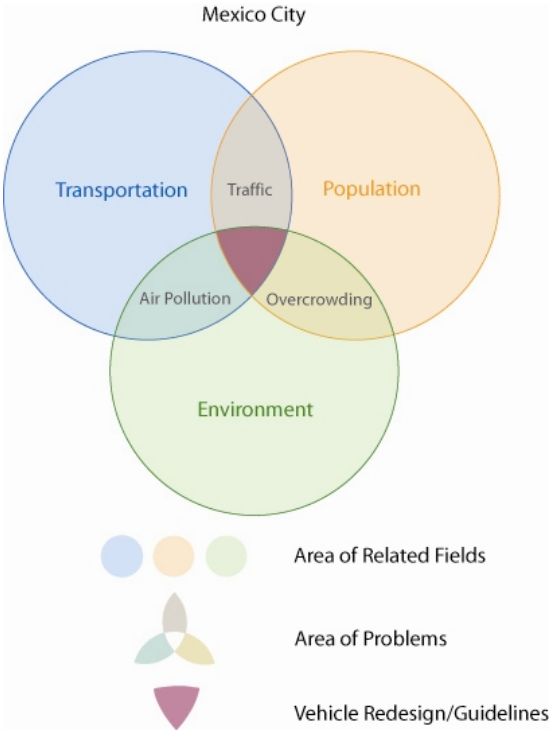


Figure 1: Vinn Diagram of Proposed Solution (Carmona: 2006)

1.5 ASSUMPTIONS

Parts of the project that will not have any statistical proof and only estimations due to the fact that the final deliverable for this project will not be the actual vehicle, but the design Guidelines to create this type of vehicle are:

- A detailed analysis will not be able to be conducted to prove the air pollution reduction after the design guidelines are produced.
- A detailed analysis will not be able to be conducted to prove the traffic congestion on the city's streets after the design guidelines are produced.
- A detailed analysis will not be able to be conducted to prove that employees residing in Mexico City obtain any time benefits while traveling to and from work after the design guidelines are produced.

Personal social beliefs regarding this project:

I believe that it is necessary to aid cities that obtain tremendous amounts of pollution to reach cleaner and healthier environments for their inhabitants. Mexico City is the largest metropolitan area where poverty increases by the day, and cleaner environments are crucial for these people to survive. The solution to this crucial problem can easily be obtained affordably through a set of design guidelines for this city's future automotive industry. Mexico City houses upper class residents who are the main cause of this city's pollution problem through the use of leaded gasoline in their private automobiles.

Personal world views regarding this project:

Law makers in Mexico City are very corrupt and do not try to aid the city's inhabitants, much less the problems they currently have. I believe that the heavy problem of transportation, which in turn has effects on other problems of the city that have been

previously stated, can be solved with design and controlled by the hands of the city's consumers.

Project philosophy:

Better automotive design can aid the major problems that the city of Mexico is faced with daily: pollution, traffic accidents and jams, limited parking, and transportation affordability.

1.6 SCOPE AND LIMITS

My proposed study to create a set of guidelines which I believe will solve the problems regarding the transportation system in Mexico City is scheduled for completion in one year.

Extent of research:

The following topics comprise my research, specifically:

-The population, urbanization, transportation, and air pollution of Mexico City.
-The current function and use of electric and hybrid vehicles to aid air pollution.
-The comprised data collected through a survey analysis of Mexico City's current residents over the matters mentioned above.
-The development of design guidelines for a vehicle that can aid Mexico City in its major transportation problems.
-This project is geared for upper class residents who can already afford private transportation but would like to save money on fuel efficiency.

Limits:

The following restrictions may affect my research:

-The limit of surveyed individuals who reside in Mexico City.
-The finalized, scaled and not fully functional prototype.
-The ergonomic and anthropometrical data of Latin America. It is different from the American percentiles and data found could be dated.

-The time constraint of the one academic year duration for research and development.

1.7 APPROACH AND PROCEDURE

-Plan for procedure and methodology:

1. Identifying the problem:

Conduct research on topic history with books, online articles, etc.

- Research in detail an overview of Mexico City in the following areas: Population, Urbanization, Transportation, Pollution, Styling/Design.
- Examine popular vehicles in Mexico City: Volkswagen Beetle, Nissan, etc.

2. Conducting related design research:

Conduct research on traffic pollution solutions with books, online articles, etc.

- Research small, electric, and hybrid vehicles including how they work.
- Conduct research of the parts of electric and hybrid vehicles including parts analysis.
- Conduct research on how vehicle materials are produced.
- Conduct a comparative vehicle analysis of all researched vehicles.

3. Conducting an anthropometric Study:

Conduct research on ergonomics regarding the percentiles of Latin America with books, online articles, etc.

- Define the ergonomic percentiles of Latin America.
- Conduct research on Human Factors in vehicle design.
- Develop an interaction matrix regarding all human and environmental elements.

4. Examining styling/design in Latin America and Mexico City:

Conduct research on styling and design in books, online articles, surveys, etc.

- Create mood boards with architecture, fashion, art, etc. from Mexico City and Latin America.
- Research current electric vehicles – styling trends.
- Conduct research on design principles associated with current electric vehicles.

5. Conceptualizing based on new guidelines:

Use developed guidelines to develop a vehicle concept as an example.

- Record all brainstorming.
- Develop tentative 2D solutions: concept sketches as marker renderings.

- Create concept alternative sketches-best solutions.
- Develop an evaluation checklist for each concept.
- Construct the most effective solution (prototype).
- Compose a related evaluation checklist.
- Conduct an evaluation of the prototype.
- Develop construction drawings for the prototype (orthographic views).
- Gather building sequence photos.
- Gather photos of final solution.

6. Summary and Findings

Comprise all finished data and design process into a written thesis format (an ongoing progress).

1.8 ANTICIPATED OUTCOME

My thesis objective is to create a set of guidelines which I anticipate will help the crucial problems regarding the transportation system in Mexico City. The most severe problems include declining road conditions, overcrowded streets, massive air pollution, and the continually rising costs of transportation both public and private. My thesis guidelines will discuss and instruct how to design vehicles which will approach and aid these problems.

I hypothesize that Mexico City's future automobiles will be three passenger vehicles. Today, many of the drivers that crowd the roads of Mexico City are middle aged men and women who can be identified as commuters and the sole occupiers of their vehicles. Therefore, a smaller vehicle is not only a practical solution to drive around the narrow and rugged streets of the city, but also it allows more space for the city's vehicles to navigate its busiest streets. In addition, fuel efficiency, mainly electrical and hybrid technology, is waiting to be implemented and introduced into Mexico City where the use of leaded gas by its inhabitants caters to its serious current and rising pollution problem.

Lastly, the inhabitants who cannot afford private automobiles resort to the use of public transportation, where they spend close to ten percent of their yearly income. Due to its size and fuel efficiency, the vehicle of the future that I have planned for Mexico City could possibly open the doors for residents who can almost afford a “low-cost” vehicle, to purchase an efficient type of private transportation. My end deliverable of detailed guidelines for the construction of this automobile will alleviate this ancient city of its transportation nightmare.

CHAPTER TWO: AN ANALYSIS OF THE ELEMENTS NEEDED FOR DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

2.1 AN INTRODUCTION TO ANALYZING THE ELEMENTS RELATED TO DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

Prior to developing a set of guidelines to aid the problems regarding the transportation system in Mexico City, it is crucial to examine the areas related to the subject. These subjects include what a current resident of Mexico City is looking for in a new type of transportation vessel, how current transportation systems address and have failed to meet these needs in the past, and all of the elements that are necessary to create the set of guidelines that are intended to produce the transportation system that meet the needs of Mexico City's residents.

Studying what a current resident needs out of an effective type of transportation will specifically deal with identifying the daily transportation routines average inhabitants of Mexico City are exposed to. With the use of surveys and literature, information will be gathered to identify how many residents of Mexico City use private transportation, the average financial income and status of these users as well as the correct anthropometric and ergonomic values for correct posture and safety. An overall, general study of the transportation systems pertaining to Mexico City will also be completed. Popular, private vehicles and transportation trends of the past will be reviewed and identified as well as

the current main problems with both public and private transportation systems in Mexico City.

Basic hybrid technology and driving standards, as well as current vehicle safety regulations for driving in Mexico City, will be identified and a list of these requirements will be formulated.

Manufacturing processes of materials will also be studied to further aid in the establishing of the design criteria for the proposed guidelines.

2.2 STUDY THE USER

2.2.1 The Significance of Studying the User

It is crucial to study the physical characteristics, needs and capabilities of the residents who daily use Mexico City's transportation systems so that the proposed guidelines are designed to better aid them in their current problems. Also, the user study aids the designer in avoiding mismatches between the products designed using the guidelines and the user.

2.2.2 Identifying the Public Life and Urban Society of the User

The standard of living in Mexico is higher than most other countries in Latin America. Thus, Mexico draws other natives from different countries such as Argentina, Brazil and Cuba to the country in search for better opportunities (Nord, 1996: 10). Three cities including Mexico City, Guadalajara, and Monterrey dominated the urban landscape in the mid-1990s (Nord, 1996: 11). According to the studies of ethnic researcher Bruce Nord, "their metropolitan areas accounted for about one-fourth of the nation's population

and more than forty percent of the total urban population" (Nord, 1996:11). Therefore, "Mexico City should be viewed not as a single metropolitan area but rather as an emerging megalopolis also incorporating the cities and surrounding pueblos of Puebla, Toluca, and Cuernavaca" (Nord, 1996: 12). The region continued to grow during the 1990s, and included slightly more than 18 million people in the year 2000 (Nord, 1996: 13).

With the recent economic growth, most middle and high income families live in single houses, commonly found within a walled neighborhood, called "fraccionamiento" (Nord, 1996: 10). According to a recent study conducted by ethnic researcher, Bruce Nord "the reason these places are the most popular among the middle and upper classes is that they offer a sense of security, since most of them are within walls and have survelliance, and living in one also provides social status, due to the infrastructure of most of these neighborhoods" (Nord, 1996: 11). Swimming pools, golf clubs and other commodities are found in these fraccionamientos. Houses inside them tend to be of higher quality, and larger than other homes, most of them with at least three or four bedrooms and even maid quarters and laundry (Nord, 1996: 13).

2.2.3 Identifying the User and Their Needs

Mexico City would definitely be a candidate for the largest metropolitan city, along with Tokyo and Sao Paulo (Ward, 1990: 17). While cities such as New York are built vertically upwards with tall buildings in a small area, Mexico City lies in an earthquake zone not permitting for many tall buildings (Ward, 1990: 21). Instead, Mexico

City is built out horizontally in an endless sea of houses where, given the spatial vastness of the city, getting around becomes an important part of daily life.

To travel a long distance in Mexico City, there are four major modes of transportation, the private use of cars and public transportation methods including taxis, buses and the metro (Ward, 1990: 25). The types of population of Mexico City who choose a particular type of transportation method has less to do with age or sex related types of demographic characteristics. It has more to do with the needs and means of the individuals as well as their socio-economic levels (Pick and Butler, 1997: 241). There is a very strong relationship between automobile usage and socio-economic level, since possession and operation of automobiles require significant financial means. There is also an inverse relationship between bus riding and socio-economic level. In addition to the low bus fares, the buses will travel to places not covered by the Metro (Pick and Butler, 1997: 242).

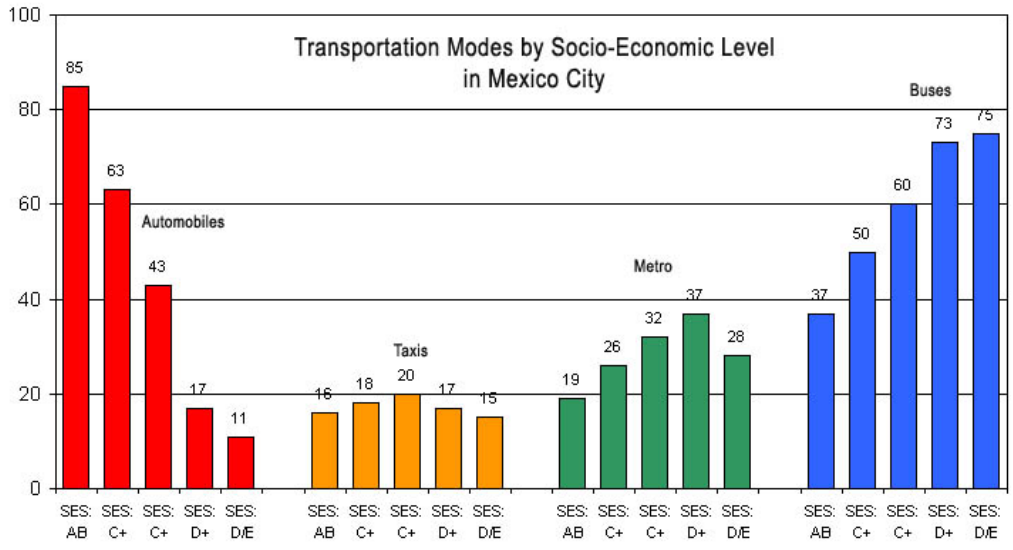


Table 1: Transportation Modes by Socio-Economic Levels (Pick and Butler, 1997: 243).

The incidences of usage for people in different employment and unemployment situations may also vary. Consistent with the socio-economic characteristics, the senior managers and professionals have the highest usage of automobiles and lowest usage of buses. Compared to senior managers, the middle and lower-level managers are less likely to use automobiles and more likely to use buses (Pick and Butler, 1997: 244). Among the unemployed looking for work, taxis are almost never used for economic reasons and among the retired, transportation of any form is used less than other people. The disabled are much more likely to use taxis to get around rather than the Metro system (Pick and Butler, 1997: 244).

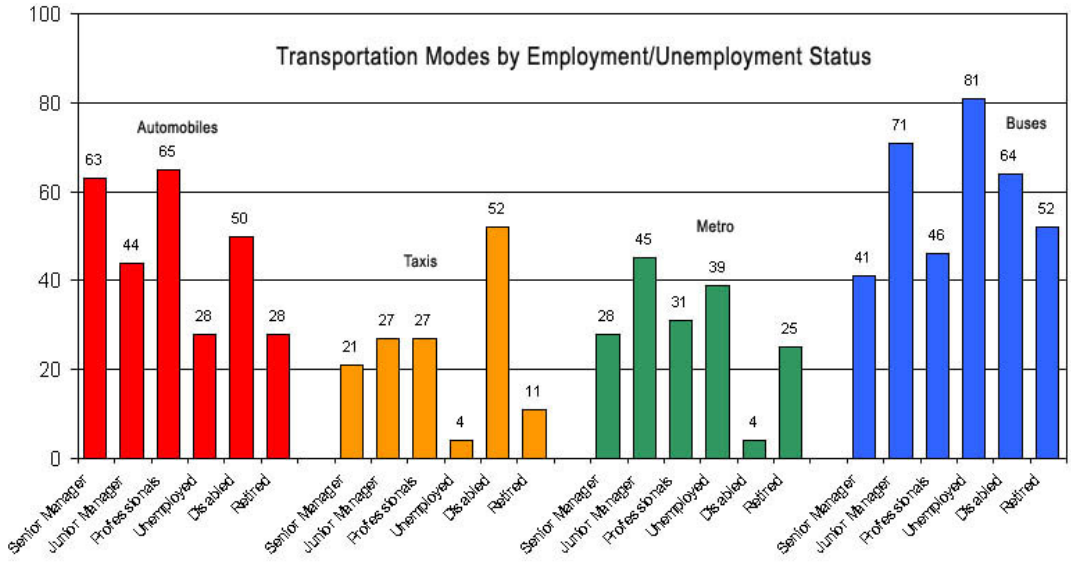


Table 2: Transportation Modes by Employment/Unemployment Status (Pick and Butler, 1997: 245).

The transportation problem in Mexico City is one of the major public issues in urban systems (Pick and Butler, 1997: 244). I believe it is impossible to create a single

solution that will meet the needs and means of all the city's residents. Therefore, the proposed guidelines that will be generated from this thesis will focus on the socio-economic group who has the financial means to purchase a hybrid system subject to the tensions of accessibility, convenience, affordability, comfort, efficiency, safety, and environmental friendliness.

2.2.4 Identifying the User's Human Factors that need to be addressed in Conceptualizing a New Vehicle

Although many factors must be considered in the conceptualizing of a new vehicle, human factors should be addressed first.

1. Passenger Space: The space that is large enough and geometrically appropriate for the number of passengers the automobile is planned to accommodate. Passengers who are expected to be riding in the vehicle only once in awhile are not to be excluded (Tillman and Woodson, 1981: 77).
2. Passenger Seating: Properly designed seats and restraints for all passengers. No passengers are to be forced to sit in less-than-adequate seats or be less protected because these are used infrequently (Tillman and Woodson, 1981: 77).
3. Driver Control, Display and Visibility: Creating the best possible driving configuration so that the driver has the best possible chance of operating the vehicle safely and efficiently in all expected environments (Tillman and Woodson, 1981: 77).

4. Environmental Control: Adequate heating, cooling, ventilation, and noise and vibration control to minimize stress on passengers and especially on the driver (Tillman and Woodson, 1981: 77).
5. Passenger Compartment Structural Integrity: The vehicle compartment should be able to withstand expected crash loads and possible penetrations (Tillman and Woodson, 1981: 77).
6. Interior Safety: Adequate passenger restraint and freedom from structural contact injury should be provided to minimize the possibility of injury or death during a crash (Tillman and Woodson, 1981: 77).
7. Ingress and Egress: The ease of getting into and out of the vehicle should be a prime consideration under both normal and emergency circumstances (Tillman and Woodson, 1981: 77).
8. Visibility: Providing the necessary visibility for the driver not only in terms of angle of view but also in terms of keeping that visibility under typical environmental disruptions such as rain, fog, etc. (Tillman and Woodson, 1981: 77).
9. Road Illumination: To provide a properly controllable headlight system to ensure that the driver can see where he or she is going and can observe other vehicles, pedestrians and other obstructions (Tillman and Woodson, 1981: 77).
10. Identifying Lights: To provide auxiliary light systems that indicate when the driver plans to turn, which is the front or rear of the vehicle, and when the driver is going to stop (Tillman and Woodson, 1981: 77).

11. Headlight Beam Control: To provide control of the headlight beam direction so that the driver can reduce the potential visual disturbance that the headlights may cause for an oncoming motorist (Tillman and Woodson, 1981: 77).
12. Rear—Collision Protection: To provide proper energy absorption and isolation of the fuel tank so that, in the event of a crash, the fuel tank is protected and passengers are not injured (Tillman and Woodson, 1981: 77).
13. Minimization of Injuries to Pedestrians: Providing a front-end configuration that causes minimal injury in the event of the vehicle running into a pedestrian (Tillman and Woodson, 1981: 77).
14. Rear—Impact Energy Absorption: To provide a design that will reduce structural distortion and the possibility of penetration to the passenger compartment (Tillman and Woodson, 1981: 77).
15. Ease and Safety of Tire Replacement: Adequate consideration should be given to the problems of replacing a flat or blown tire, including the safety aspects of jacking up the vehicle (Tillman and Woodson, 1981: 77).
16. Side—Impact Energy Absorption: To provide adequate internal padding and a design that will reduce structural distortion and the possibility of penetration of the passenger compartment (Tillman and Woodson, 1981: 77).
17. Ease and Safety of Maintenance and Service: To provide proper access to frequently used components, ease of refueling and refurbishing, removing and replacing parts, and protection of the service technician and of the owner from hazards such as electric shock, hot surfaces, moving parts, and fire (Tillman and Woodson, 1981: 77).

18. Baggage: To provide reasonable storage capacity and ease of loading and unloading, removing and replacing the spare tire, etc. Consider all user sizes and strengths (Tillman and Woodson, 1981: 77).

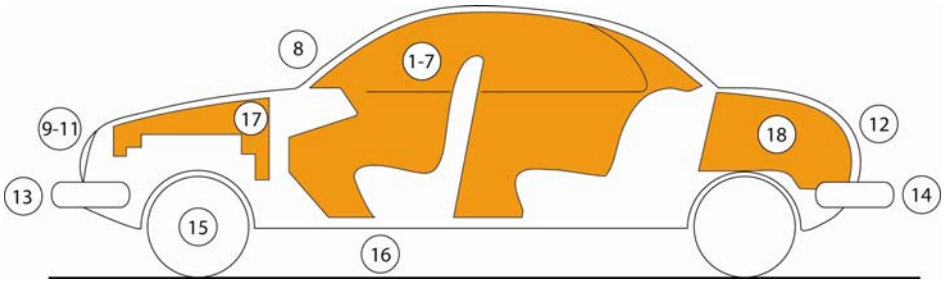


Figure 2: Diagram of Automotive Human Factors (Tillman and Woodson, 1981: 77).

All dimensions in mm	Men			Women		
	5th	50th	95th	5th	50th	95th
Dimension	%ile	%ile	%ile	%ile	%ile	%ile
Stature	1640	1755	1870	1520	1625	1730
Eye Height	1595	1710	1825	1420	1525	1630
Shoulder Height	1330	1440	1550	1225	1325	1425
Elbow Height	1020	1105	1190	945	1020	1095
Hip Height	835	915	995	760	835	910
Sitting Height	855	915	975	800	860	920
Sitting eye Height	740	800	860	690	750	810
Sitting Shoulder Height	545	600	655	510	565	620
Sitting Elbow Height	195	245	295	185	235	285
Thigh Thickness	135	160	185	125	155	185
Buttock-knee length	550	600	650	525	575	625
Buttock-popliteal length	445	500	555	440	490	540
Knee Height	495	550	605	460	505	550
Popliteal Height	395	445	495	360	405	450

Table 3: Ergonomic estimates for Mexican adults from the age range of 19-60 (Tillman and Woodson, 1981: 557)

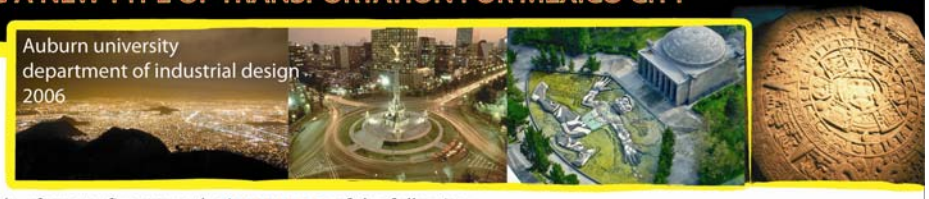
2.2.5 Conducting a User Transportation Survey

It is critical to understand the specific needs of the residents of Mexico City. In developing a questionnaire regarding their daily transportation routines, I was able to

further enhance my research and more specifically attempt to aid their problems by obtaining current data. The following questionnaire was translated into Spanish:

DESIGNING A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

Maria Elisa Carmona



On a scale of one to five score the importance of the following:

	Low				High
The aesthetic appearance of a transportation product.	1	2	3	4	5
The comfort deliverable of a transportation product.	1	2	3	4	5
The overall user satisfaction of a transporation product.	1	2	3	4	5
The safety of a transportation product.	1	2	3	4	5
The impact of the transportation product to the environment.	1	2	3	4	5

Short Answer:

- Would you be willing to purchase another vehicle in addition to the one you already own if the new vehicle were more convenient and cost less to operate? Why or why not?
- How are you affected by daily travel conditions?
- Do you believe that you are affected by air pollution?
- Do you consider a smaller and compact vehicle a necessity to drive in Mexico City? Why or why not?

Circle One

- On average, how long does it take you to reach your travel destination by private transportation?
  20-40 minutes 40 minutes.-1 hour 1-1.5 hours 5 hours or more
- On average, how long does it take you to reach your travel destination by public transportation?
  20-40 minutes 40 minutes.-1 hour 1-1.5 hours 5 hours or more
- In a week, how much time to you spend alone in your car?
  1-2 hours 2-3 hours 3-4hours 4-5 hours 5 hours or more
- In a week, how much time do you spend with other individuals in your car?
  1-2 hours 2-3 hours 3-4hours 4-5 hours 5 hours or more
- On a daily basis, about how many individuals are with you in the car?
  1 2 3 4 5 or more

The previous questionnaire was developed in April of 2006 and was conducted in June of 2006. This questionnaire was answered by one-hundred upper class inhabitants of Mexico City. The averages of the results from the rating sections as well as the similar reasons given in the short answer section were comprised to generate the following data.

Questionnaire results of 100 surveyed residents of Mexico City: Part One

The importance of the aesthetic appearance, comfort, overall user satisfaction and safety of a transportation product and the impact of the transportation product to the environment are presented below:

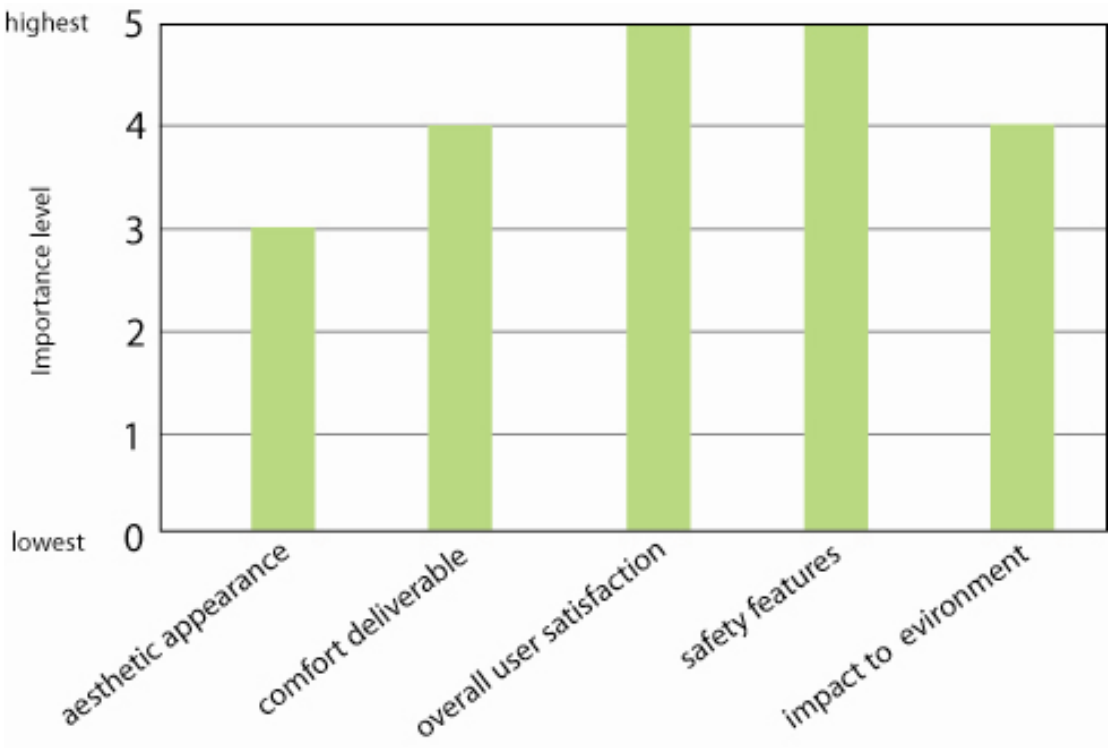


Table 4: Data from Questionnaire (Carmona, 2006)

This table suggests that the residents of Mexico City rely heavily on a vehicle that will bring them the ultimate satisfaction that they need for their transportation experience.

The importance of safety was also stressed due to the road rage caused by the heavy traffic found within the city. Air pollution is also a concern for the inhabitants of Mexico City. Residents are aware that the continual use of leaded gasoline is causing serious problems in the city's pollution levels and, therefore, will affect their health. Due to the extended periods of time that the inhabitants of Mexico City endure sitting in their vehicles due to the congested roads, the comfort deliverable of a vehicle was just as important as the vehicle's impact to the environment. Finally, the aesthetic of a transportation vessel scored a mediocre three, which further proves the definition of design itself, that the function of a product is more important to it's user than its form.

Questionnaire results of 100 surveyed residents of Mexico City: Part Two

The following responses from the short answer section of the questionnaire were comprised from the similarities in the reasons given from the answers of the people surveyed:

Question One:

Would you be willing to purchase another vehicle in addition to the one you already own if the new vehicle were more convenient and costs less to operate? Why or why not?

Answer given by 80% of individuals surveyed:

'Yes, because it would save more money in the future'.

Question Two:

How are you affected by daily travel conditions?

Answer given by 63% of individuals surveyed:

'It takes a long time to get to work and parking is a hassle'.

Question Three:

Do you believe that you are affected by air pollution?

Answer given by 75% of individuals surveyed:

'Yes'.

Question Four:

Do you consider a smaller and compact vehicle a necessity to drive in Mexico City? Why or why not?

Answer given by 55% of individuals surveyed:

'Yes, I travel to work by myself'.

'Yes, parking would be easier'.

Questionnaire results of 100 surveyed residents of Mexico City: Part Three

1. The duration it takes a resident to reach his or her travel destination by private transport:

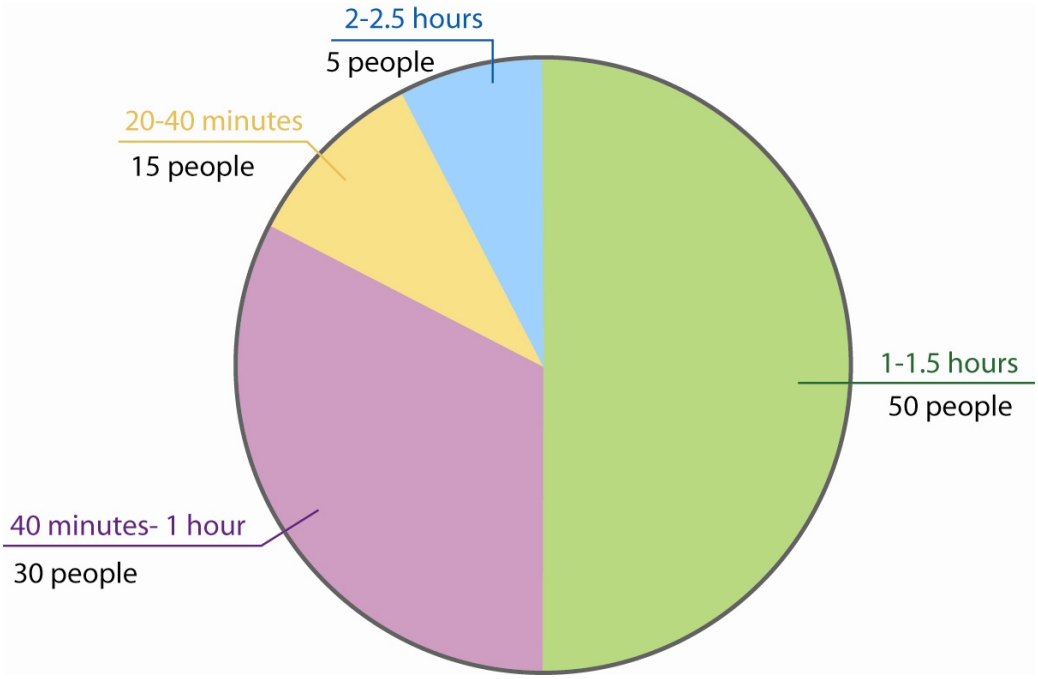


Table 5: Data from Questionnaire (Carmona, 2006)

2. The duration it takes a resident to reach his or her travel destination by public transport:

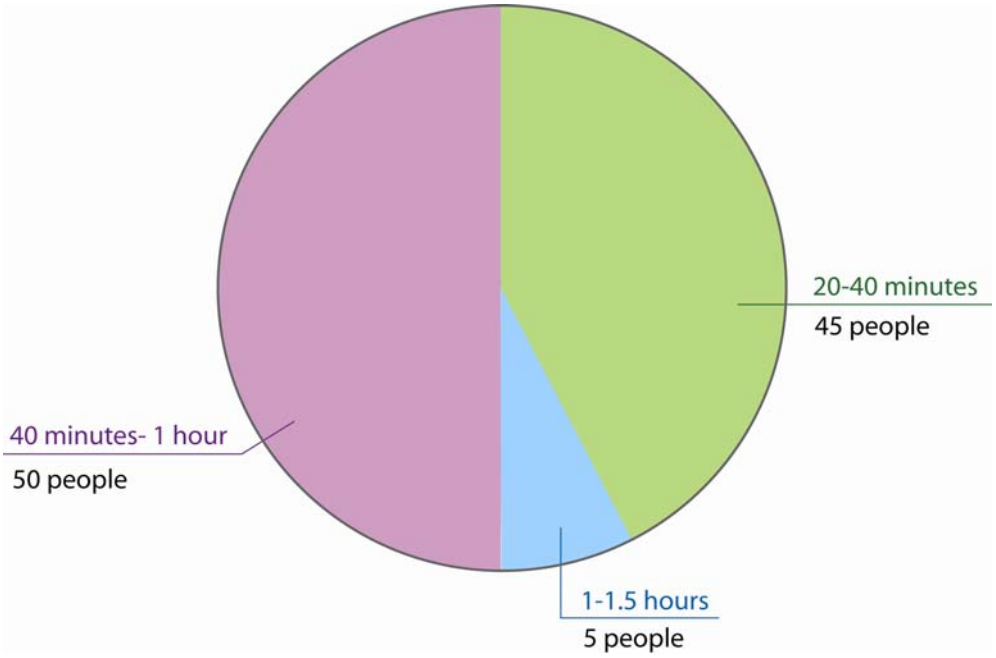


Table 6: Data from Questionnaire (Carmona, 2006)

3. A week's time spent alone by a resident in his or her vehicle:

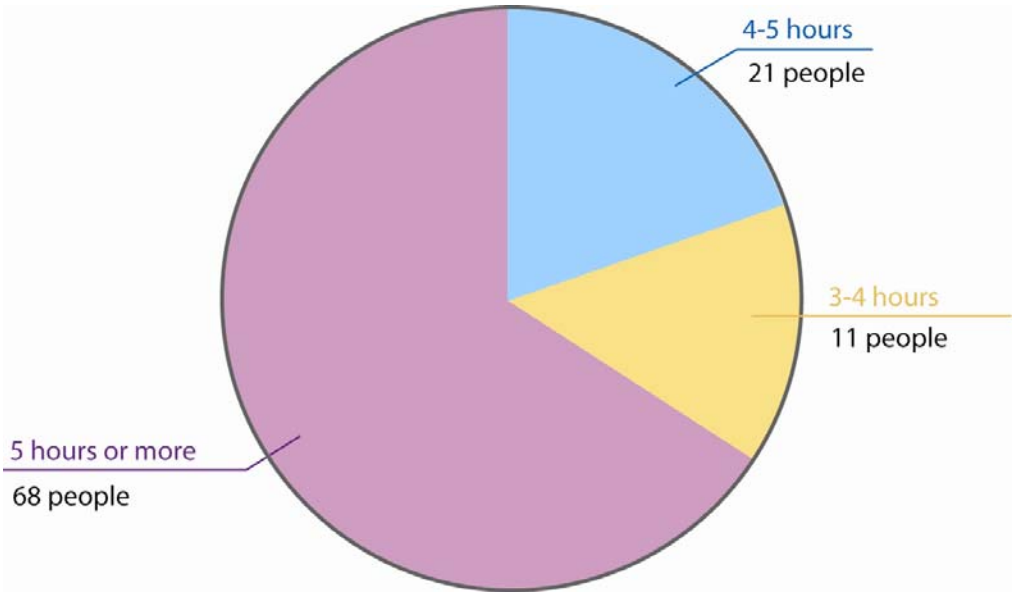


Table 7: Data from Questionnaire (Carmona, 2006)

4. A week's time spent with other individuals by a resident in his or her vehicle:

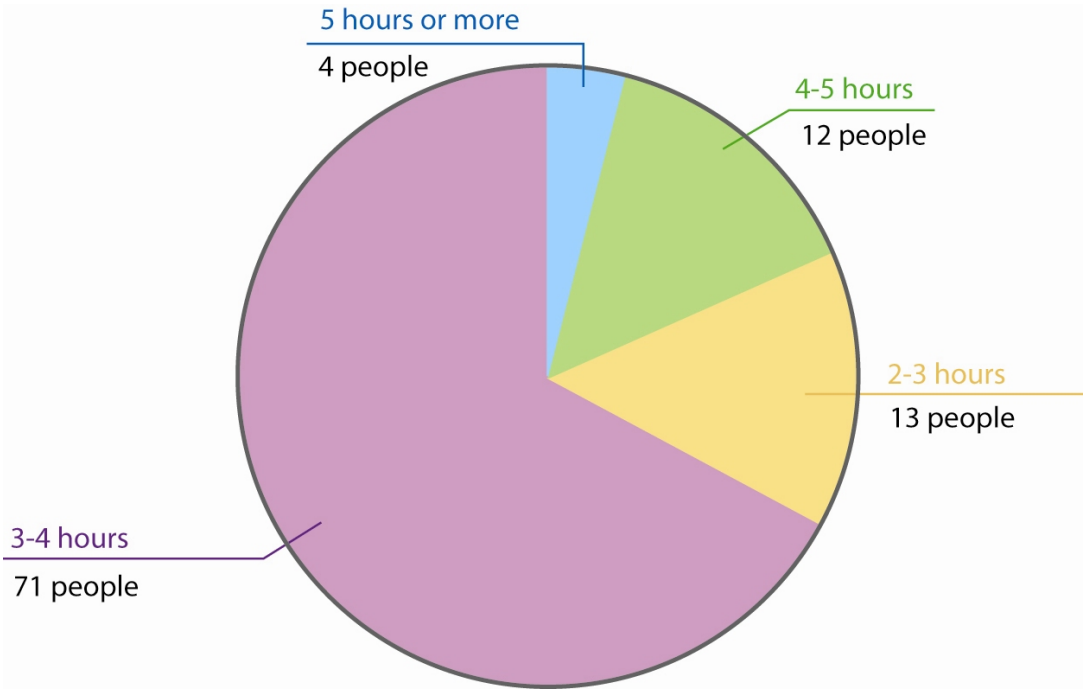


Table 8: Data from Questionnaire (Carmona, 2006)

5. The number of daily passengers (including the driver) in the resident's vehicle:

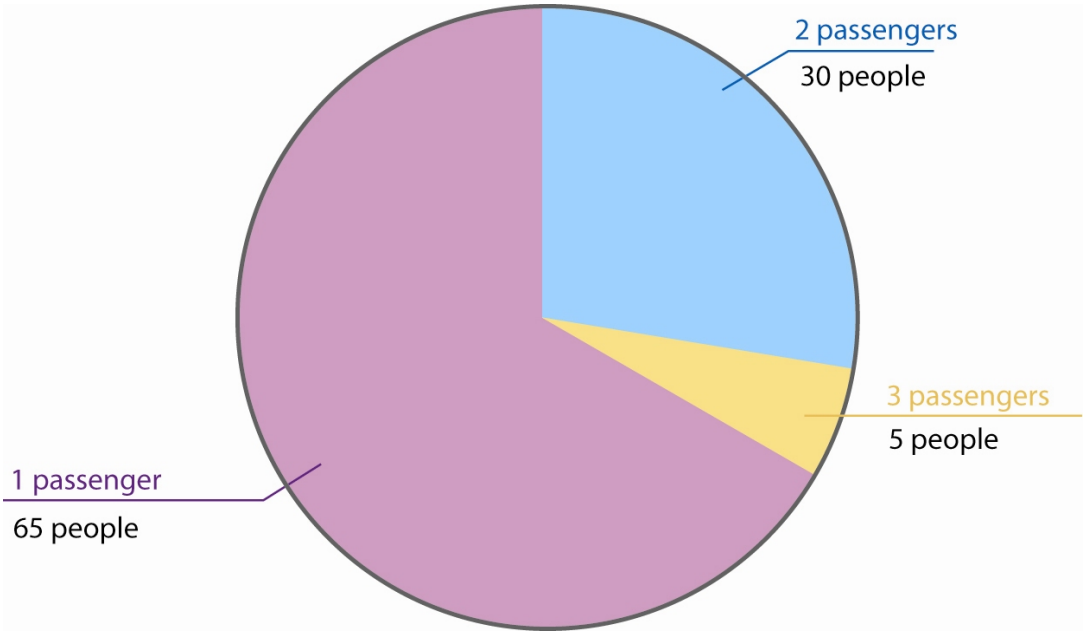


Table 9: Data from Questionnaire (Carmona, 2006)

2.3 MEXICO CITY'S CURRENT TRANSPORTATION

2.3.1 The Significance of Studying Current Transportation Methods

In order to accurately aid the residents of Mexico City with their current transportation tribulations, it is critical to study and understand these problems themselves. By studying the land transportation systems that the city provides its inhabitants, the designer will be able to identify these problems at their source to further pin point the actual needs of the residents. The designer is thereby enabled to rectify their poor traveling experiences by developing an appropriate design solution.

2.3.2 Defining the Current Transportation Methods

To travel any long distance in Mexico City, there are four major modes of transportation (Davis, 1994:42).

Automobiles: Over the years, the Mexican government undertook the massive project of developing an elaborate system of highways including a five-lane "Periférico" and the network of one-way four and six-lane highways "Ejes viales" (Davis, 1994: 43). These actions soon became controversial since public green areas and private residential areas had to be condemned to make way (Davis, 1994: 43). However, the tremendous growth in the number of automobiles has outpaced the development of the highway system thereby causing certain parts of Mexico City to become one large parking lot of congested automobiles going nowhere (Davis, 1994:44).

Most cars in Mexico in the 1990s were of American origin, such as Oldsmobile and American Fords. According to transportation researcher Diane Davis, "the growth of Mexico's economy has stimulated car sales in Mexico since the mid 1990s" (Davis, 1994: 48). Annual passenger vehicle sales in Mexico crossed the 1 million mark in 2005,

causing there to be more models offered in Mexico than in the United States (Davis, 1994: 49).

Successful vehicles in Mexico City include the Nissan Tsuru, Volkswagen Pointer, Volkswagen Jetta and the Volswagen Beatle where the average price a resident of Mexico City pays for these vehicles is 133,708.25 pesos or 13,370.83 United States dollars (Davis, 1994: 51).

The Metro: The Metro is the simplest method of transportation for the citizens of Mexico City. It is reliable with nine different lines carrying five million passengers per day and it is relatively cheap for residents in high class social groups (Davis, 1994: 53). According to transportation researcher Diane Davis, "a ticket from any station to any other currently costs between $6.00 and $8.00 pesos, the equivalent to $0.60 and $0.80 in U.S currency" (Davis, 1994: 53). Also, access for disabled and elderly citizens of Mexico City is free (Davis, 1994: 54). Residents can purchase a smartcard with prepaid trips costing about 300 pesos or 30.00 American dollars for 150 trips (Davis, 1994: 54).

The Mexico City Metro was the first metro system in the world to identify each station individually with a symbol in order to help the illiterate segment of the population (Davis, 1994: 56). The weekday operating hours for the Metro are 6am to midnight; Saturdays from six in the morning to one in the morning; and Sundays from six in the morning to midnight (Davis, 1994: 56).

Taxis: There is a variety of taxis in Mexico City. There are plenty of lime-green colored taxi cabs which can be occasionally unsafe (Davis, 1994: 58). However, if taken randomly from the street instead of designated locales these taxi cabs are known to be

very cheap. Recently, they have been joined by red and white taxis as part of a program to replace older vehicles with newer models (Davis, 1994: 58).

Buses: The city government operates a network of large buses in addition to privately operated microbuses which seem to be more expensive than the Metro (Davis, 1994: 59). The city's first bus transit line was known as the Metrobus, which currently allows passengers to travel to destinations that the metro cannot reach (Davis, 1994: 60). Private microbuses were later removed from their routes in hopes that the Metrobus could reduce pollution and decrease transit time for passengers (Davis, 1994: 62).

In the chart below, the usage of the four principal modes of transportation within the seven days that a survey was conducted was recorded. The data below is comprised from 6,000 surveyed residents between the ages of 16 and 64 in the year of 2001.

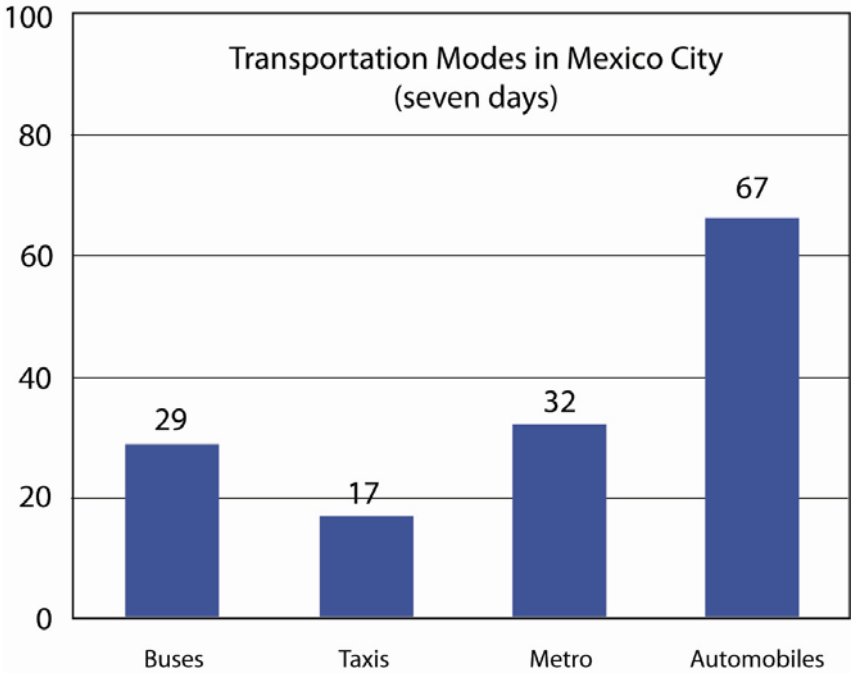


Table 10: Transportation Modes in Mexico City (Eskeland, 2002: 20).

2.3.3 Defining the Problems Related with the Current Transportation of Mexico City

Automobiles: In recent years, Mexico City has found itself faced with extremely high levels of air pollution (Pick and Butler, 1997: 203). Automobiles are a major source of Mexico City's air pollution in that most residents use leaded gasoline in an effort to save money (Pick and Butler, 1997: 203). With the transport sector contributing a great factor to the rising levels of pollution, it was necessary for the government to take strict measures in an effort to alleviate the city of this crucial problem (Pick and Butler, 1997: 204). To reduce traffic on the roads, the government launched a system in 1989 to ban certain cars from the roads on certain days based upon the last digit of the vehicle's license plate where offending vehicles of the policy are impounded (Pick and Butler, 1997: 204). According to researchers Edgar Butler and James Pick, the once promising system backfired. "One of the odd effects of this system is that some Mexicans have more than one car, for the sole purpose of circumventing the system, thus contravening the original intent (Pick and Butler, 1997: 205).

Metro: Though the Metro of Mexico City promises a simple way to travel within the city, it can be very crowded and therefore dangerous during rush hour, such that special compartments are set aside for women and children to avoid the unpleasant possibilities of crime (Pick and Butler, 1997: 209). Due to the high crime rates within the crowded walls of the metro system, many high class inhabitants of Mexico City would rather wait in congested traffic in the privacy of their own safe vehicles than risk the possibility of exposing themselves to violence (Pick and Butler, 1997: 210). On another note, the Metro reaches only a fraction of the total inhabited area of the city, and

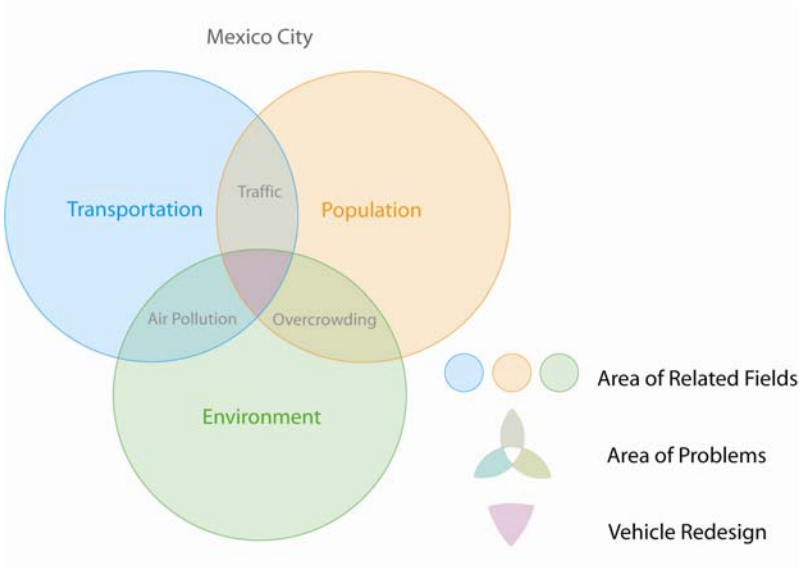
therefore an extensive network of bus routes has been implemented which in turn is adding to the city's air pollution (Pick and Butler, 1997: 212).

Taxis: The drivers of varying green taxicabs are typically moonlighters from other jobs, and their reputations have been sullied by robbery cases where according to researcher Peter Ward, "the drivers take the customers to be robbed by armed accomplices" (Ward, 1990: 100). The orange-colored cabs that wait at "*sitios*" or taxi ranks are slightly more expensive, but they have the reputation to be driven by full-time professional drivers (Ward, 1990: 100). Residents as well as visitors to Mexico City must be very cautious when taking taxis because Mexico City's most common crime is the Kidnapping Express (Ward, 1990: 103).

In the Express scenario, criminals will hold victims at gun-point inside a taxi cab that was taken from the street. According to researcher Peter Ward, "they work against the clock by forcing you to withdraw money from your credit card, whisking you from one ATM to another" (Ward, 1990: 103). Kidnapping express may take place virtually anywhere in this incredibly huge metropolis, one of the largest in the world.

Buses: "The regular buses are unmistakably painted in yellow, and are antiquated, uncomfortable and polluting devices" (Ward, 1990: 110). In addition, the private mini-bus services including the "*combis*," which is the local name for the microbus, has fares that exceed that of the Metro (Ward, 1990: 110).

The following diagram illustrates and comprises the current private transportation problems of Mexico City and how these problems are all connected with the gray lines. This diagram was created after the previously mentioned research was conducted in April of 2006:



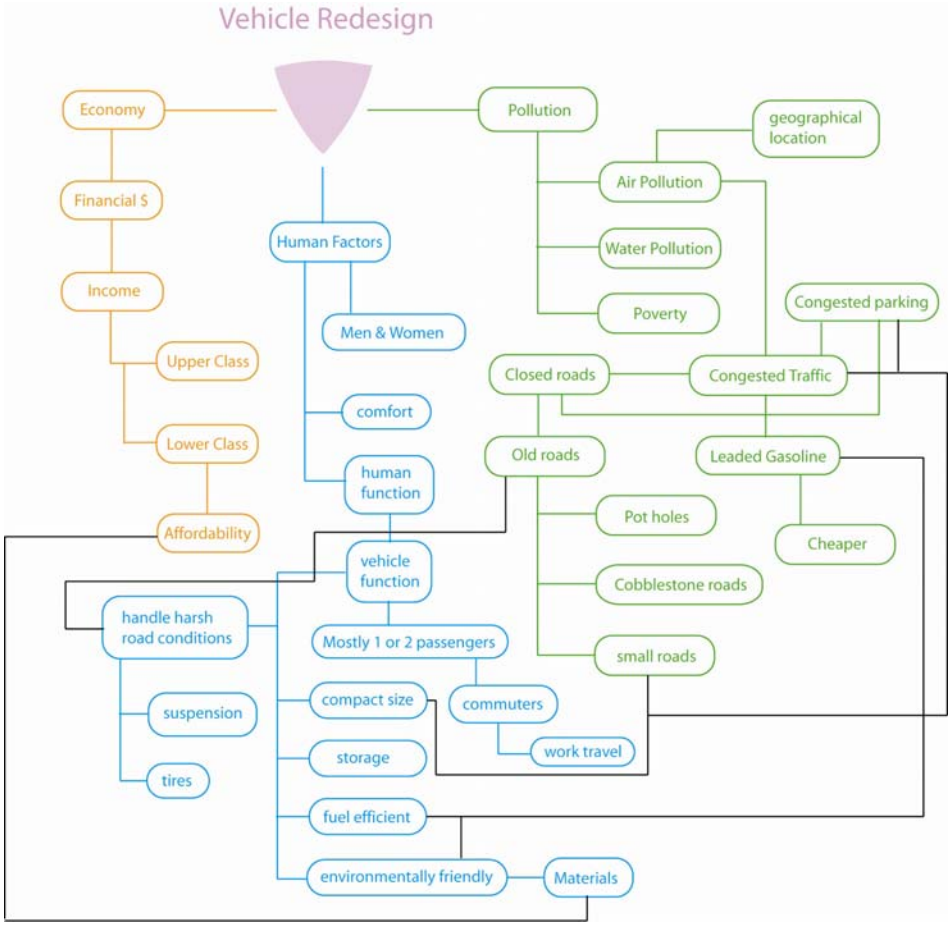


Figure 3: Diagram of Mexico City's Transportation Problems (Carmona: 2006).

2.3.4 Defining Solutions for Mexico City's Current Transportation Problems

The transportation problems mentioned above can be aided with thoughtful and prudent industrial design solutions. The previously conducted research reveals that Mexico City obtains massive amounts of air pollution, provides public transportation with rising costs, and houses residents who seem to find moving from one place to another a constant hassle. Alleviating Mexico City's residents of these tribulations lies in establishing new criteria for designing the future of Mexico's automotive industry.

Mexico City's future transportation will be compact, seating only two to three passengers. Current commuters who are the sole occupiers of their cars find themselves driving larger vehicles which seat three to five passengers, causing the congestion of traffic and the frustrating event of parking. Therefore, a smaller vehicle is not only a practical solution to drive around the narrow and rugged streets of the ancient city, but it will allow more space for vehicles to navigate through the city's busiest streets and also allow for more parking space.

Fuel efficiency, mainly electrical and hybrid technology should be introduced into this third world country where leaded gasoline is the number one source of the serious continual and constant rising of pollution. Though unleaded gasoline has recently been introduced to Mexico City, most residents who own vehicles choose not to use it due to its high cost.

Lastly, in a city whose households commit large portions of their yearly earnings to gasoline and public transportation, fuel efficiency will cause less spending on both gasoline and public transportation. A more efficient vehicle for those who own private cars will eliminate the need for reliance on public transportation which can be both

dangerous and limiting in destinations. Vehicles are needed which will avoid these conditions at their source to alleviate this metropolitan city of its dreadful transportation circumstances.

2.4 IDENTIFYING HYBRID ELECTRIC VEHICLES

2.4.1 Hybrid Electric Vehicles Defined

A hybrid electric vehicle also known as an HEV combines the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle (U.S. Department of Energy, 2006: 1). This combination offers low emissions, with the power, range, and convenient fueling of conventional vehicles such as gasoline and diesel, and according to the U.S. Department of Energy "these models never need to be plugged in like most current electric vehicles on the market, they are recharged using regenerative braking or by using an on-board generator making them well suited for fleet and personal transportation" (U.S Department of Energy, 2006:1).

2.4.2 How Hybrid Electric Vehicles Operate

An HEV is powered by two energy sources, an energy conversion unit such as a combustion engine which may be powered by gasoline, methanol, compressed natural gas, hydrogen or other alternative fuels and an energy storage device such as a battery (U.S. Department of Energy, 2006: 3). According to the U.S Department of Energy, "hybrid electric vehicles have the potential to be two to three times more fuel-efficient than conventional vehicles" (U.S. Department of Energy, 2006: 3). A hybrid electric vehicle has multiple and various components:

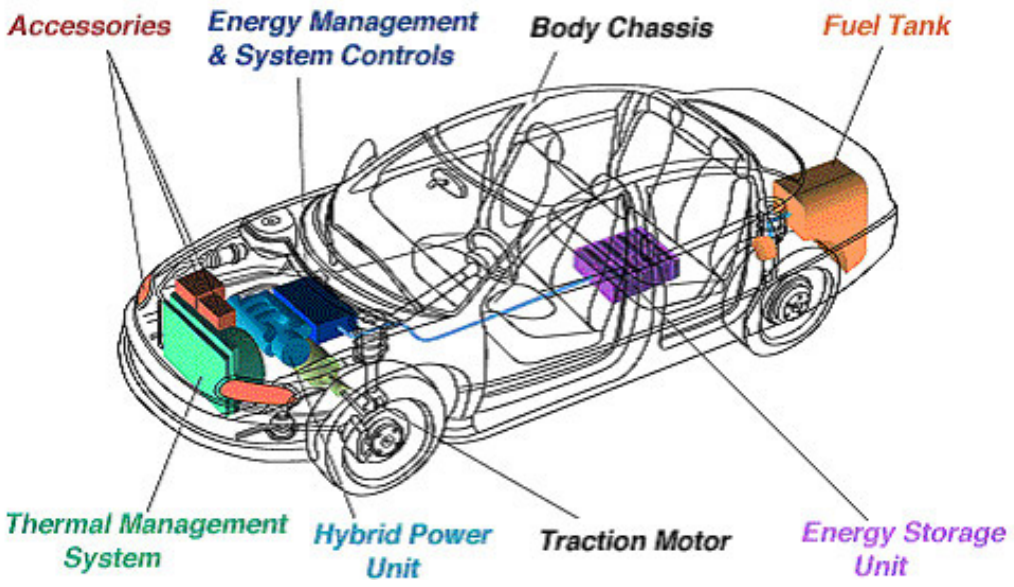


Figure 4: HEV Components (U.S Department of Energy, 2006)

Electric Traction Motors: The motors of Hybrid Electric Vehicles are known as the "work horses" of the drive systems. In an HEV, an electric traction motor converts electrical energy from the energy storage unit to mechanical energy that drives the wheels of the vehicle (U.S. Department of Energy, 2006: 5). According to the U.S. Department of Energy, “unlike a traditional vehicle, where the engine must ramp up before full torque can be provided, an electric motor provides full torque at low speeds. This characteristic gives the vehicle excellent off the line acceleration” (U.S. Department of Energy, 2006: 5). Other important characteristics of an HEV motor include excellent driving control and fault tolerance, low noise and high efficiency, flexibility in relation to voltage fluctuations and most importantly, acceptable mass production costs (U.S. Department of Energy, 2006: 6).

Electric Energy Storage Systems: Batteries are an essential component of the HEV system. According to the U. S. Department of Energy, “desirable attributes of high power batteries for HEV applications are high-peak and pulse-specific power, high specific energy at pulse power, a high charge acceptance to maximize regenerative braking utilization, and long calendar and cycle life” (U.S Department of Energy, 2006: 6).

Hybrid Power Units: “A spark ignition engine runs on an Otto cycle—most gasoline engines run on a modified Otto cycle” (U.S Department of Energy, 2006: 8). According to the U.S. Department of Energy, “this cycle uses a stoichiometric air-fuel mixture, which is combined prior to entering the combustion chamber. Once in the combustion chamber, the mixture is compressed and ignited using a spark plug also known as a spark ignition” (U.S Department of Energy, 2006: 8). The SI engine is controlled by limiting the amount of air allowed into the engine which is accomplished through the use of a throttling valve placed on the air intake also referred to as the carburetor or throttle body” (U.S. Department of Energy, 2006: 8). For the last century, the SI engine has been developed and used widely in automobiles due to its many promising advantages. According to the U.S. Department of Energy “continual development of this technology has produced an engine that easily meets emissions and fuel economy standards and is the lowest costing engine due to the huge volume currently produced” (U.S. Department of Energy, 2006: 9).

Thermal Management System: Just as conventional gasoline engines require a cooling system, an HEV needs proper thermal management of the power and energy

storage units for optimum performance and durability (U. S Department of Energy, 2006: 12). The type of thermal management system required depends completely on the type of power and energy storage units selected, and in many cases waste heat from these components can be used for cabin air and other heating needs (U.S Department of Energy, 2006: 12).

Fuel: "The two primary fuels used in automobiles today are gasoline and diesel. The infrastructure is in place to produce, refine, truck, or tank diesel and gasoline" (U.S. Department of Energy, 2006: 15). Therefore, the current HEV and the ones that will be available in the near future will use either gasoline or diesel to fuel the hybrid power units (U.S. Department of Energy, 2006: 15).

Energy Management and Systems Control: An HEV has two or more sources of on-board power (U.S Department of Energy, 2006: 18). The integration of these power-producing components with the electrical energy storage components allows for many different types of HEV designs (U.S Department of Energy, 2006: 18). A power control strategy is needed to control the flow of power and to maintain adequate reserves of energy in the storage devices (U.S Department of Energy, 2006: 18). According to the U.S Department of Energy, "although this is an added complexity not found in conventional vehicles, it allows the components to work together in an optimal manner to achieve multiple design objectives, such as high fuel economy and low emissions" (U.S Department of Energy, 2006: 19).

The largest distinction between different HEV designs is whether they are parallel or series or a combination of the two (U.S. Department of Energy, 2006: 21). In a parallel design, the energy conversion unit and electric propulsion system are connected directly to the vehicle's wheels. The primary engine is used for highway driving while the electric motor provides added power during hill climbs, acceleration, and other periods of high demand (U.S Department of Energy, 2006: 21).

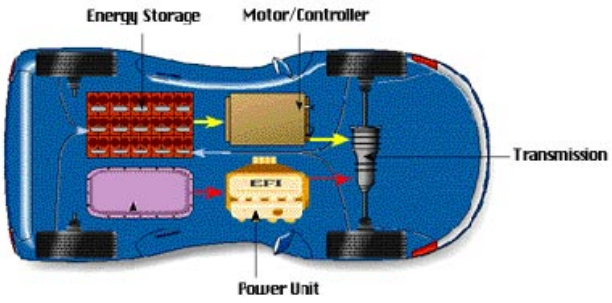


Figure 5: HEV Parallel Design (U.S. Department of Energy, 2006)

In a series design, the primary engine is connected to a generator that produces electricity. The electricity charges the batteries, which drive an electric motor that powers the wheels (U.S Department of Energy, 2006: 21).

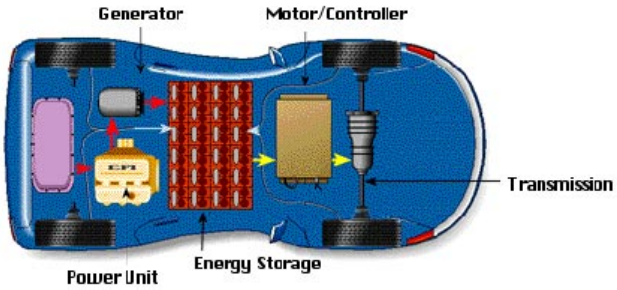


Figure 6: HEV Series Design (U.S. Department of Energy, 2006).

According to the U.S. Department of Energy, “an HEV can also be built to use the series configuration at low speeds and the parallel configuration for highway driving and acceleration” (U.S Department of Energy, 2006: 22). Using both the parallel and series configuration designs, the full hybrid system is capable of operating in gas or electric modes, as well as a mode in which both the gas engine and electric motor are in operation to provide improved fuel economy (U.S Department of Energy, 2006: 22). The engine provides most of the vehicle’s power, and the electric motor provides additional power when needed, such as for accelerating, passing and hill climbing allowing for a smaller, more efficient engine to be used (U.S Department of Energy, 2006: 22). According to the U.S. Department of Energy, “the generator has a higher peak operating speed that increases electric-mode operation in city and freeway stop and go operation; while the motor alone provides power for low-speed driving where internal combustion engines are least efficient” (U.S Department of Energy, 2006: 23). Also, when the vehicle arrives at a complete stop, the engine will automatically shut off allowing the vehicle to become 100% electric. The engine will restart immediately when the acceleration is pressed which prevents wasted energy from idling (U.S Department of Energy, 2006: 23). The following diagram illustrates the components found in an HEV that utilizes both the series and parallel designs:

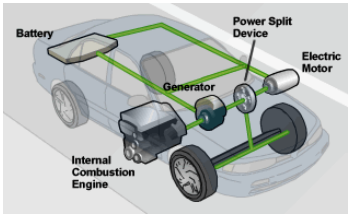
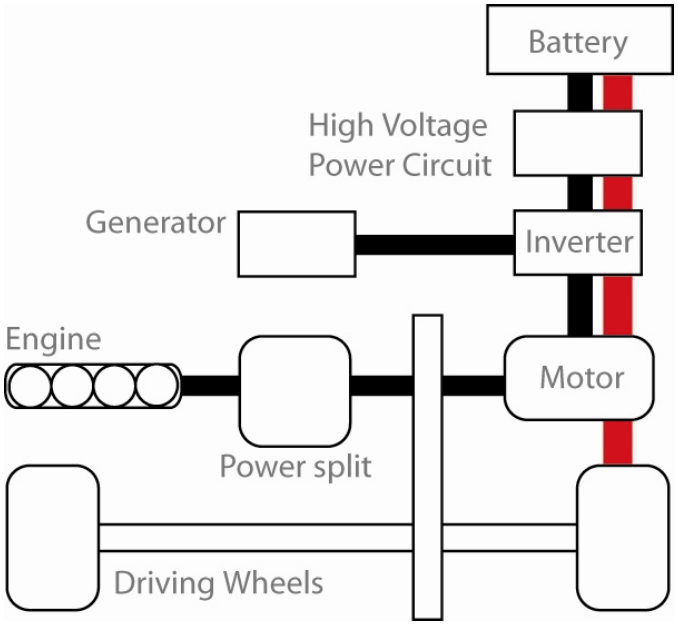


Figure 7: An HEV Parallel and Series Design System (U.S. Department of Energy, 2006)

The following diagram illustrates how the parallel and series design systems perform together as one hybrid system:

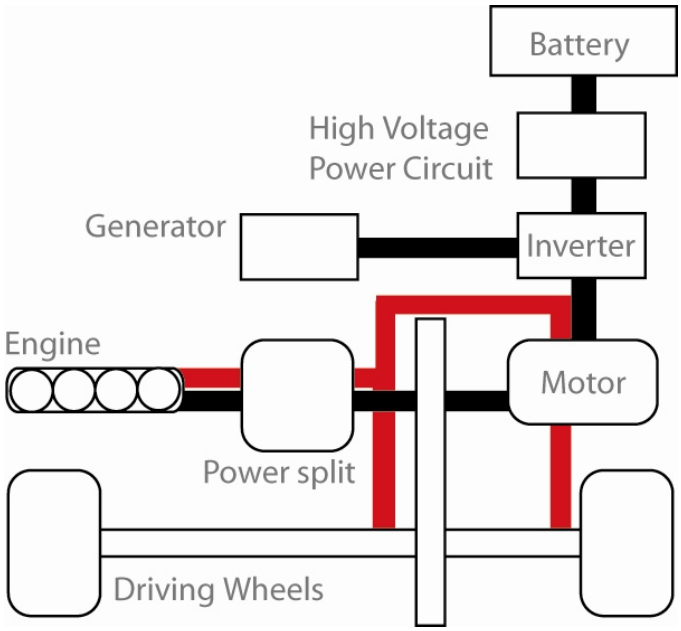
<u>At acceleration from start and at low to mid-range speeds</u>:



The engine is stopped when it encounters a poor-efficiency range under a wider range of operational conditions such as acceleration from standing start and up to mid-range speed. The vehicle runs entirely on power generated by the motor.

Figure 8: HEV Parallel and Series Systems as One Hybrid System (U.S. Department of Energy, 2006)

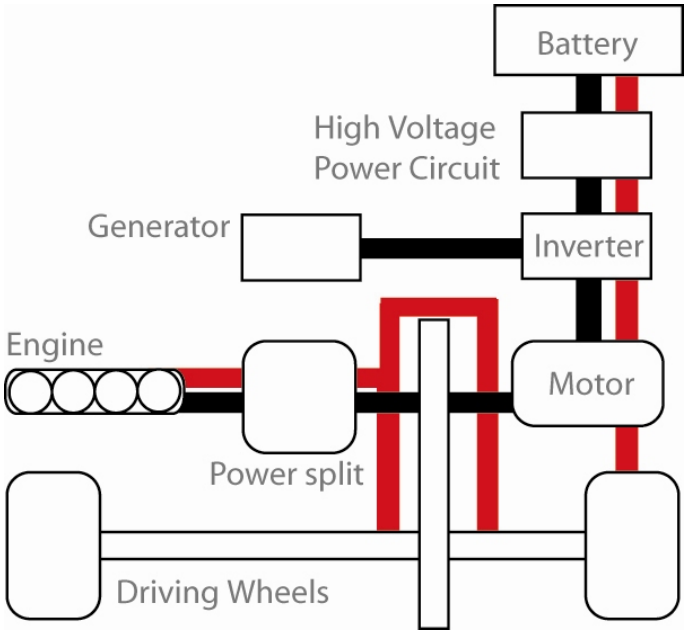
During driving under normal conditions:



Power generated by the engine is distributed two ways by the power split device. One power stream is used to drive the generator, which in turn drives the motor. The other power stream is used to directly drive the wheels. The distribution of these power streams is controlled to provide maximum efficiency.

Figure 9: HEV Parallel and Series Systems as One Hybrid System (U.S. Department of Energy, 2006)

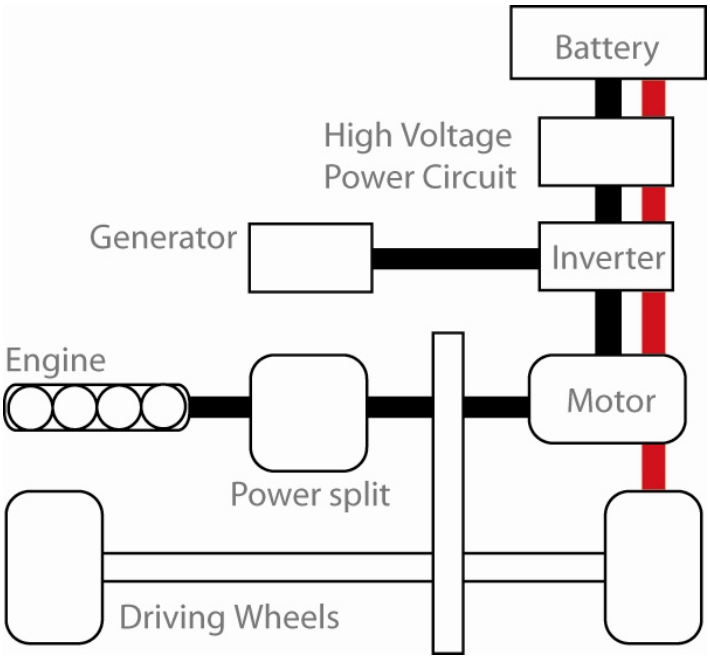
During sudden acceleration:



During sudden acceleration, extra power is supplied from the battery while the engine adds drive to the high-output motor, providing good response and a smooth drive, as well as improved acceleration performance.

Figure 10: HEV Parallel and Series Systems as One Hybrid System (U.S. Department of Energy, 2006)

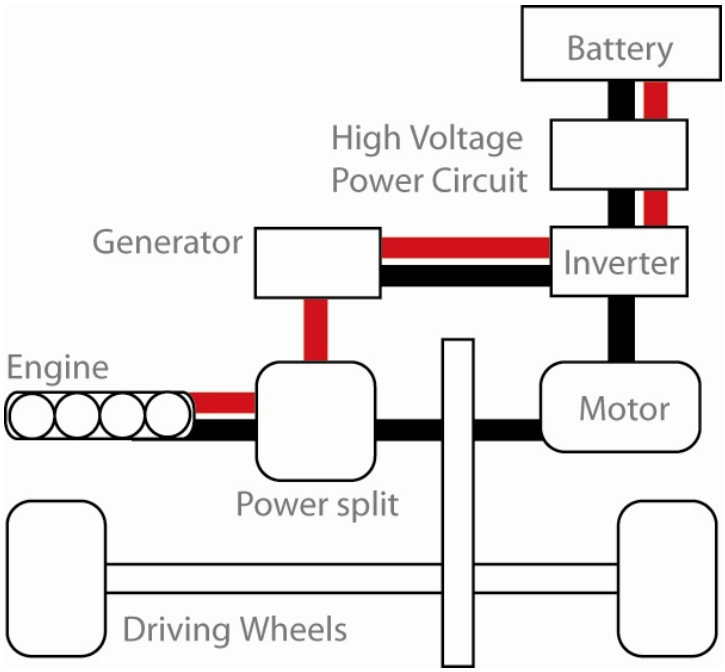
During braking and other forms of deceleration:



During deceleration through braking and other methods, the high-output motor functions as a large capacity generator, controlling power distribution to the wheels. The system functions as an efficient regenerative braking system recovering the vehicle's kinetic energy as electrical energy. The recovered energy is then stored in the high-performance battery.

Figure 11: HEV Parallel and Series Systems as One Hybrid System (U.S. Department of Energy, 2006)

While the battery is recharging:



The battery is controlled to maintain a certain level of charge. When the charge level becomes low the generator kicks in to recharge it.

Figure 12: HEV Parallel and Series Systems as One Hybrid System (U.S. Department of Energy, 2006)

2.4.3 Popular Vehicles of Mexico City Compared to Hybrid Electric Vehicles

Current successful Vehicles in Mexico City include the 2007 Nissan Tsuru, the 2007 Volkswagen Pointer and Beetle and the 2006 Volkswagen Jetta.

In 1984, the first Nissan Sentra was launched in Mexico and became the Tsuru after a Japanese bird. While the Tsuru was quickly known for its affordability and comfort by the inhabitants of Mexico City, it did not replace the Volkswagen Beetle as the top selling automobile in Mexico (Wikepedia.org).

Figure 13: 2007 Nissan Tsuru/Sentra (NissanTsuru.com)

The Pointer is Volkswagen's response to the success of the Nissan Tsuru where it first launched in 1998 with rising sales in Mexico City in the year 2000. It has become a success as a fleet vehicle for taxis as well as a private automobile (Wikepedia.org). The latest model of the Pointer gave the residents of Mexico City a flashy exterior and a new interior without a major price difference making it the number one selling auto in 2006 (Wikepedia.org).

Figure 14: 2007 Volkswagen Pointer (vw.com.mx)

The Volkswagen Atlantic was the first Jetta in Mexican territory. With good sales, Volkswagen began to manufacture this car in their factory at Puebla, Mexico (Wikepedia.org). In late 1999 the fourth generation Jetta reached Mexico City where the Jetta converted into a hit, reaching the top three selling automobiles. With the new aesthetic design, the automobile's popularity increased among the inhabitants of Mexico City (Wikepedia.org).

Figure 15: 2006 Volkwagen Jetta (vw.com.mx)

The first Volkswagen car sold in Mexico and in the world was the Beetle. It began selling in the city of Mexico as early as 1954. The popularity of the Beetle caused

Volkswagen to house its very own factory in Puebla, Mexico (Wikepedia.org). Reasons behind the success of this car were the price and the quality. In the early 80s, Mexico was the only country producing the Beetle, causing foreigner enthusiasts to import the car and keep it as a collectors item (Wikepedia.org).

Figure 16: 2007 Volkswagen Beetle (vw.com.mx)

The following are comparative product charts illustrating the cost and features of each successful vehicle in Mexico City as well as current leading Hybrid Electric Vehicles:

Vehicle	Model Year	Price (Pesos)	Price (U.S.)	mpg city / mpg highway
Volkswagen Jetta 	2006	$157,933	$15,793	36/41
Volkswagen Pointer 	2007	$89,200	$8,920	38/46
Volkswagen Beetle 	2007	$184,700	$18,470	36/41
Nissan Tsuru/Sentra 	2007	$103,000	$10,300	28/36
Average money spent on a vehicle =		$133,708.25	$13,370.75	

Table 11: Comparative Product Chart (vw.com.mx, NissanTsuru.com)

Vehicle	Model Year	Price (Pesos)	Price (U.S.)	mpg city / mpg highway
Volkswagen Jetta 	2006	$157,933	$15,793	36/41
Volkswagen Pointer 	2007	$89,200	$8,920	38/46
Volkswagen Beetle 	2007	$184,700	$18,470	36/41
Nissan Tsuru/Sentra 	2007	$103,000	$10,300	28/36
Honda Insight 	2006	$193,010	$19,301	61/66
Toyota Prius 	2006	$238,190	$23,819	60/51
Toyota Yaris 	2007	$134,250	$13,425	61/53
Honda Civic Hybrid 	2006	$139,840	$13,984	49/51

Average money spent on a non-HEV =	$133,708.25	$13,370.75
Average money spent on an HEV =	$176,322.5	$17,632.25

Table 12: Comparative Product Chart (vw.com.mx, NissanTsuru.com, Honda.com, Toyota.com)

From this data we can conclude that it would actually be cheaper for the inhabitants of Mexico City to purchase Hybrid Electric Vehicles due to the money they would save on the consumption of unleaded gasoline. This method of transportation would reduce the levels of air pollution within the city and eliminate the need for the government to enforce its system where only certain automobiles occupy the roads of Mexico City according to the last digits on license plates and furthermore, alleviate future residents of Mexico City from purchasing more vehicles than necessary in attempts to avoid this law.

2.5 BASIC DRIVING SAFETY STANDARDS

2.5.1 The Significance of Safety Standards

While operating a vehicle there is no guarantee that harm will not come to the driver. Though the operation of any automotive vehicle requires a certain degree of personal responsibility by the driver, any drivers of a vehicle can and will cause themselves physical harm due to the lack of this responsibility or that of the other drivers in other vehicles. However, there does exist a collection of safety precautions and guidelines that any designer must follow when designing a vehicle to lessen the repeat of safety violations and mistakes. In learning these safety standards, designers can drastically reduce the overall risk of physical harm to the vehicle's users.

2.5.2 Formulating a List of Basic Requirements

The following criteria of safety standards are a list developed by the Federal Motor Vehicle Safety Standards (FMVSS):

101 Control location, identification, and illumination—passenger cars, multipurpose passenger vehicles, trucks and buses.

102 Transmission shift lever sequence, starter interlock, and transmission braking effect—passenger cars, multipurpose passenger vehicles, trucks and buses.

103 Windshield defrosting and defogging systems—passenger cars, multipurpose passenger vehicles, trucks and buses.

104 Windshield wiping and washing systems—passenger cars, multipurpose passenger vehicles, trucks and buses.

105 Hydraulic brake system—passenger cars, multipurpose passenger vehicles, trucks and buses.

106 Reflecting surfaces—passenger cars, multipurpose passenger vehicles, trucks and buses.

107 Lamps, reflective devices, and associated equipment—passenger cars, multipurpose passenger vehicles, trucks, buses and motorcycles.

108 Rearview mirrors—passenger cars, multipurpose passenger vehicles, trucks and buses.

109 Headlight concealment devices—passenger cars, multipurpose passenger vehicles, trucks and buses and motorcycles.

110 Hood latch systems—passenger vehicles, trucks and buses.

111 Theft protection—passenger cars.

112 Power operated window systems—passenger cars and multipurpose vehicles.

113 Accelerator control systems—passenger cars, multipurpose passenger vehicles, trucks and buses.

114 Occupant protection in interior impact—passenger cars.

115 Head restraints—passenger cars.

116 Impact protection for the driver from the steering control system—passenger cars.

117 Steering control rearward displacement—passenger cars

118 Glazing materials—passenger cars, multipurpose passenger vehicles, trucks, buses and motorcycles.

119 Door locks and door retention components—passenger cars, multipurpose passenger vehicles, trucks and buses.

120 Seating systems—passenger cars, multipurpose passenger vehicles, trucks and buses.

121 Seat—belt assembly anchorages—passenger cars, multipurpose passenger vehicles, trucks and buses.

122 Windshield mounting—passenger cars

123 Side-door strength—passenger cars

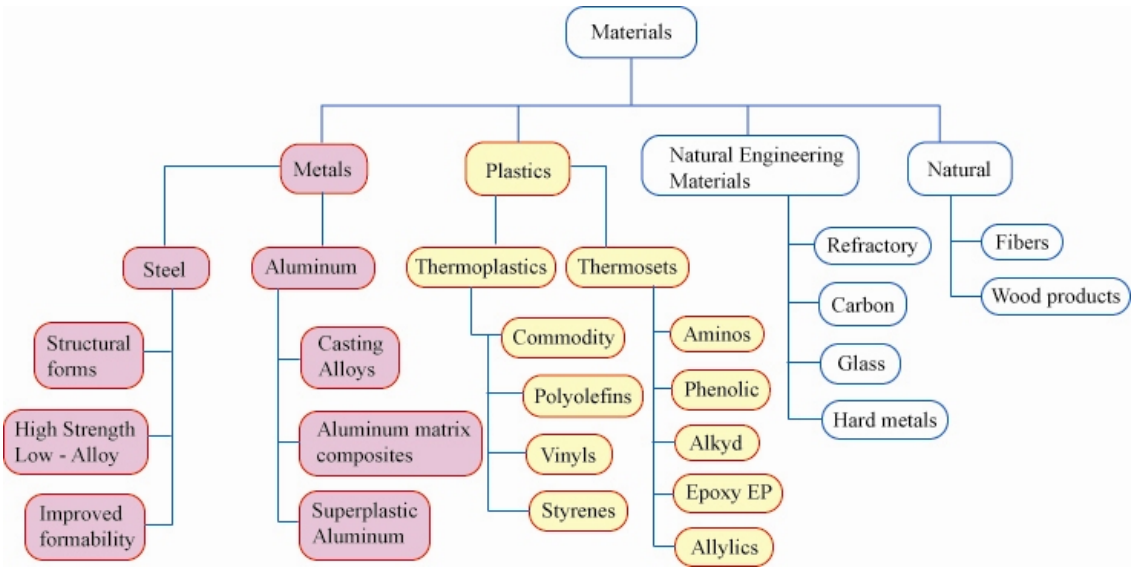
124 Roof crush resistance—passenger cars

125 Flammability of interior materials—passenger cars, multipurpose passenger vehicles, trucks and buses.

2.6 BASIC MATERIALS AND PRODUCTION METHODS

2.6.1 Main Applicable Existing Materials

Automobiles are constructed out of varying types of materials including metals, plastics, natural engineering and natural materials. Within these categories, different types of metals, plastics, natural engineering and natural materials are used to create an automobile. Due to the numerous materials included in the construction of a vehicle only the main materials used in the manufacturing of a vehicle's frame and body along with their production processes will be examined. These materials include aluminum, steel and plastic.



Pink and Yellow = materials to study.

Table 13: Materials Chart (Lesko,1999)

Metal:

Aluminum accounts for approximately 245 pounds of a vehicle's weight, a dramatic increase from the 160 pounds in 1991 (Bingham, 2000: 2). The primary reason behind a vehicle's weight reduction is this recent increase of aluminum content and significant increases are already apparent in varying 2001 models (Bingham, 2000: 2). According to materials expert Lora Bingham, "the aluminum flagship is Oldsmobile's Aurora, weighing in with up to 480 pounds of aluminum -- almost double the average. Using aluminum, the Aurora 4.0 sheds approximately 165 pounds from its 2000 incarnation" (Bingham, 2000: 2). Most vehicles shed pounds with the application of aluminum cylinder heads and die-cast aluminum open deck cylinder blocks, and aluminum hoods (Bingham, 2000: 2). Other applications include bumper beams, front and rear control arms, seat frames, steering parts and the front axle carrier is sometimes hot-forged aluminum; the rear axle is cast aluminum (Bingham, 2000: 2).

While some vehicles are reducing weight by employing new plastics and aluminum, others are returning to classic steel construction (Bingham, 2000: 2). According to materials expert Lora Bingham, "Ford is using Material Science Corps.' Quiet Steel for the dash panel of the Explorer Sport Trac. Quiet Steel is comprised of two metal skins surrounding a 25-micron weldable viscoelastic polymer core" (Bingham, 2000: 3). This steel requires only a fiberglass dash insulator allowing it to save seven pounds of weight compared to a conventional assembly, and laminated steel is also specified for several automotive dash panels" (Bingham, 2000: 3).

Many vehicles are built with steel body closures such as the Thunderbird Roadster, and Ford's Explorer and Expedition door inners use steel tailor-welded blanks and a steel upper front rail (Bingham, 2000: 3). There are many hybrid electric vehilces who are known for having steel body frames such as the Toyota Prius and the Honda Civic and Accord HEV models (Bingham, 2000: 3).

Plastic:

The availability of new, high-tech, cost-effective and durable plastics is on the rise, and several vehicles are currently making use of them (Bingham, 2000: 1). According to materials expert Lora Bingham, "rear bumpers lose weight as new automobiles feature thermoplastic bumpers molded from Xenoy 1103 polycarbonate/polyester resin" (Bingham, 2000: 1). This is the first non-metallic, non-glass mat technology-based rear bumper weighing only 11.4 pounds which is 41 percent lighter than steel and is claimed to reduce time and investment costs for construction compared with convential stamped steel bumpers (Bingham, 2000: 1).

Johnson Controls supplies the Chrysler Sebring Convertible with a poly-propylene and natural fiber blend material for its door trim panels (Bingham, 2000: 1). Sold under the name EcoCor, Lora Bingham states that "the material eliminates the need for glue, increases strength while reducing weight and provides side-impact protection characteristics (Bingham, 2001: 1). Other vehicles are known to replace their steel front-end support with a SMC 3374 plastic composite such at the Oldsmobile Aurora, reducing its front-end support mass by 25 percent (Bingham, 2000: 1).

New high-tech nylons make a strong showing in the types of plastics found in vehicle production (Bingham, 2000: 1). The Dodge Stratus and Chrysler Sebring have nylon air-intake manifolds comprised of Ultramid nylon from BASF Plastics manufactured by Siemens Automotive (Bingham, 2000: 1). According to materials expert Lora Bingham, "Ultramid is a 35 percent glass fiber-reinforced nylon produced by standard injection molding. The total manifold weight is about 6 pounds (Bingham, 2000: 1)".

DSM Engineering Plastics has contracts for several automotive companies to produce nylon engine covers using Akulon ReCap, a nylon 6 material comprised of 25 percent post-consumer waste (Bingham, 2000: 1). DSM also allows vehicles to include Stanyl High Flow and Akulon Ultraflow nylons. "Stanyl High Flow is a flame retardant nylon marketed as a high-strength, cost-saving replacement for liquid crystal polymer; Akulon Ultraflow is a glass fiber-reinforced nylon offering energy savings in injection molding applications" (Bingham, 2000: 1). According to The Automotive Composites Allience, the use of reinforced thermoset composites is expected to rise 47 percent over the next seven years (Bingham, 2000: 1).

Sustainable Materials:

Researchers at Pacific Northwest National Laboratory are working to develop cost-effective, high-strength, lightweight materials that will reduce vehicle weight without compromising cost, performance or safety (U.S Department of Energy, 2006: 30). The U.S. Department of Energy and Vehicle Technologies is researching materials

with auto manufacturers and suppliers in the transportation industry to develop lightweight, fuel-efficient cars, and to develop new methods for joining dissimilar materials (U.S Department of Energy, 2006: 30).

In 2006, the U.S. Department of Energy partnered with MeadWestvaco, a business dedicated to paper and specialty chemicals, to investigate lowering the cost of carbon fiber composites through the processing of lignin-based precursors (U.S. Department of Energy, 2006: 30). According to researchers of MeadWestvaco, “carbon-fiber composites weigh about one-fifth as much as steel but are comparable in terms of stiffness and strength, depending on fiber grade and orientation. They have the potential to reduce vehicle weight by as much as 60 percent, significantly increasing fuel economy” (U. S. Department of Energy, 2006: 31).These benefits come with no sacrifice in safety. Computer crash simulations performed at Oak Ridge National Laboratory indicate that “cars made with some carbon fiber composites would be just as safe -- if not safer -- than today's cars” (U. S. Department of Energy, 2006: 31). The U.S. Department of Energy states that “the purification and control of impurity levels in kraft-based lignin are critical to reliable carbon fiber” (U.S. Department of Energy, 2006: 32). MeadWestvaco is developing the concept for a cost-effective purification process which has the potential to be low-cost, efficient, and environmentally friendly (U.S Department of Energy, 2006: 32).

Researchers at the U.S. Department of Energy are also focusing on other areas to reduce manufacturing costs and develop new lightweight materials that are economical for manufacturers (U.S. Department of Energy, 2006: 32). A partnership with

DaimlerChrysler and Alcoa, the world's largest aluminum producer, allowed the completion of a project that involved developing three prototype lightweight vehicle frames (U.S. Department of Energy, 2006: 32). The prototypes, which are steel and aluminum hybrids, were tested on the 2002 Dodge Durango resulting in success. "The test results exceeded everyone's expectations, successful to the point that a more challenging follow-on program called the Next Generation Frame has been initiated" (U.S. Department of Energy, 2006: 33). The Next Generation Frame prototype abandoned the steel portion of the frame, focusing entirely on an aluminum frame. The aluminum frame resulted in a weight savings exceeding 40 percent, and is now being tested on the latest model of the Dodge Durango (U.S. Department of Energy, 2006:33).

2.6.2 Main Applicable Existing Production Methods

- Metal forming, cutting and joining:

There are three ways to form metals, in a liquid state, plastic state or solid state. In a liquid state also known as casting, melted metals are poured into a molds (Lesko, 1999: 23). The process is efficient in that the metal goes where required making this process efficient for complex parts and the most frequently used (Lesko, 1999: 23).

There are many casting methods, and selecting the best method to produce the desired part completely depends on a number of factors such as the material to be cast, all related costs, size, quantity, tolerance, section thickness, design features or complexity, weld ability and machinability (Lesko, 1999: 23).

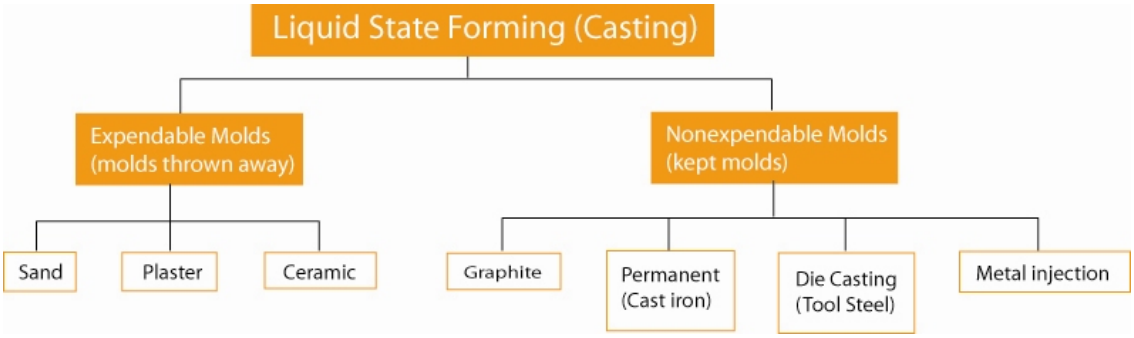


Table 14: Liquid State Forming Methods (Lesko, 1999: 25)

In a plastic state also known as forging, existing shaped parts and bars are heated just below their melting points, making them simple to reshape (Lesko, 1999: 23). This type of process is known to be labor intensive but provides the advantage of enhanced strength in the reshaped grain structure of the parts (Lesko, 1999: 23).

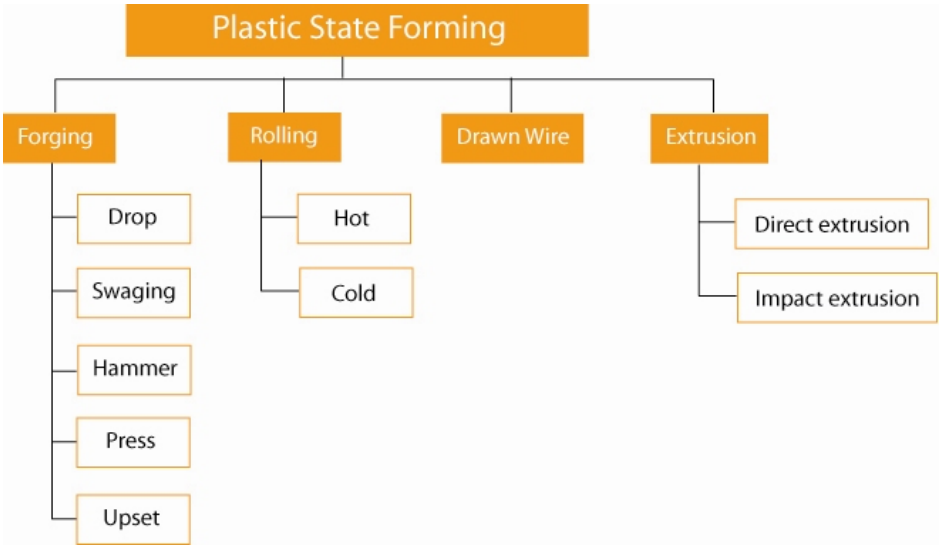


Table 15: Plastic State Forming Methods (Lesko, 1999: 42)

In solid state forming only sheets, rods and tubes are formed at room temperature where grain-direction control is the objective. Heating is sometimes required if the metal is thick, not very ductile or hardened during the forming process (Lesko, 1999: 48). Mechanical properties are affected during this process and strength gain does occur, yet the forming process can cause metal to become brittle and can require annealing before the process is continued (Lesko, 199: 48).

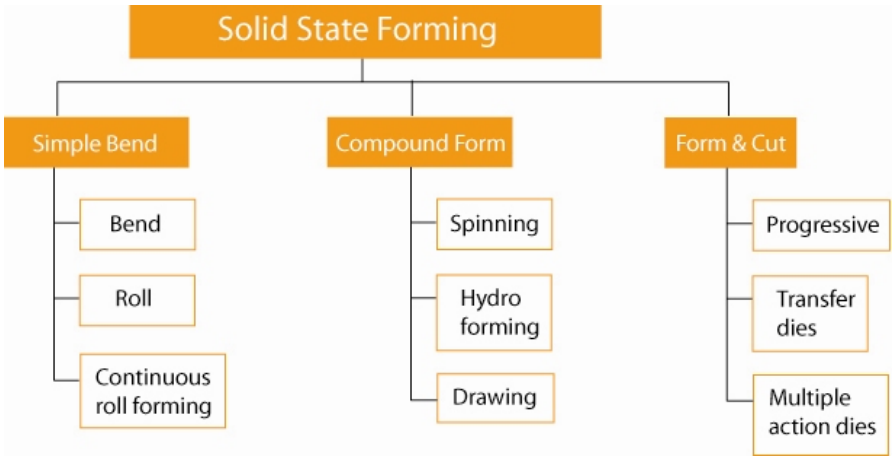


Table 16: Solid State Forming Methods (Lesko, 1999: 48)

The word cut in the sheet metal industry is not used to describe the process, except to size or rough-cut sheet stock which is usually referred to as a shear (Lesko, 1999: 58). The actual scraps are referred to as cut-offs. Blanks or punches are words that the sheet metal industry uses when referring to a cutting a hole into a sheet or creating a shape (Lesko, 1999:58).

The word machining is used when cutting into a block of metal (Lesko, 1999: 58). Though a specific cutting utensil is used to perform this activity, the word machining is used due to an actual machine which drives the cutting utensil (Lesko, 1999: 58).

In chip forming the term cutting refers to the reduction of a material by the removal of chips (Lesko, 1999: 62). In order for this procedure to be achieved efficiently, the cutting utensil must be harder than the material to be cut (Lesko, 1999: 62).

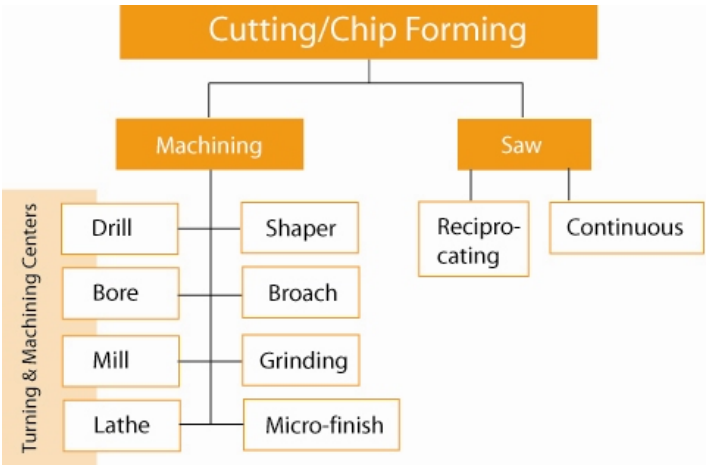


Table 17: Cutting/Chip Forming Methods (Lesko, 1999: 63)

Using high-tech processes nonchip forming is used extensively in the fabrication of scientific, electronic and defense equipment (Lesko, 1999: 69). This process is distinct from the machining process in that it is primarily used for bulk cutting (Lesko, 1999: 69). In thermal cutting, oxygen gases are mixed in a cutting chamber and released using a special tip. Once the metal is heated to a particular temperature, the flow of oxygen is increased to oxidize the metal and causes a cut through the material (Lesko, 1999: 72).

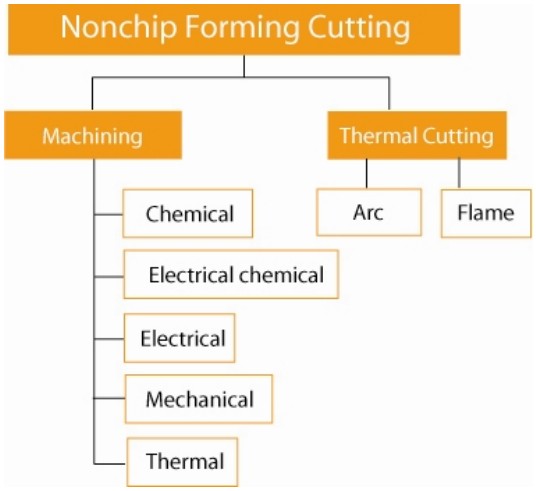


Table 18: Nonchip Forming Cutting (Lesko, 1999: 63)

All products are assemblies and their manufacturing process requires the joining of various materials and parts (Lesko, 1999: 74). There are three main options for joining product parts known as thermo joining, adhesive joining and mechanical joining (Lesko, 1999: 74).

There are two types of thermo joining known as soldering or brazing and welding. Soldering and brazing are very simple and typically consist of joining two similar metals by a third metal which is used as an adhesive (Lesko, 1999: 75). Welding is more complex in that there is fusion of the metals being joined due to a physical and mechanical change (Lesko, 1999: 75). Recent advances in welding have lessened the physical and mechanical harm to the metals being joined, yet heat treatment may be required to create a strong weld (Lesko, 1999: 75).

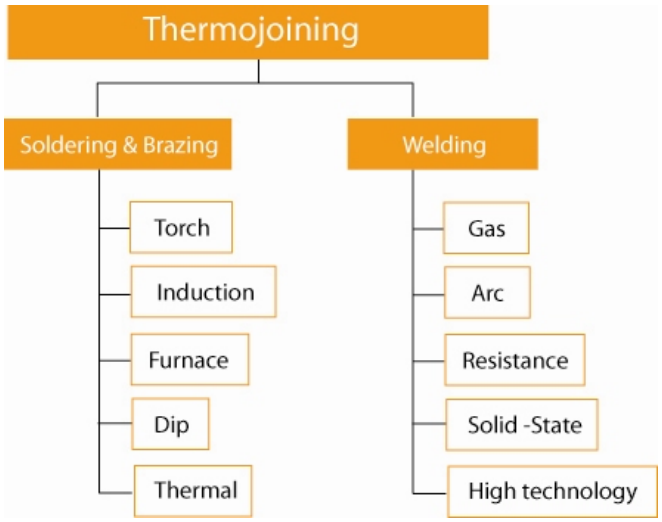


Table 19: Thermo joining (Lesko, 1999: 75)

Synthetic organic adhesives are often used in joining very thin materials and invisible joints (Lesko, 1999: 87). The following characteristics must be met by adhesives: toughness, strength, resistance to chemicals and fluids and the degradation of environmental elements such as heat and moisture (Lesko, 1999: 87). Joints which are to be secured by adhesives should be designed to withstand compressive and tensile forces and the joint should not be exposed to peeling forces (Lesko, 1999: 87). A common application of adhesives in product design is in the attachment of labels and switches on operating panels (Lesko, 1999: 87).

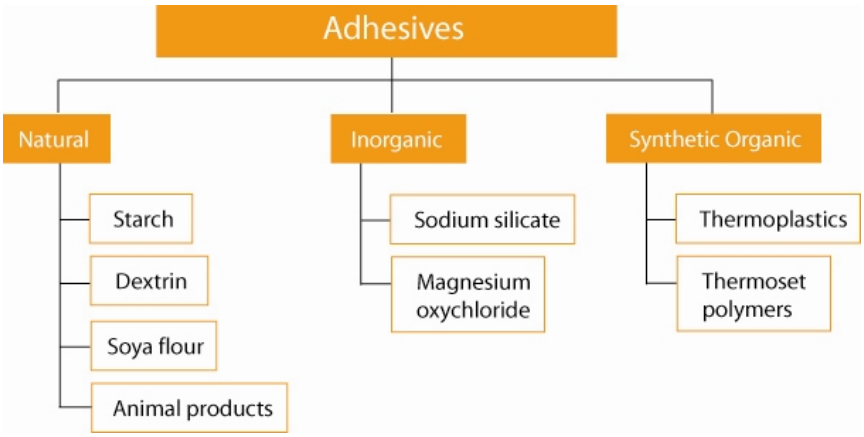


Table 20: Adhesives (Lesko, 1999: 87)

Mechanical fasteners are used when the product is being assembled and can impact the cost of the production process. It is prudent for a designer to design in a way to minimize the need of mechanical fasteners (Lesko, 1999: 89). About fifty percent of total production time is spent on mechanical –fastening in the assembly process thereby giving standardization importance to lower assembly costs (Lesko, 1999: 89).

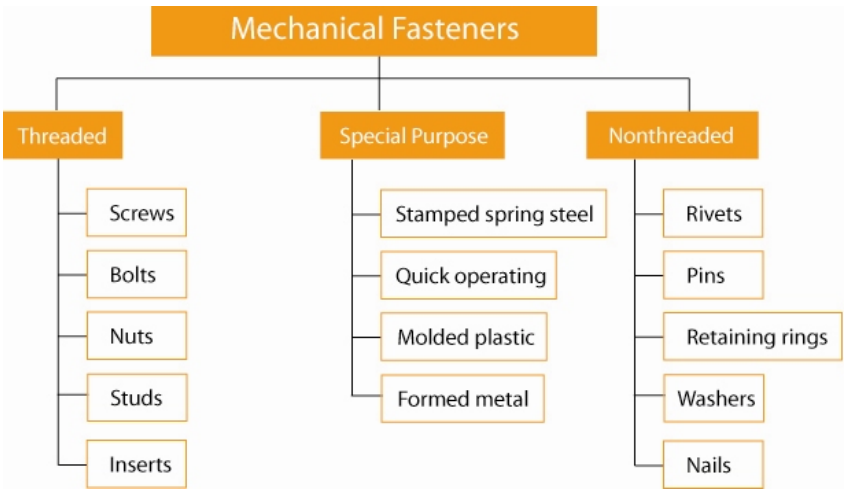


Table 21: Mechanical Fasteners (Lesko, 1999: 89)

- Thermoset and Thermoplastic forming:

The liquid-state forming for plastics is very similar to the liquid-state forming for metals. Heated resins become liquids upon entering molds or they are mixed inside the mold (Lesko, 1999: 143). In some cases the resin never appears to be a fluid. Thermosets are often dough-like mixtures that are placed by hand in the mold (Lesko, 1999: 143).

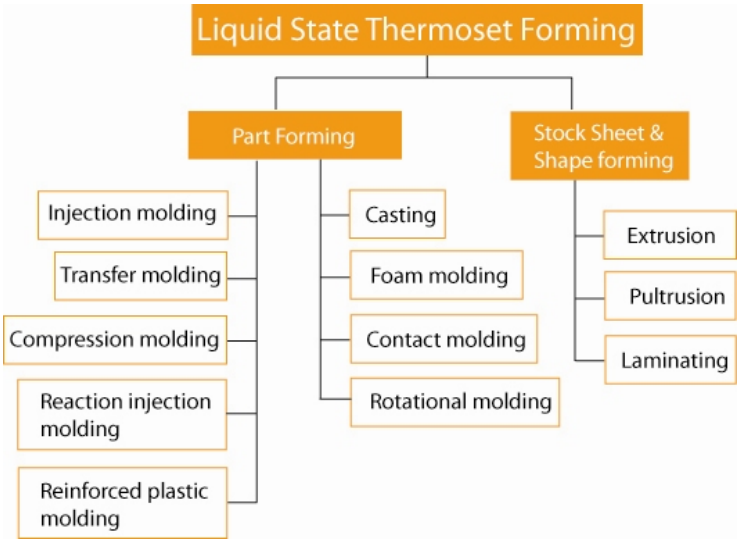


Table 22: Liquid-State Thermoset Forming (Lesko, 1999: 143)

Thermoplastics do not become liquid, instead they become viscous as honey when heated (Lesko, 1999: 143). This type of plastic is forced by high pressures during many processes which cause them to act as liquids as they fill their molds thereby allowing thermoplastics to also have the ability to be injection molded just as thermoset resins (Lesko, 1999: 143).

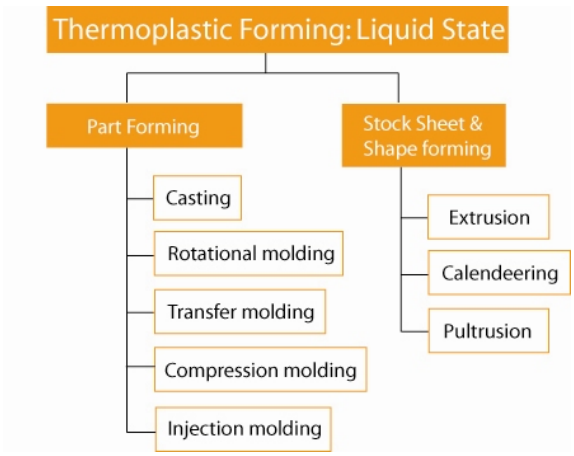


Table 23: Liquid-State Thermoplastic Forming (Lesko, 1999: 143)

Cold forming and solid-phase forming processes use special equipment that is actually designed to form metals (Lesko, 1999: 167). Most plastics are sufficiently ductile at room temperature allowing form manipulation by means of rolling, extrusion, deep drawing, closed-die forging and coining processes (Lesko, 1999: 167). The advantages that cold forming provide over other methods of shaping plastic are: strength, toughness, forming speeds and low forming forces (Lesko, 1999: 167).

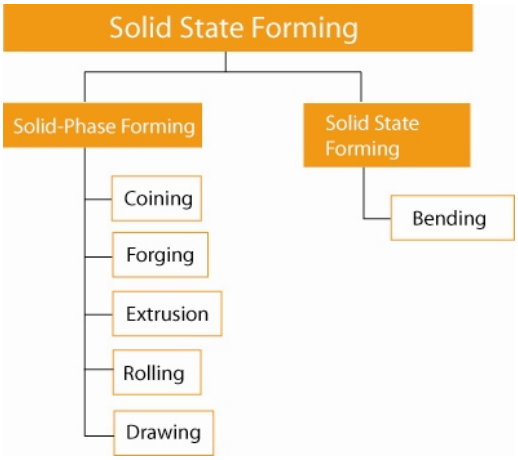


Table 24: Solid-State Forming (Lesko, 1999: 167)

- Machining and joining plastic parts:

Machining is the best process when forming resin parts because it is so economical when the quantity of parts is so low that molding tooling would be too expensive (Lesko, 1999: 168). Parts may also require slight variations and molding would not be efficient wihle some resins are difficult to form by standard manufacturing processes. New computer controlled equipment allows machining to compete with other standard forming processes, making it a viable forming option (Lesko, 1999: 169).

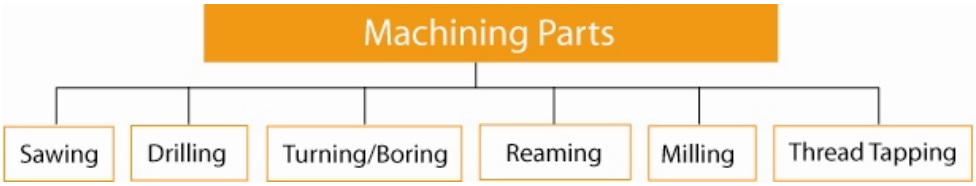


Table 25: Machining Parts (Lesko, 1999: 168)

Plastic parts may be joined to each other as well as to other materials using many different adhesive methods, solvent bonding procedures and with the use of mechanical fasteners (Lesko, 1999: 170). Due to the fact that adhesive bonding involves the application of a chemical substance between two parts, the importance of adhesive selection is critical (Lesko, 1999: 170). Solvent bonding, also known as welding involves the dissolving of a chemical agent's outer skin over two resins to allow them to be joined and bonded together (Lesko, 1999: 171).

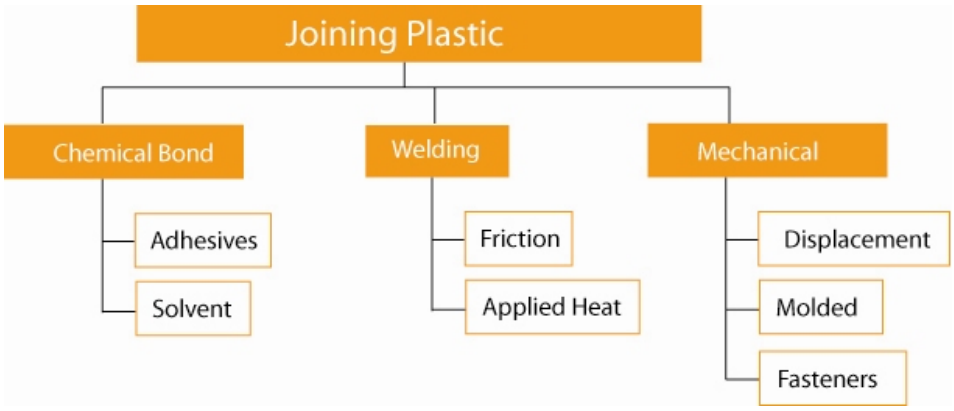


Table 26: Joining Plastic (Lesko, 1999: 170)

CHAPTER 3: THE FORMATION OF THE DESIGN GUIDELINES FOR A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

3.1 AN INTRODUCTION TO THE FORMATION OF THE DESIGN GUIDELINES

These guidelines are to aid any designer who has the desire to alleviate the previously mentioned problems of Mexico City caused by its transportation systems. They are to follow these guidelines as the design methodology process by which they will create an appropriate new type of transportation that will fulfill the needs of this city's residents.

3.1.1 An Introduction to Industrial Design and Industrial Design Methodology

Personal definition of Industrial Design and Industrial Design Methodology:

Industrial Design is the symbolic quality of a solution that represents an improvement of a problematic situation while enhancing the value, function and appearance of products for the benefit of both the manufacturer and user. Industrial Design exists in all possibilities of products which are intended to be mass produced. It may be assumed that Industrial Design lies in business in order to draw profit from consumer benefits. Therefore, the branch of business between these two forces is Industrial Design.

Design Methodology can be defined as examining the use of products. Design Methodology identifies side effects and safety codes in the early stages of product development, thereby keeping track of design solutions. These methods are tools to reveal, analyze and solve problems by designing new tools for design problems.

Why is Industrial Design Methodology important?

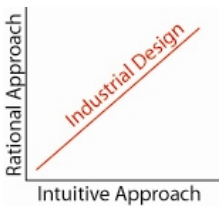
1. Due to the complexity of products, product systems, and product environments.
2. Due to the need of rational solutions.
3. Due to the means of communication of our work to other professions.

What do we use Design Methodology for?

1. To break down problems and view them in different perspectives.
2. To solve problems systematically.
3. To create rational solutions with the ability to evaluate them.

3.1.2 Design Theories and Philosophies on Systematic and Intuitive Problem Solving

There are only two methods by which people solve problems: The Rational Approach, and the Intuitive Approach. The Rational Approach involves solving a prompt by using materials, science and technology. The Intuitive Approach solves a problem using humanities and the fine arts. Industrial designers must apply both of these methods to excel in their profession.



3.1.3 The Function of a Product in Three Dimensions

A product functions in three dimensions: Human Function, Technical Function and the Production Function (Schaer, 1958). The following definitions are taken from a handout given in an Auburn University Industrial Design Course in the year 2002 and written by Walter Schaer in 1958.

The Human Function can be defined as the relationship of the product to the user. This function is divided into human needs, which are: *Social Economic*, dealing with the price quality of the product, *Cultural Aesthetic*, dealing with form quality, and *Practical Physiological* which is based on the functional relationships of the product to the user.

The Technical Function is the relationship of the product to its own parts and other objects in its environment. This function is divided into two sections: *Direct Technical Function*, dealing with the relationship of the product to its own parts and components and *Indirect Technical Function*, dealing with the relationship of the product to other objects.

The Production Function is the relationship of the product to its planning and manufacturing. This function is also divided into two sections: *Planning*, which includes all planning and marketing of the product and *Manufacturing* which is the actual production of the product.

The following is a diagram illustrating a view of the three functions outlined by Schaer:

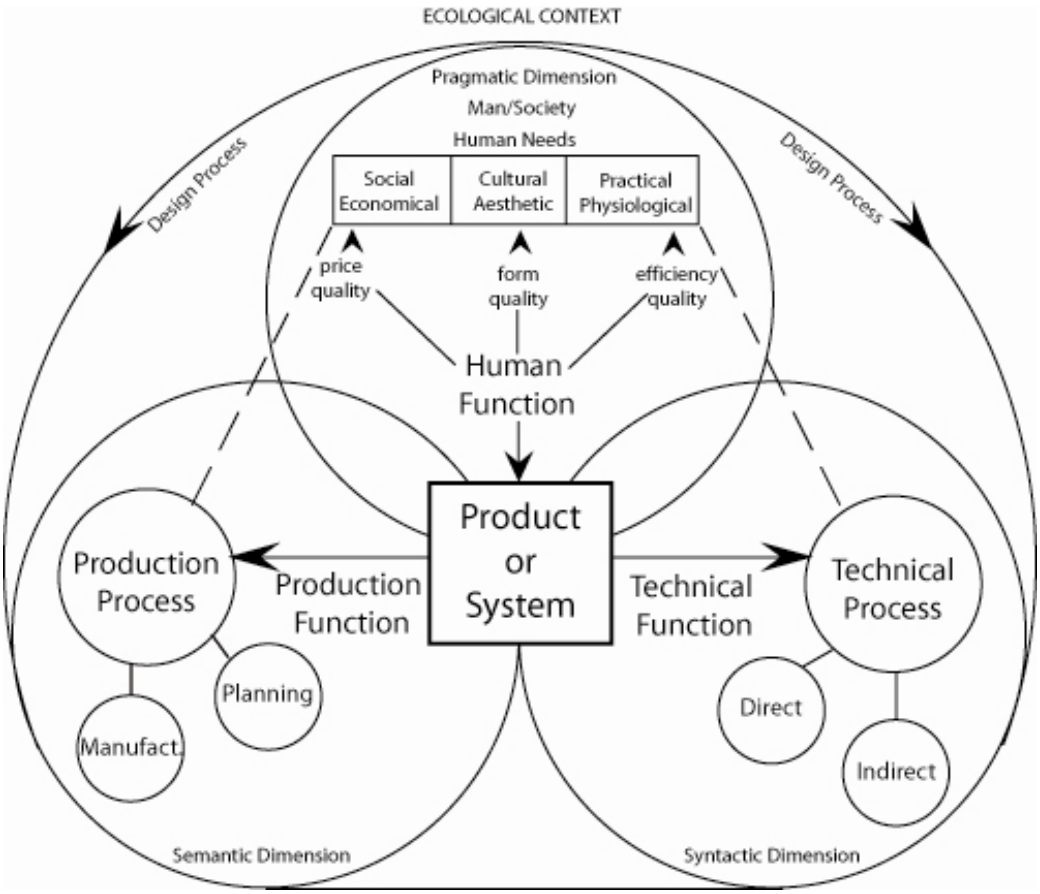


Figure 17: The Three Functions of an Artifact (Schaer, 1958).

3.2 THE DESIGN GUIDELINES FOR A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

3.2.1 Defining the Structure of the Guidelines

Phase One: The Problem

1.1 *Preliminary Analysis*

1.11 Brief (letter from client presenting problem to the designer)

1.12 Contract (agreement between client and designer)

1.2 *Time Scheduling*

1.21 Develop a Gantt Chart

1.3 *Problem History Research - Defining the User of Mexico City.*

1.31 Identify the public life and urban society of the user.

1.32 Identify the user status and their needs.

1.33 Conduct a user transportation questionnaire.

1.4 *Problem History Research - Defining the Transportation of Mexico City.*

1.41 Identify the current transportation systems of Mexico City.

1.42 Identify the problems with the current transportation of Mexico City.

1.43 Identify Hybrid Electric Vehicle benefits for the transportation problems of Mexico City.

1.5 *Problem History Research - Defining Hybrid Electric Vehicles.*

1.51 Define Hybrid Electric Vehicles.

1.52 Define how Hybrid Electric Vehicles operate.

1.53 Identify current successful vehicles of Mexico City.

1.54 Conduct a Comparative Product Chart comparing Hybrid Electric Vehicles and the successful vehicles of Mexico City.

1.6 *Problem History Research – Defining Safety Criteria.*

1.61 Formulate a safety requirement list for automobiles.

Phase Two: Design Development

2.1 *Human Function*

2.11 Analyze anthropometrics (related to the problem/product)

2.12 Develop an Interaction Matrix (human and environmental)

2.13 Develop a Performance Criteria (human, technical and production).

3.1 *Production Function*

3.11 Identify existing applicable and sustainable materials.

3.12 Identify existing applicable production methods.

4.1 *Conceptualization Process*

4.11 Brainstorm (form and color study)

4.12 Conceptualize 2D Sketches (refinement of three best solutions).

4.13 Evaluate three solutions with a Design Evaluation Checklist.

5.1 *Best Possible Solution*

5.11 Identify best possible solution to prototype.

6.1 *Building the Prototype*

6.11 Develop construction drawings for Prototype (orthographic views).

6.12 Document the photographic building sequence.

Phase Three: Design Communication

7.1 *Further Items to help communicate the finalized design to the client.*

7.12 Create an interior rendering and a full scale exterior rendering.

7.13 Create photographs of the prototype with marketing ads.

7.14 Create scaled views with anthropometric documentation.

7.14 Create a finalized presentation with all documentation.

7.15 Create recommendations for further design studies.

3.3 THE GUIDELINES DEFINED

3.3.1 Phase One: The Problem – *Preliminary Analysis*

- Brief (letter from client presenting problem to the designer)
- Contract (agreement between client and designer)

If the design of this new vehicle is not a personal and private project conducted by designers themselves, there are usually two preliminary activities that other designers who work for clients must complete before the design process of the guidelines can begin. First, the designer receives a brief from the client. This brief is a description of the problem or product to be developed and describes the problem not the solution. The next preliminary step is the proposal or contract between the designer and the client. This document is prepared by the designer and describes the work to be done by the designer, the duration of the project and the manpower and money that will be involved.

After the contract has been reviewed by the client, and the appropriate changes have been made, the contract is signed by both the client and the designer and the design process begins.

3.3.2 Phase One: The Problem – *Time Scheduling*

- Gantt Chart

A Gantt chart is a horizontal bar chart developed as a production control tool in 1917 by Henry L. Gantt, an American engineer and social scientist. Frequently used in project management, a Gantt chart provides a graphical illustration of a schedule that

helps to plan, coordinate, and track specific tasks in a project. Gantt charts may be simple versions created on graph paper or more complex automated versions created using project management applications such as Microsoft Project or Excel.

A Gantt chart is constructed with a horizontal axis representing the total time span of the project broken down into increments (for example, days, weeks or months) and a vertical axis representing the tasks that make up the project. Horizontal bars of varying lengths represent the sequences, timing and time span for each task. Automated Gantt charts store more information about tasks, such as the individuals assigned to specific tasks and notes about the procedures. These helpful charts offer the benefit of being easy to change and give the designer a clear illustration of a project's status.

3.3.3 Phase One: The Problem – *Problem History Research - Defining the User of Mexico City.*

Refer to Chapter Two, Sections 2.2 - 2.2.1

3.3.4 Phase One: The Problem – *Problem History Research - Defining the Transportation of Mexico City.*

Refer to Chapter Two, Sections 2.3 - 2.3.1

3.3.5 Phase One: The Problem – *Problem History Research - Defining Hybrid Electric Vehicles.*

Refer to Chapter Two, Sections 2.4 – 2.4.1

3.3.6 Phase One: The Problem – *Problem History Research – Defining Safety Criteria.*

Refer to Chapter Two, Sections 2.5 – 2.5.1

3.3.7 Phase Two: Design Development – *Human Function*

- Anthropometrics (related to the problem/product)

Anthropometry is the branch of the human sciences that deals with body measurements including the measurements of body size, shape, strength and working capacity (Pheasant, 1998: 6). Anthropometrics is a very important part of ergonomics in that it deals directly with environmental ergonomics thereby matching physical forms and dimensions of a product or workspace to those of its user (Pheasant, 1998:6).

- Interaction Matrix (human and environmental)

An Interaction Matrix is a chart that is developed to aid and guide designers showing which parts of a particular product interact with human and environmental elements. The parts of the product being examined are to be listed vertically down the side of the table and the related human and environmental elements are to be listed horizontally. Follow the vertical listing of the part across until it is below the horizontal listing of the human and environmental elements to chart interactions. Numbers are used to denote the level of interaction between parts and the human and environmental elements. The number two is usually used to show heavy interaction, meaning that those parts and elements are frequently interacting with one another. One is a light interaction, meaning that those parts rarely interact. Zero is where there is no interaction between

parts and elements. Once all the interactions are charted the numbers for each row are totaled and listed in the last column. The higher the number, the closer the parts and elements are in proximity to each other.

- Performance Criteria (human, technical and production)

A Performance Criteria can be defined as a qualitative and quantitative standard by which alterative and or final solutions will later be evaluated. These standards are expressed in terms of satisfying a human objective and not a technical objective. Performance Criteria evaluations do not state how the problem physically will be solved but rather, what the solution should do and the characteristics that need to be addressed for the solution. This method provides the designer with a list of specific goals to keep in mind while designing a product.

3.3.8 Phase Two: Design Development – *Production Function*

Materials and manufacturing are considered a necessary part of the learning process for design students. Designers sometimes seem to sense that they will not have the prime responsibility in selecting materials or in specifying the manufacturing process in the design of products, but the truth of the matter is that they need to be knowledgeable on the subject since materials and manufacturing methods will be a determinant factor in a design.

3.3.9 Phase Two: Design Development – *Conceptualization Process*

- Brainstorming

Brainstorming is a process for developing creative solutions to problems. It works by focusing on a problem, and then deliberately coming up with as many solutions as possible and by pushing the ideas as far as possible. One of the reasons it is so effective is that designers produce large quantities of ideas and develop and refine these ideas into concepts.

- Conceptualization

After the brainstorming process a designer can create concepts based on their ideas from brainstorming sessions. These concepts are usually drawn out as quick sketches emphasizing the function of the product as well as how it relates to the user. These concepts can be evaluated to further enhance the more realistic concepts into further development.

- Design Evaluation Checklist

A Design Evaluation Checklist allows designers to review key factors which are required to be met by the product's design. The length of the list may vary depending on the amount of requirements the design needed to follow. The checklist usually encloses a title column directed towards each task, a description, a mark and comment area. The chart is designed to analyze and rank the concepts designers have designed.

3.3.10 Phase Two: Design Development – *Best Possible Solution*

A designer's views to solve problems are broadened with the Design Evaluation

checklist. The designer may now focus on the best possible solution according to the results of the checklist and build a scale prototype of the chosen concept.

3.3.11 Phase Two: Design Development – *Building the Prototype*

- Construction Drawings

Construction drawings are a set of technical drawings that a designer must create before building a prototype of the finalized product solution. These drawings provide the designer with critical information such as dimensions, scale and form in order to construct a prototype. Construction drawings may be created by hand drafting or in a computer program.

3.3.12 Phase Three: Design Communication – *Further Items to help communicate the finalized design to the client.*

After finishing a design project, a designer must present his or her ideas to a client either to fulfill an obligation or to sell a product to any potential candidate. In order to communicate a finalized product to an audience of non-designers, a designer must create a visual presentation that is easy to understand and that sells the product to its full potential. The designer is free to have extra visuals apart from the main presentation if he or she feels it will aid the client to fully understand what the product does, how it is used and its scale to the user. The following are additional materials that may enhance a presentation:

- A final interior rendering and a full scale exterior rendering.

- A part placement analysis.

- Extra professional photos of the prototype.

- Views of the product with anthropometric documentation.

- Any documentation of recommendations for further design studies.

CHAPTER FOUR: THE APPLICATION OF THE DESIGN GUIDELINES FOR A NEW TYPE OF TRANSPORTATION FOR MEXICO CITY

4.1 Phase One: The Problem - *Preliminary Analysis*

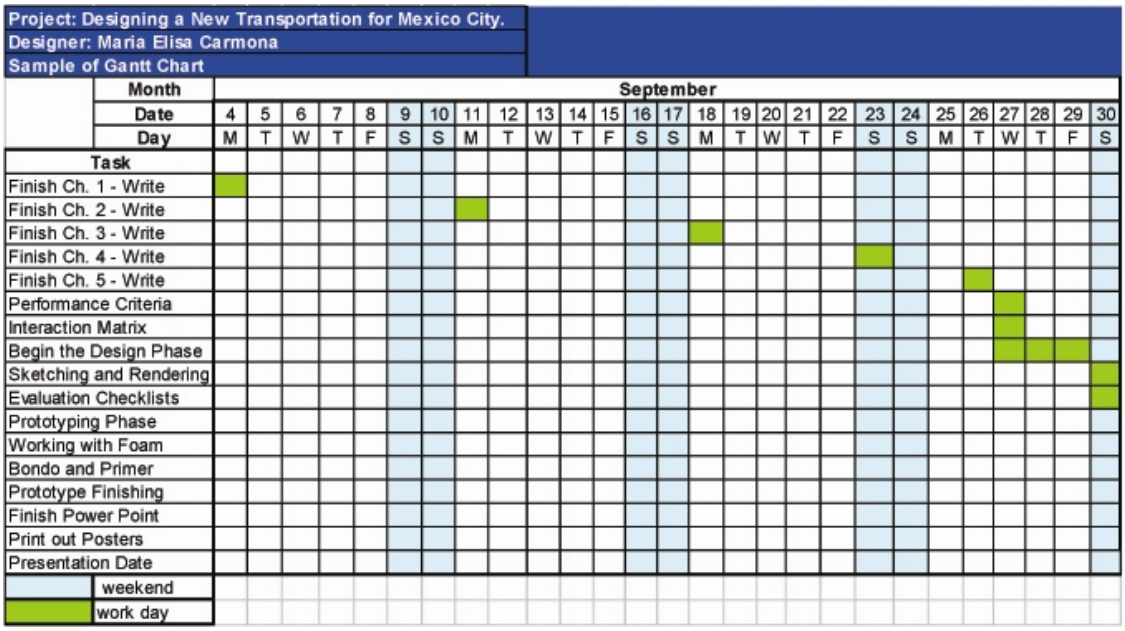
-Brief: not applicable

-Contract: not applicable

4.2 Phase One: The Problem - *Time Scheduling*

-Develop a Gantt chart:

Gantt chart Part One:



Gantt chart Part Two:

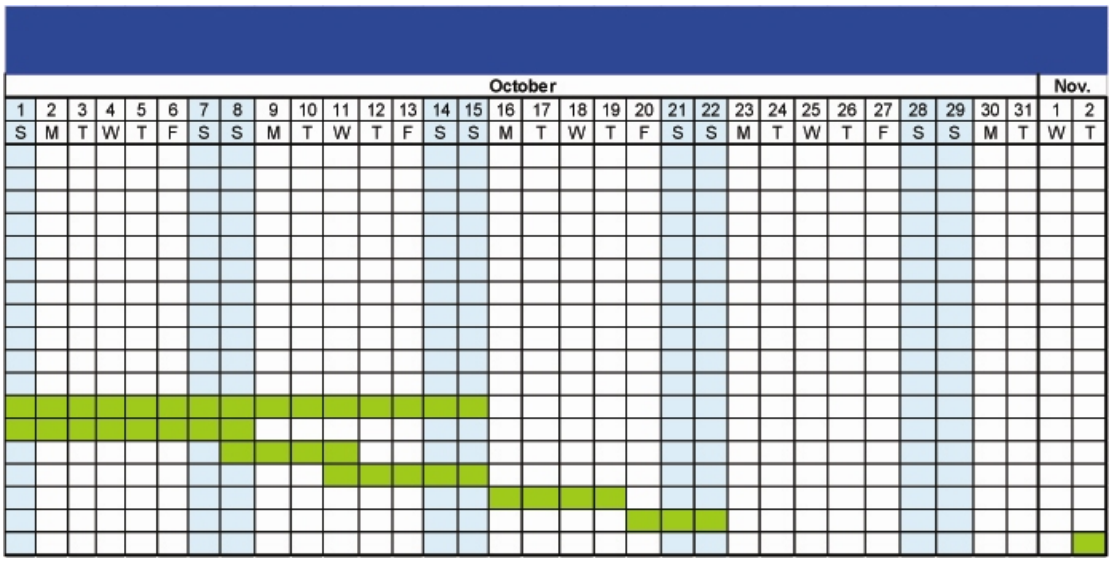


Table 27: Sample Gantt Chart (Carmona, 2006).

4.3 Phase One: The Problem- ***Problem History Research - Defining the User of Mexico City.***

Refer to Chapter Two, Sections 2.2.2 – 2.2.5

-Identify the public life and urban society of the user

-Identify the user status and their needs.

-Conduct a user transportation questionnaire.

4.4 Phase One: The Problem- ***Problem History Research - Defining the Transportation of Mexico City.***

Refer to Chapter Two, Sections 2.3.2 – 2.3.4

-Identify the current transportation systems of Mexico City.

-Identify the problems with the current transportation of Mexico City.

-Identify Hybrid Electric Vehicle benefits for the transportation problems of Mexico City.

4.5 Phase One: The Problem: *Problem History Research - Defining Hybrid Electric Vehicles.*

Refer to Chapter Two, Sections 2.4 – 2.4.3

-Define Hybrid Electric Vehicles.

-Define how Hybrid Electric Vehicles operate.

-Identify current successful vehicles of Mexico City.

-Conduct a Comparative Product Chart comparing Hybrid Electric Vehicles and the successful vehicles of Mexico City.

4.6 Phase One: The Problem: *Problem History Research – Defining Safety Criteria.*

Refer to Chapter Two, Section 2.5.2

-Formulate a safety requirement list for automobiles.

4.7 Phase Two: Design Development – *Human Function*

Refer to Chapter Two, Section 2.2.4

-Analyze anthropometrics (related to the problem/product)

-Develop an Interaction Matrix (human and environmental)

Project: Designing a New Type of Transportation for Mexico City.																			
Designer: Maria Elisa Carmona																			
		Environmental Elements									Human Elements								
	Product Parts	Rain	Sun	Water	Wind	Dust	Temp.	Humidity	Score		Waist	Hands	Eyes	Back	Legs	Rear	Feet	Head	Score
Exterior Parts	Housing/ Body	■	■	■	■	■	■	■	7			■							2
	Windows	■	■	■		■			4			■	■					■	2
	Antenna	■		■	■	■	■		5			■							1
	Side Mirrors	■	■	■		■			4			■	■					■	3
	Tires	■	■	■	■	■	■	■	7			■							1
	Lights	■	■			■			3				■						1
	Wipers	■		■	■	■			4			■	■						2
	Door Handles	■		■		■			3			■							1
	Trunk Handle/ Access	■		■		■	■		4			■		■				■	3
Interior Parts	HEV Parts					■	■		2			■		■				■	3
	Seats		■			■			2		■	■		■	■	■		■	6
	Seat Belts					■			1			■							2
	Steering Wheel		■			■			2			■							1
	Control Panel					■			1			■	■						2
	Pedals					■			1						■		■		2
	Airbags					■			1		■			■	■	■		■	5
	Rear View Mirror		■			■			2			■	■					■	3
	Door Handles					■			1			■							1

Table 28: Interaction Matrix Chart (Carmona, 2006).

-Develop a Performance Criteria (human, technical and production)

Project: Designing a New Transportaion for Mexico City.			
Designer: Maria Elisa Carmona			
		Parameter	Performance Criteria
Human Function	Practical	Production Cost	40 - 50% of cost
		Price	$13,000 or less ($130,000 pesos)
		Size	Height: 5' Width: 6' Length: 9.5'
		Shape	Organic and Natural
		Method of Protection	Seatbelts, Airbags, Bumpers, Body Frame
		Number of Passengers	Maximum of three
		Passenger Seating	Properly designed seats & restraints for all passengers
		Driver Control	Creating the best driving configuration for the driver
		Environmental Control	Adequate heating, cooling, ventilation, etc.
		Ingress & Egress	The ease of getting into and out of the vehicle
		Visibility	Providing the necessary visibility for the driver
		Road Illumination	A proper headlight system for the driver to be aware of the environment
		Identifying Lights	Lights that indicate when the driver is turning and stopping
		Maintenance	Standard Cleaning & Part Maintenance
	Cultural	Color of Housing/Body	White
		Color of Accent	Cultural Colors
		Color of Interior	Matching Accent Color
		All Available Colors	Yellow, Red, Blue, Green, Orange
Technical Function	Direct	Road Terrain	Rough Terrain such as pot holes and cracked roads
		Main Materials for Housing/Body	Metals, Plastics, Natural Engineering Materials
		Main Materials for Interior	Plastics, Natural Materials
		Tire Tread	All Terrain -dirt, water, pot holes, cracked roads
		Tire Placement	2 Front tires - exposed / back tire - twice the width
		Rear and Front bumpers	For protection
		Trunk access	Adequate space for baggage or other items
		Tires	Three or Four
	Indirect	Durability of Housing/Body	Metal Body Frame, Bumpers
		Durability of Interior	Plastics, Airbags, Seatbelts
Production Function	Manufacturin	Production Process for Housing	Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.
		Production Process for Interior	Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.
		Method of Assembly	Factory
		Optimum use of Material	Injection Molding, Casting, Machining, Welding
	Planning	Market Distribution	Mexico City, Mexico
		Packaging Graphics	Technical Manual
		Primary Advertising	Television and Sales Fliers

Table 29: Performance Criteria (Carmona, 2006).

4.8 Phase Two: Design Development – *Production Function*

Refer to Chapter Two, Sections 2.6 – 2.6.2

-Identify existing applicable and sustainable materials.

-Identify existing applicable production methods.

4.9 Phase Two: Design Development – *Conceptualization Process*

-Brainstorm with an image map (form and color study)

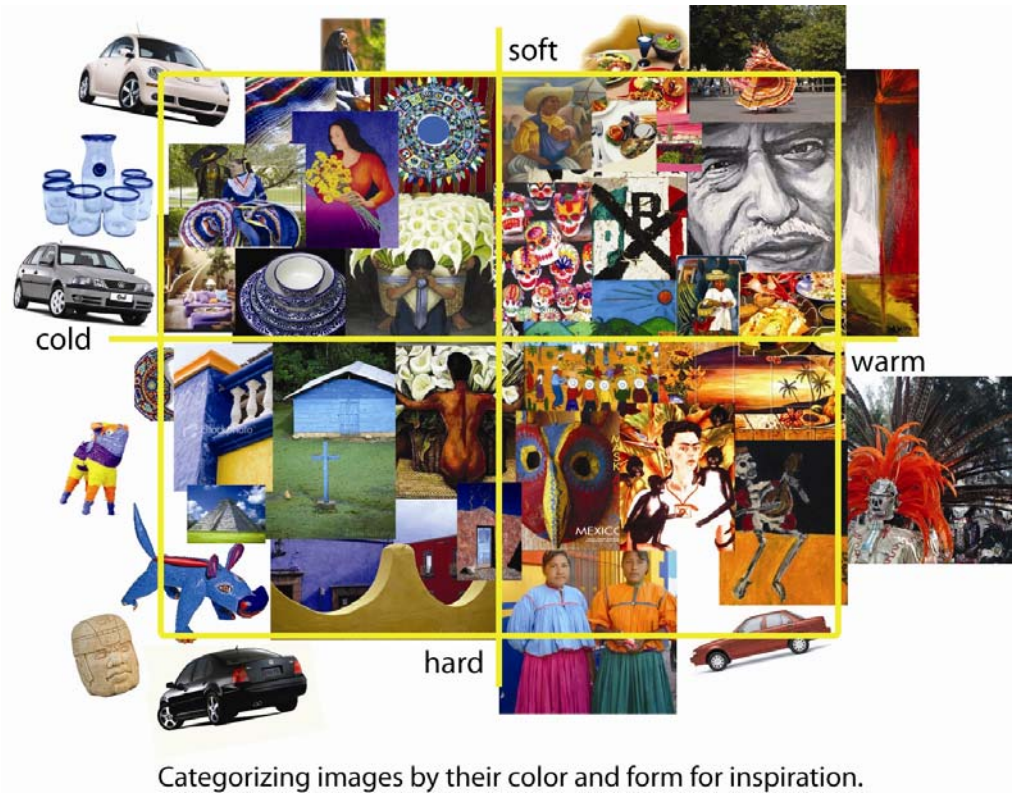


Table 30: Image Map Diagram (Carmona, 2006).

-Conceptualize 2D Sketches (refinement of three best solutions)

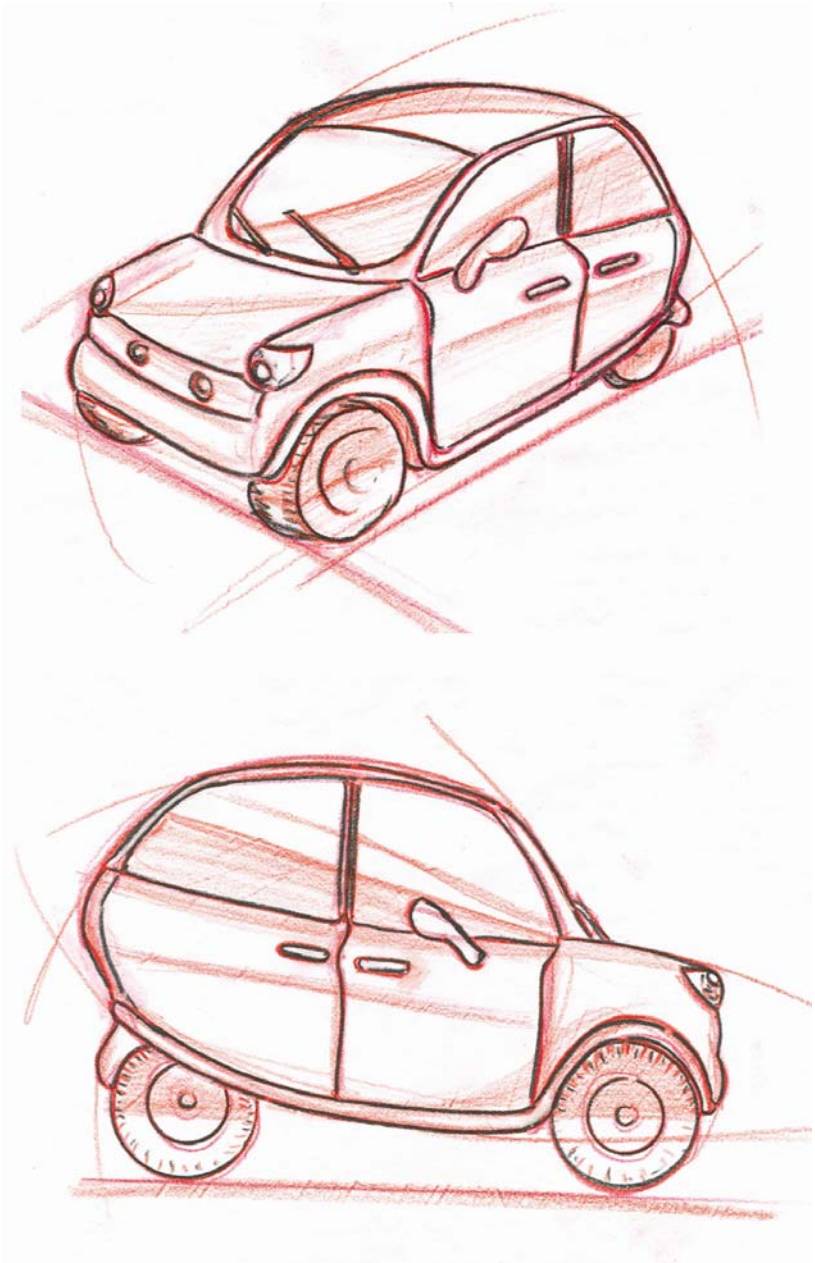


Figure 18: Concept One (Carmona, 2006).

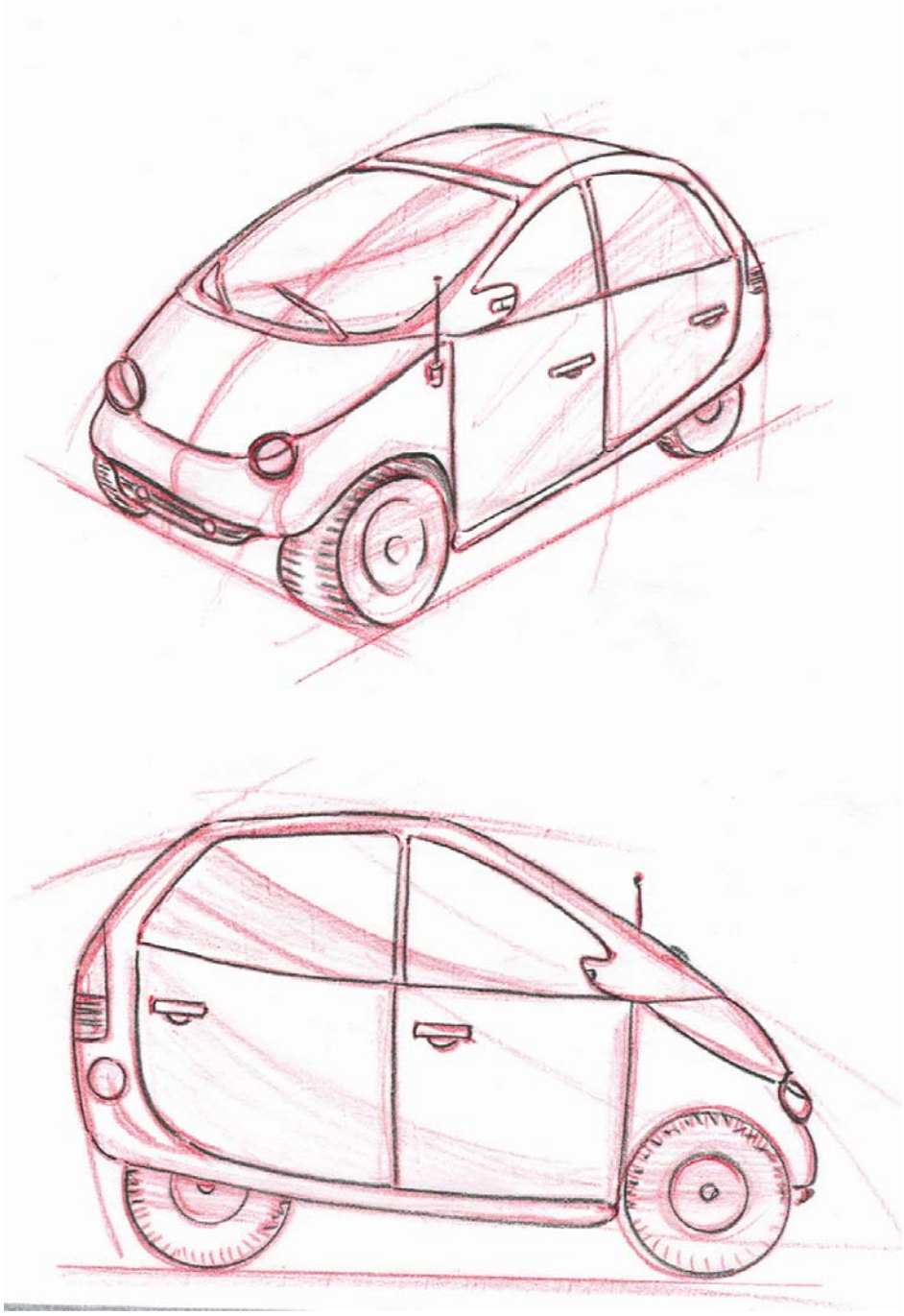


Figure 19: Concept Two (Carmona, 2006).

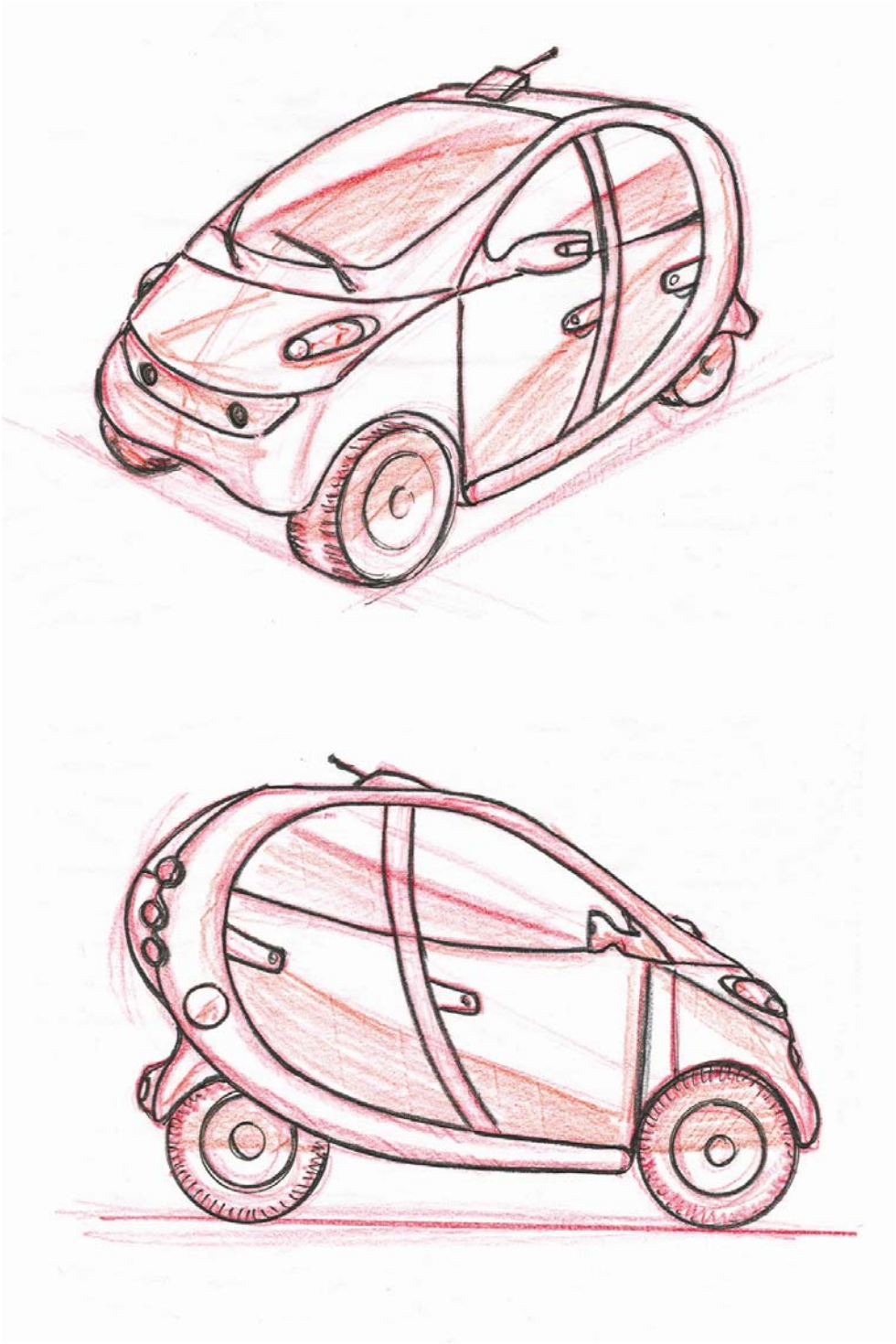


Figure 20: Concept Three (Carmona, 2006).

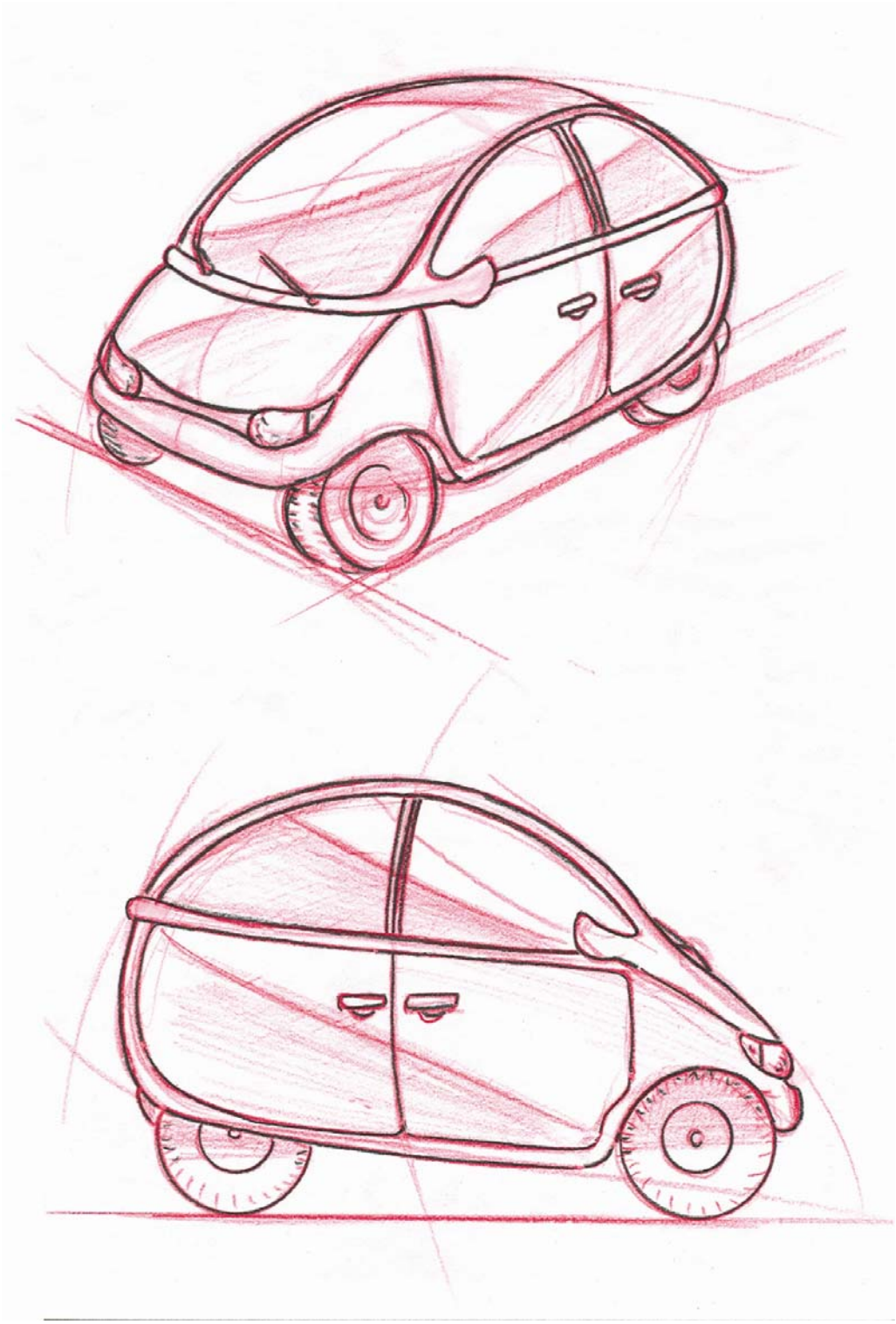


Figure 21: Concept Four (Carmona, 2006).

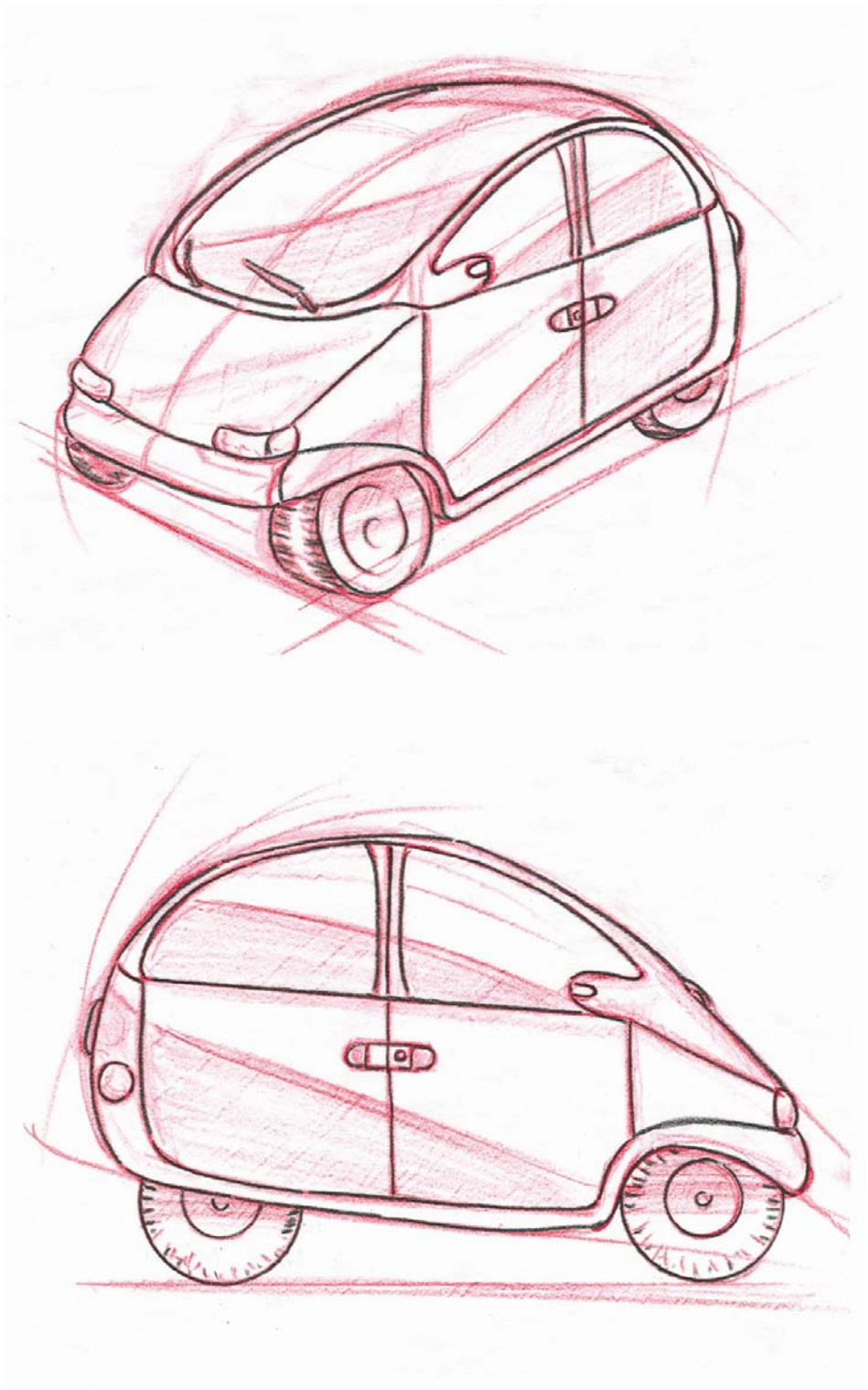


Figure 22: Concept Five (Carmona, 2006).

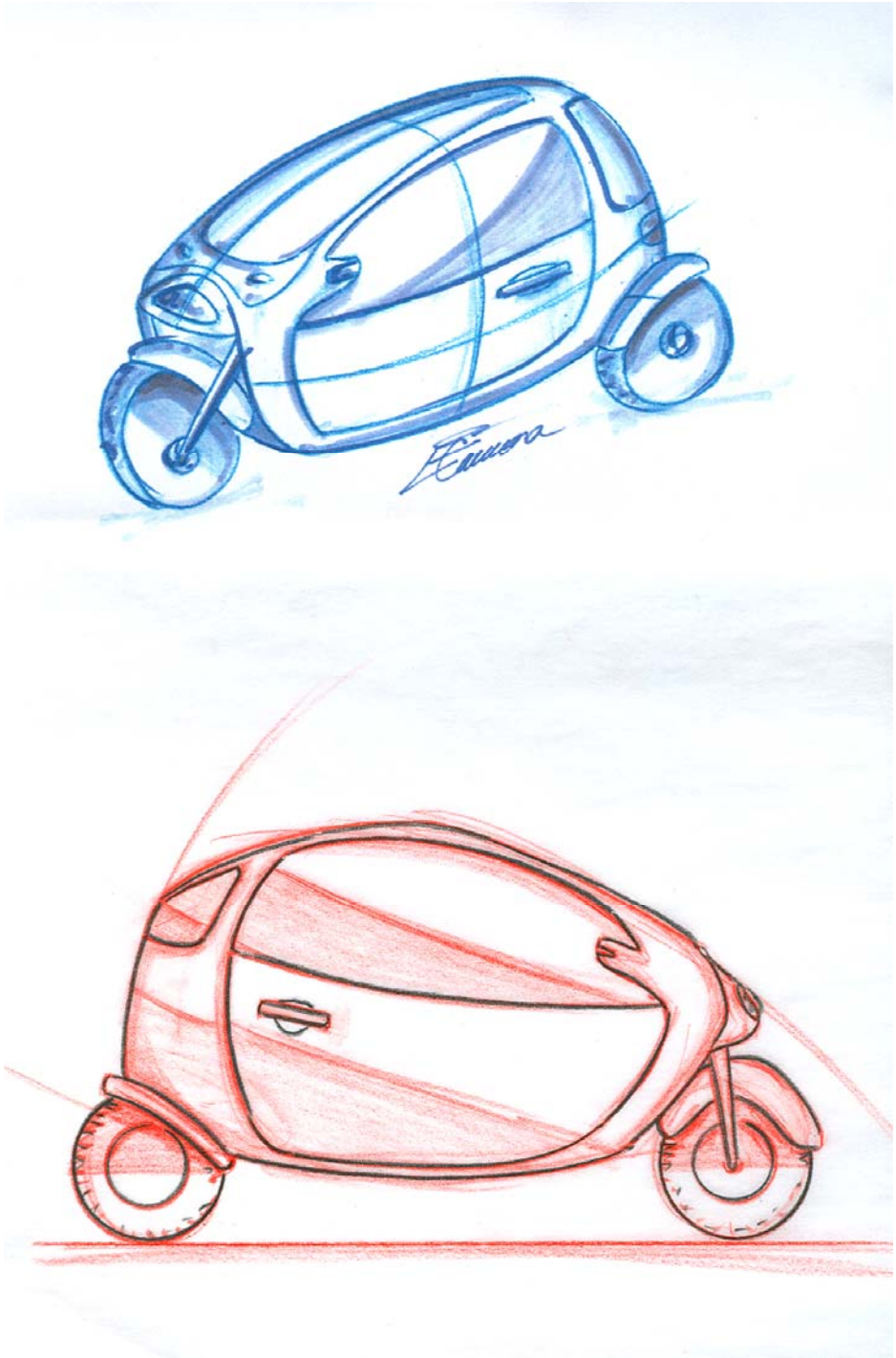


Figure 23: Concept Six (Carmona, 2006).

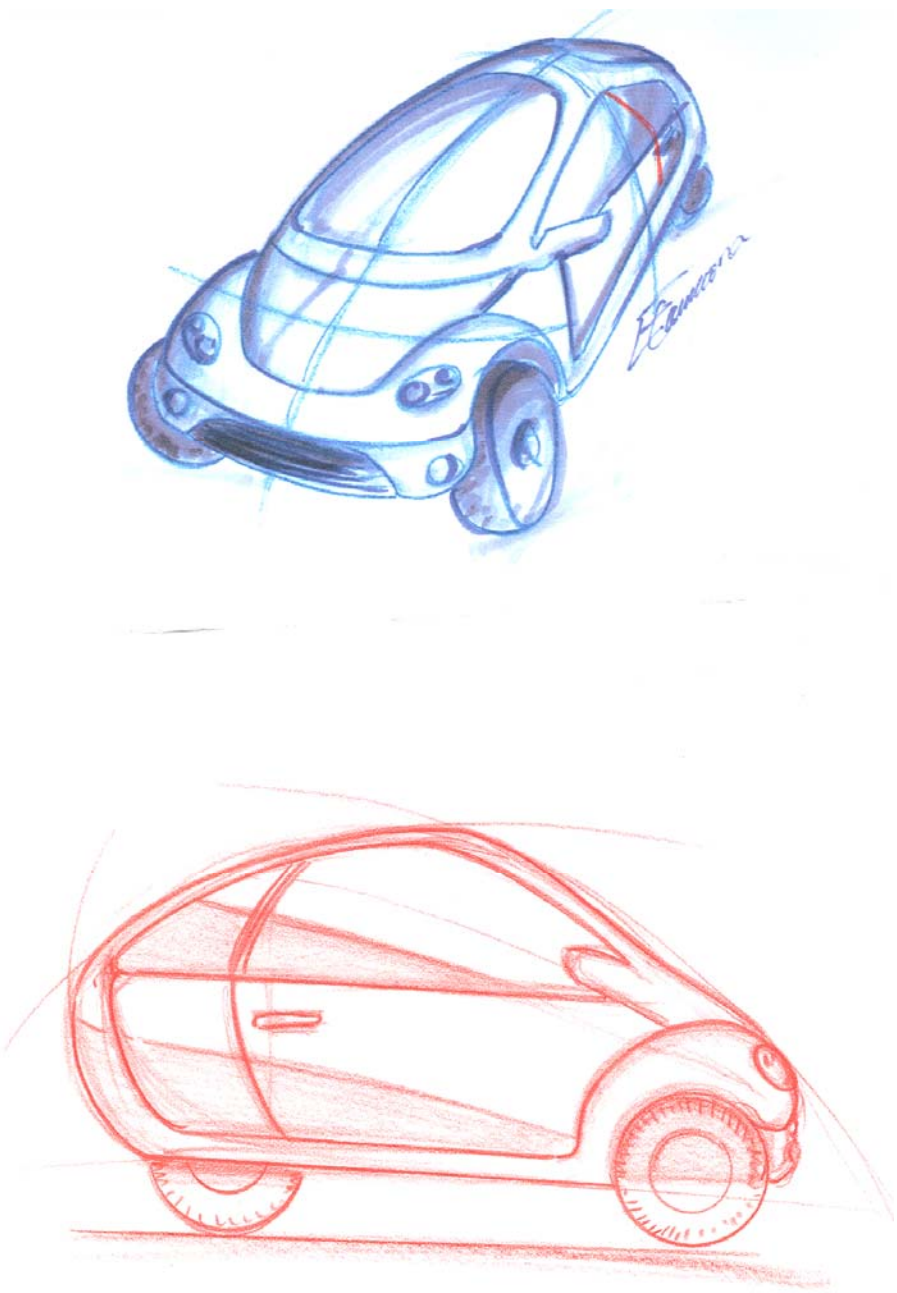


Figure 24: Concept Seven (Carmona, 2006).

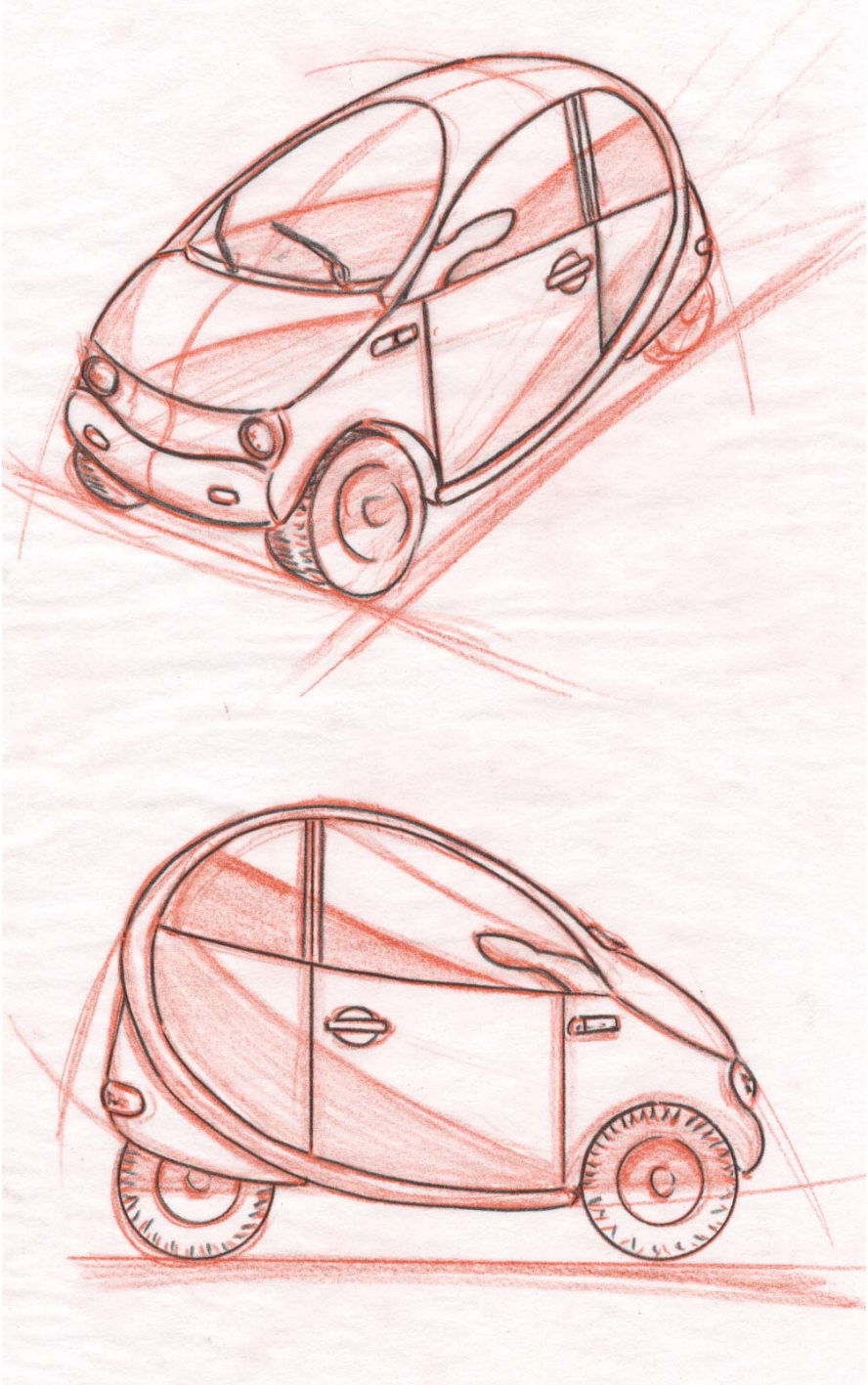


Figure 25: Concept Eight (Carmona, 2006).

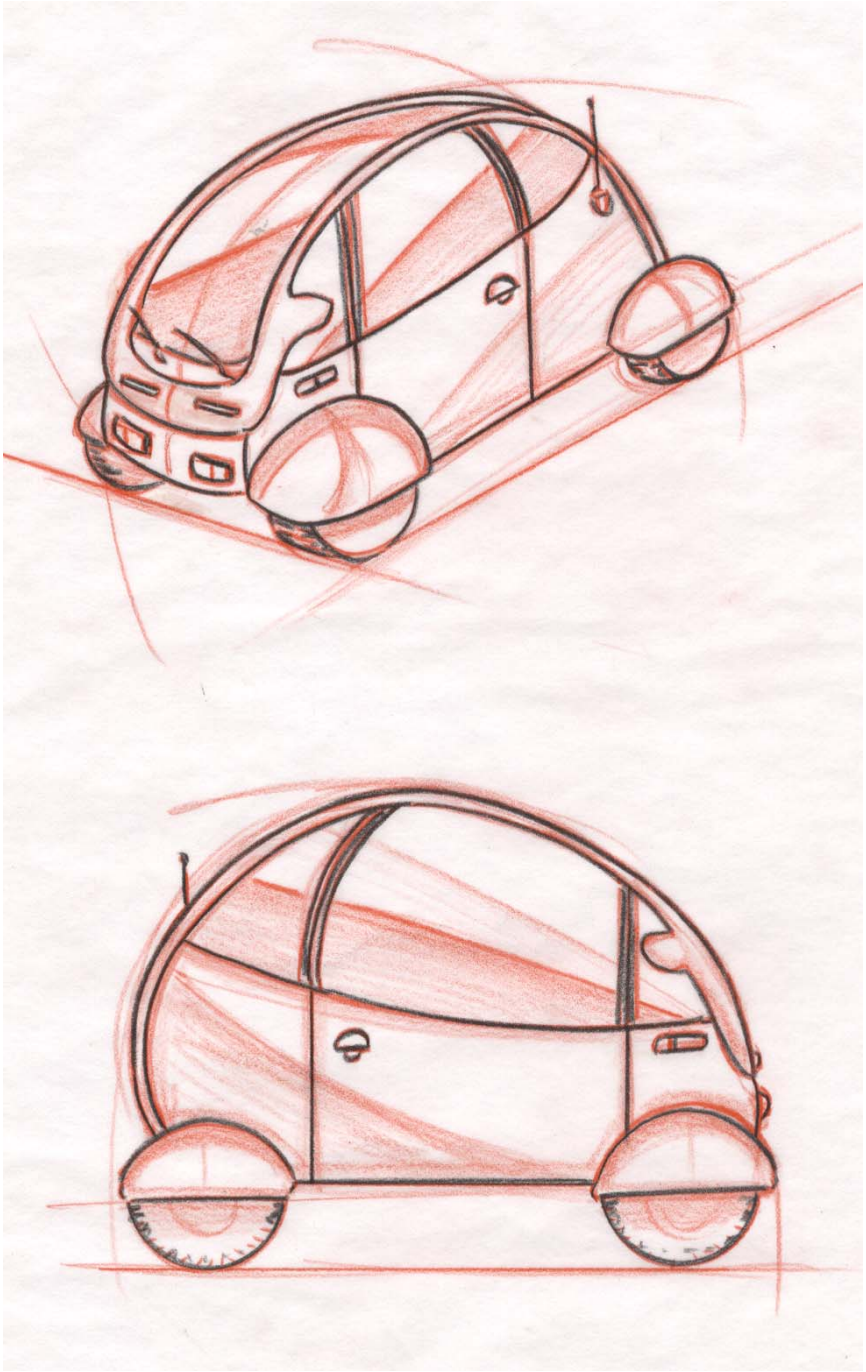


Figure 26: Concept Nine (Carmona, 2006).

Concept Refinements:

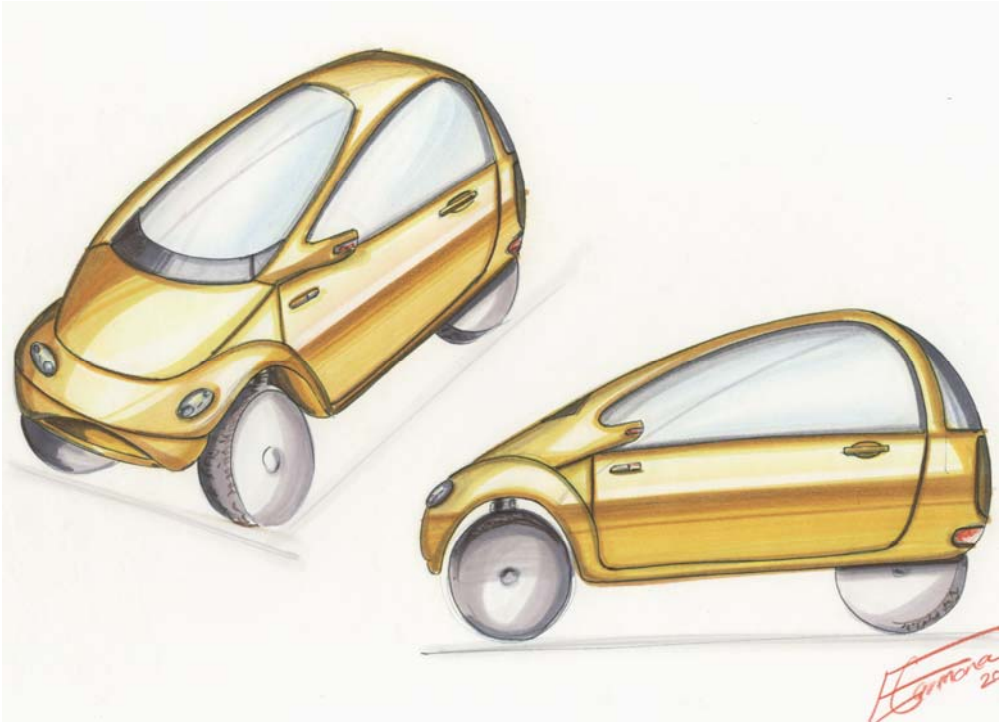


Figure 27: Concept Ten – Refinement Solution One (Carmona, 2006).

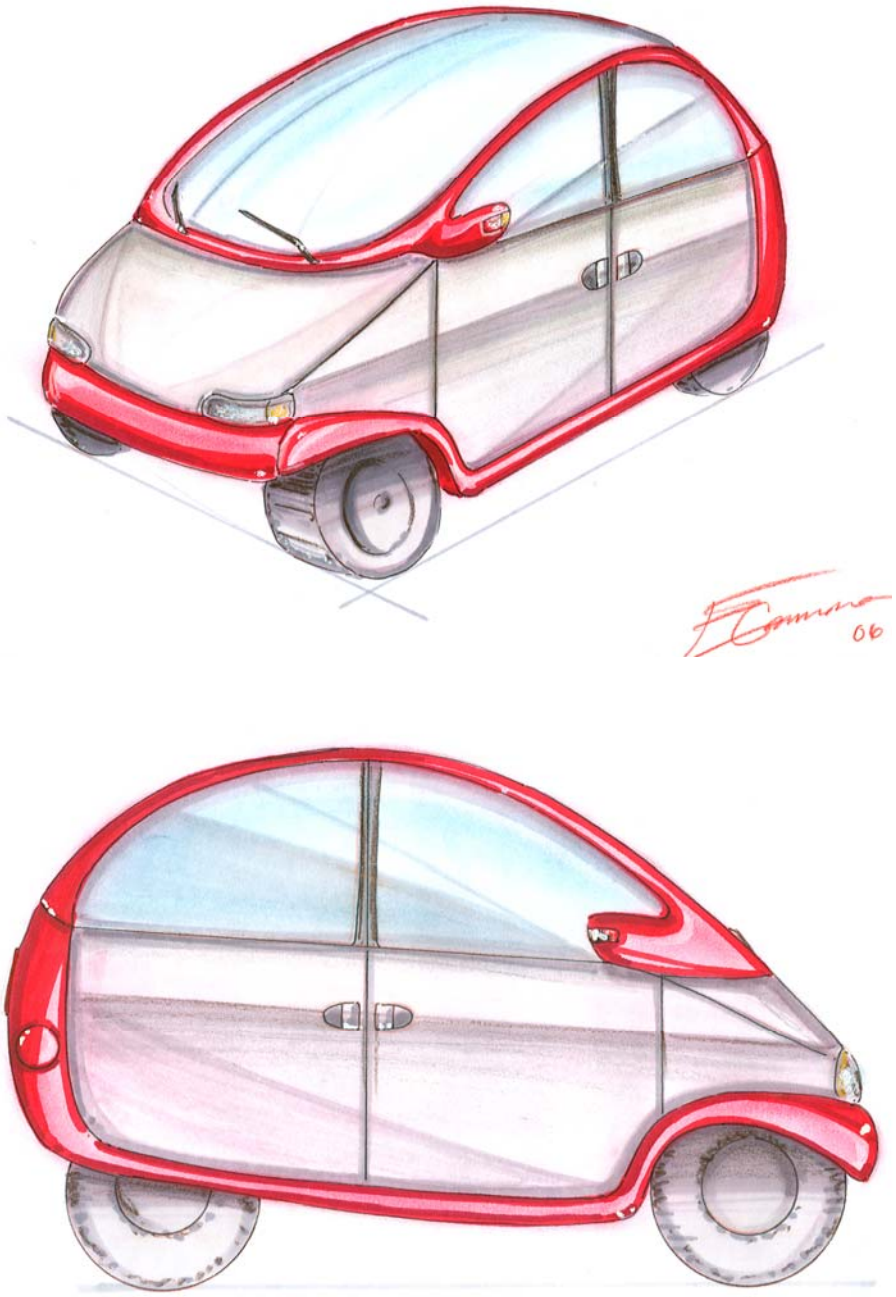


Figure 28: Refinement Solution Two (Carmona, 2006).

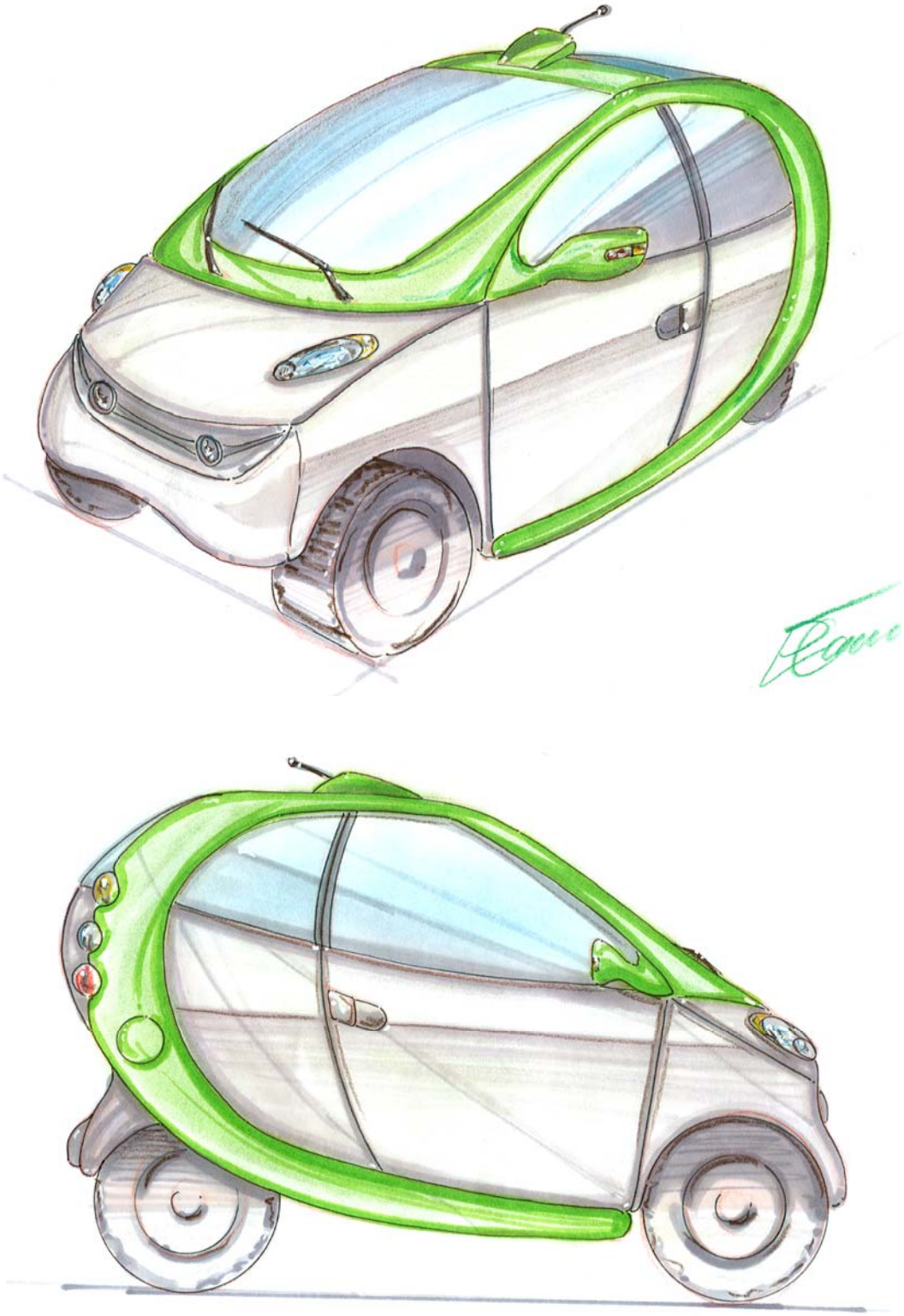


Figure 29: Refinement Solution Three (Carmona, 2006).

-Evaluate three solutions with a Design Evaluation Checklist.

Evaluation Checklist Part One:

Project: Designing a New Transportaion for Mexico City.			
Designer: Maria Elisa Carmona			
Analysis/Evaluation Checklist			
		Parameter	Performance Criteria
Human Function	Practical	Price	$13,000 or less ($130,000 pesos)
		Size	Height: 5' Width: 6' Length: 12.5' (this is the largest necessary)
		Shape	Organic and Natural
		Method of Protection	Seatbelts, Airbags, Bumpers, Body Frame
		Maintenance	Standard Cleaning & Part Maintenance
	Cultural	Color of Housing/Body	White
		Color of Accent	Cultural Colors
		Color of Interior	Matching Accent Color
		All Available Colors	Yellow, Red, Blue, Green, Orange
Technical Function	Direct	Main Materials for Housing/Body	Metals, Plastics, Natural Engineering Materials
		Main Materials for Interior	Metals, Plastics, Natural Engineering Materials
		Tires	Three of Four
	Indirect	Durability of Housing/Body	Metal Body Frame, Bumpers
		Durability of Interior	Plastics, Airbags, Seatbelts
Production Function	Manufacturing	Production Process for Housing	Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.
		Production Process for Interior	Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.
		Method of Assembly	Factory
		Optimum use of Material	Injection Molding, Casting, Machining, Welding
	Planning	Market Distribution	Mexico City, Mexico
		Packaging Graphics	Technical Manual
		Primary Advertising	Television and Sales Fliers

Evaluation Checklist Part Two:

	Refined Concept One	
Performance Criteria	Specifications	Check
$13,000 or less ($130,000 pesos)	$13,000 ($130,000 pesos)	
Height: 5' Width: 6' Length: 12.5' (this is the largest necessary)	H: 4.7' W: 5' L: 11.5'	
Organic and Natural	Very Rounded Edges	
Seatbelts, Airbags, Bumpers, Body Frame	Seatbelts, Airbags, Bumpers, Body Frame	
Standard Cleaning & Part Maintenance	Standard Cleaning & Part Maintenance	
White	Yellow	
Cultural Colors	None	
Matching Accent Color	Tan	
Yellow, Red, Blue, Green, Orange	Yellow, Red, Blue, Green, Orange	
Metals, Plastics, Natural Engineering Materials	Metals, Plastics, Natural Engineering Materials	
Metals, Plastics, Natural Engineering Materials	Metals, Plastics, Natural Engineering Materials	
Three of Four	Three	
Metal Body Frame, Bumpers	Metal Body Frame, Bumpers	
Plastics, Airbags, Seatbelts	Plastics, Airbags, Seatbelts	
Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.	Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.	
Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.	Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.	
Factory	Factory	
Injection Molding, Casting, Machining, Welding	Injection Molding, Casting, Machining, Welding	
Mexico City, Mexico	Mexico City, Mexico	
Technical Manual	Technical Manual	
Television and Sales Fliers	Television and Sales Fliers	
	Total Score:	17

Evaluation Checklist Part Three:

Refined Concept Two	
Specifications	**Check**
$13,000 ($130,000 pesos)	
H: 5' W: 5' L: 11'	
Very Round Edges	
Seatbelts, Airbags, Bumpers, Body Frame	
Standard Cleaning & Part Maintenance	
White	
Cultural Colors	
Matching Accent Color	
Yellow, Red, Blue, Green, Orange	
Metals, Plastics, Natural Engineering Materials	
Metals, Plastics, Natural Engineering Materials	
Four	
Metal Body Frame, Bumpers	
Plastics, Airbags, Seatbelts	
Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.	
Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.	
Factory	
Injection Molding, Casting, Machining, Welding	
Mexico City, Mexico	
Technical Manual	
Television and Sales Fliers	
Total Score:	**20**

Evaluation Checklist Part Four:

Refined Concept Three	
Specifications	**Check**
$13,000 ($130,000 pesos)	
H: 5' W: 6' L: 12.5'	
Very Round Edges and Sharp Lines	
Seatbelts, Airbags, Bumpers, Body Frame	
Standard Cleaning & Part Maintenance	
White	
Cultural Colors	
Matching Accent Color	
Yellow, Red, Blue, Green, Orange	
Metals, Plastics, Natural Engineering Materials	
Metals, Plastics, Natural Engineering Materials	
Three	
Metal Body Frame, Bumpers	
Plastics, Airbags, Seatbelts	
Casting, Welding, Plastic&Solid State Forming, Cutting/Chip Forming, Thermojoining, etc.	
Liquid&Solid Forming, Thermoplastic Forming, Injection Molding, Machining, etc.	
Factory	
Injection Molding, Casting, Machining, Welding	
Mexico City, Mexico	
Technical Manual	
Television and Sales Fliers	
Total Score:	**21**

Table 31: Evaluation Checklist (Carmona, 2006).

4.10 Phase Two: Design Development – *Best Possible Solution*

-Identify best possible solution to prototype.

Refined Concept Three is the best possible solution with a score of 21.

Figure 30: Best Possible Solution (Carmona, 2006).

4.11 Phase Two: Design Development – *Building the Prototype*

-Develop construction drawings for Prototype (orthographic views).

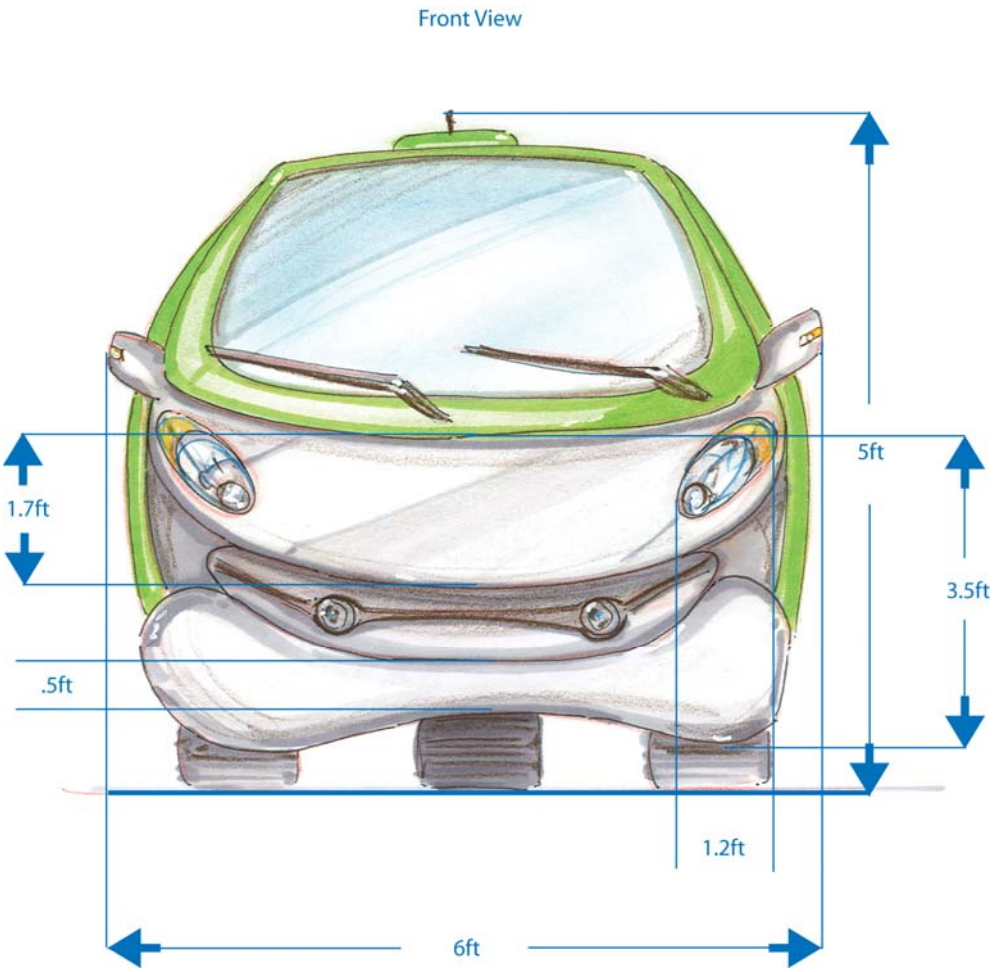


Figure 31: Front View Construction Drawing (Carmona, 2006).

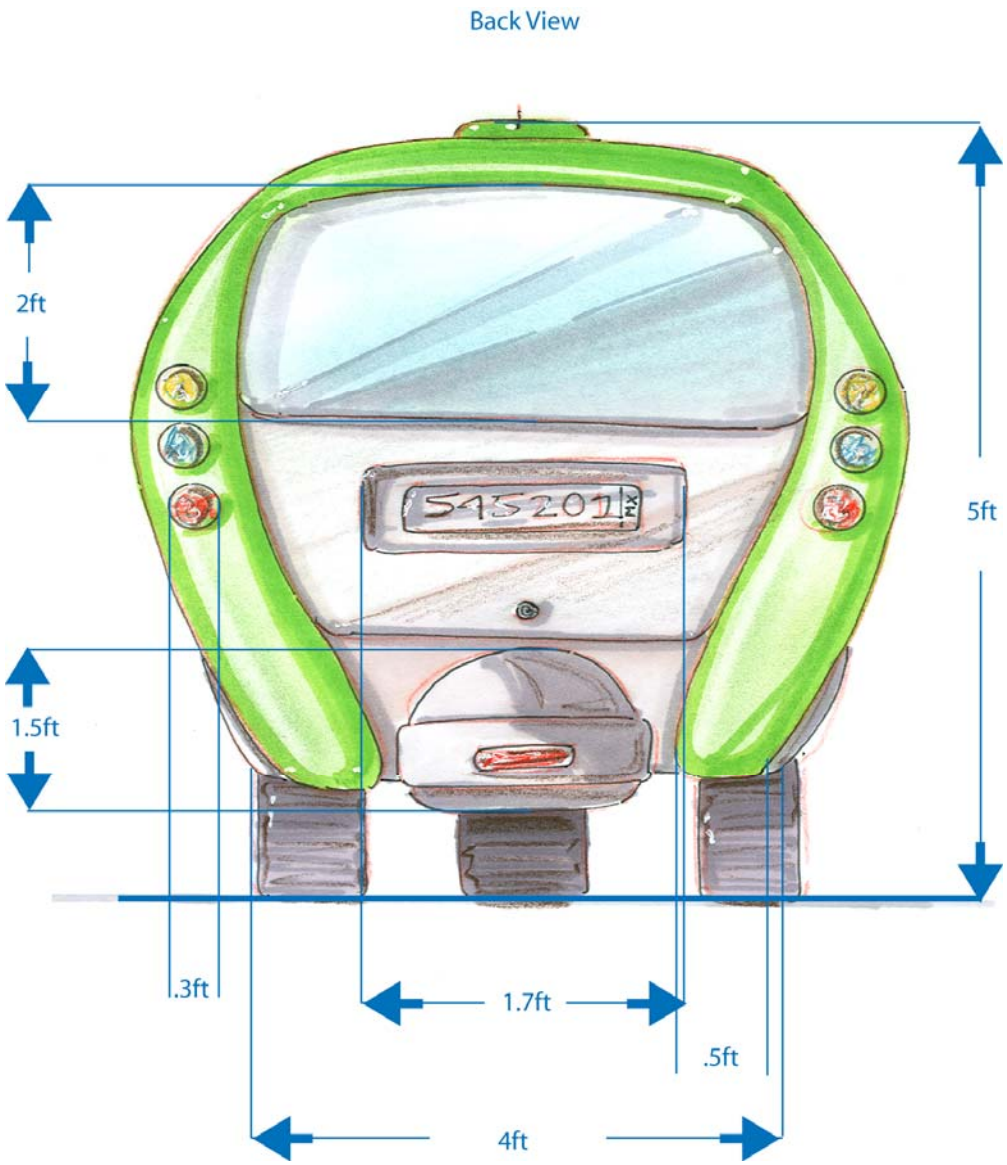


Figure 32: Back View Construction Drawing (Carmona, 2006).

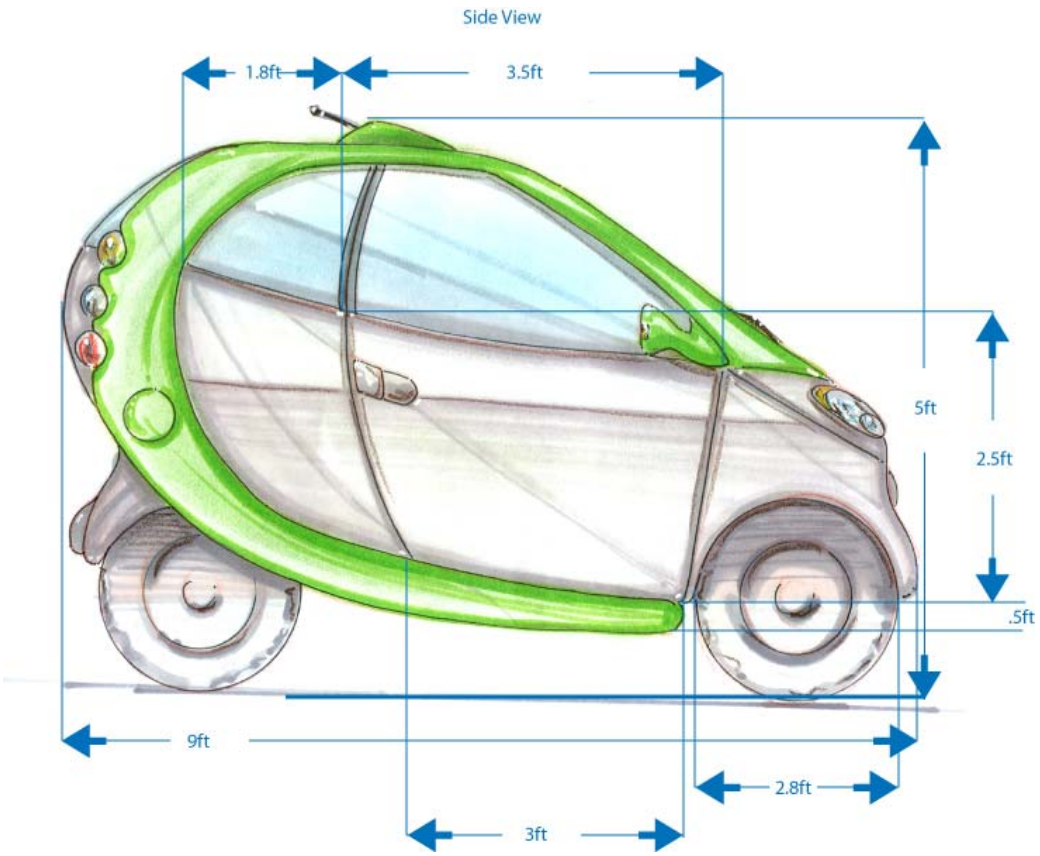


Figure 33: Side View Construction Drawing (Carmona, 2006).

-Document the photographic building sequence.

Figure 34: Building Sequence (Carmona, 2006).

Figure 35: Building Sequence (Carmona, 2006).

Figure 36: Building Sequence (Carmona, 2006).

Figure 37: Building Sequence (Carmona, 2006).

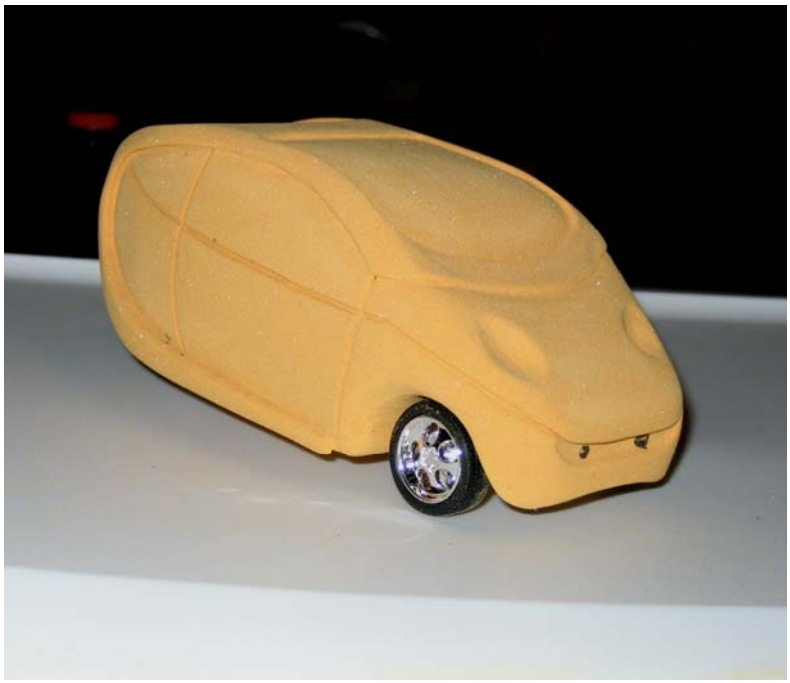


Figure 38: Building Sequence (Carmona, 2006).

Figure 39: Building Sequence (Carmona, 2006).

Figure 40: Building Sequence (Carmona, 2006).

Figure 41: Building Sequence (Carmona, 2006).

Figure 42: Building Sequence (Carmona, 2006).

4.12 Phase Three: Design Communication – ***Further Items to help communicate the finalized design to the client.***

-Create an interior rendering.

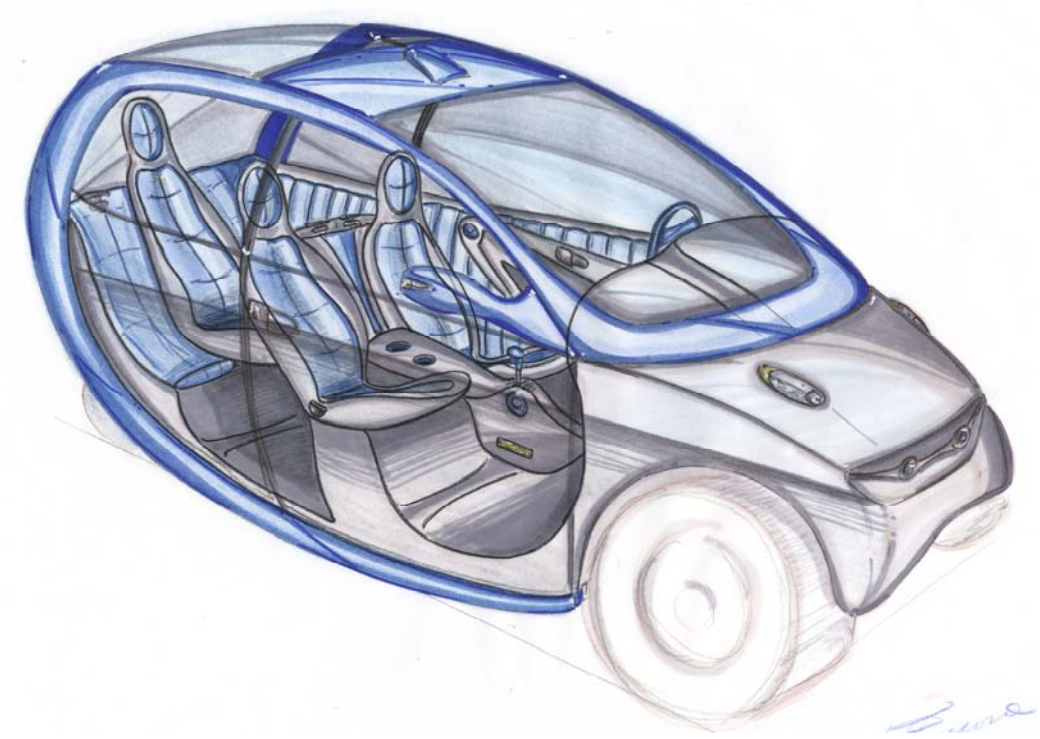


Figure 43: Interior View (Carmona, 2006).

-Create a full scale exterior rendering.

Figure 44: Full Scale Exterior Rendering (Carmona, 2006).

Figure 45: Full Scale Exterior Rendering (Carmona, 2006).

Figure 46: Full Scale Exterior Rendering (Carmona, 2006).

Figure 47: Full Scale Exterior Rendering (Carmona, 2006).

-Create a part placement.

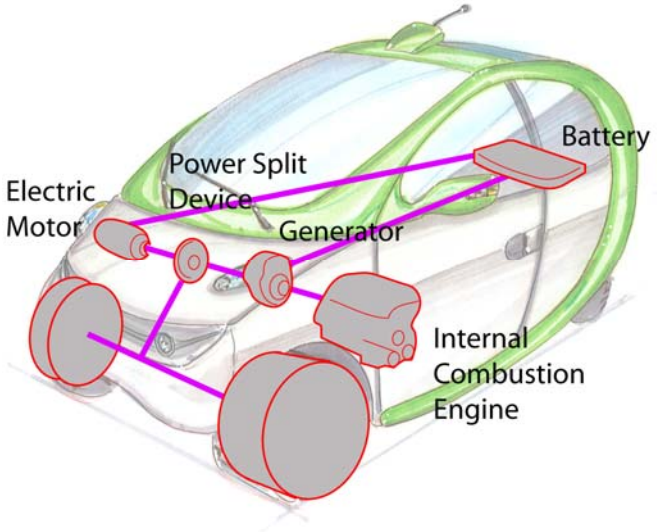


Figure 48: Hybrid Electric Vehicle Part Placement (Carmona, 2006).

-Create scaled view with anthropometric documentation.

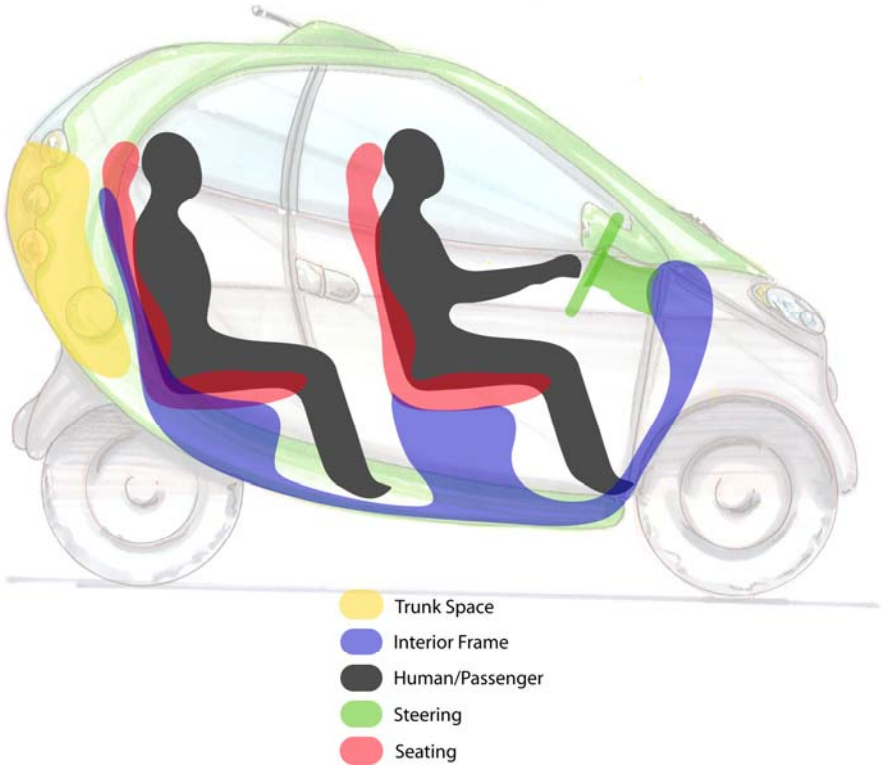


Figure 49: Anthropometric View (Carmona, 2006).

-Photographs of the Prototype with marketing ads.

Figure 50: Final Prototype Model (Carmona, 2006)

Figure 51: Final Prototype Model (Carmona, 2006)

Figure 52: Final Prototype Model (Carmona, 2006)

Figure 53: Final Prototype Model (Carmona, 2006)

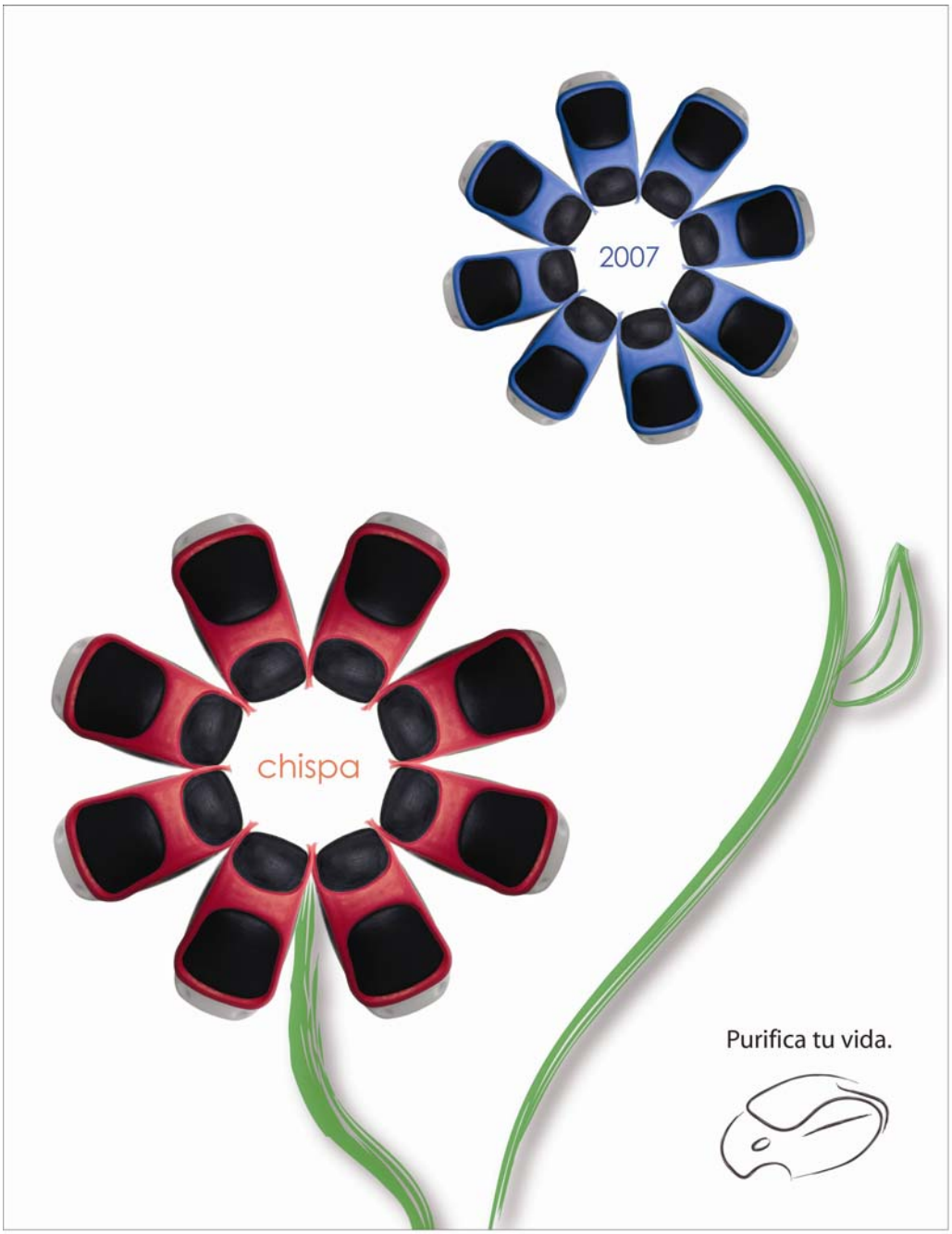


Figure 54: Marketing Ad One (Carmona, 2006).

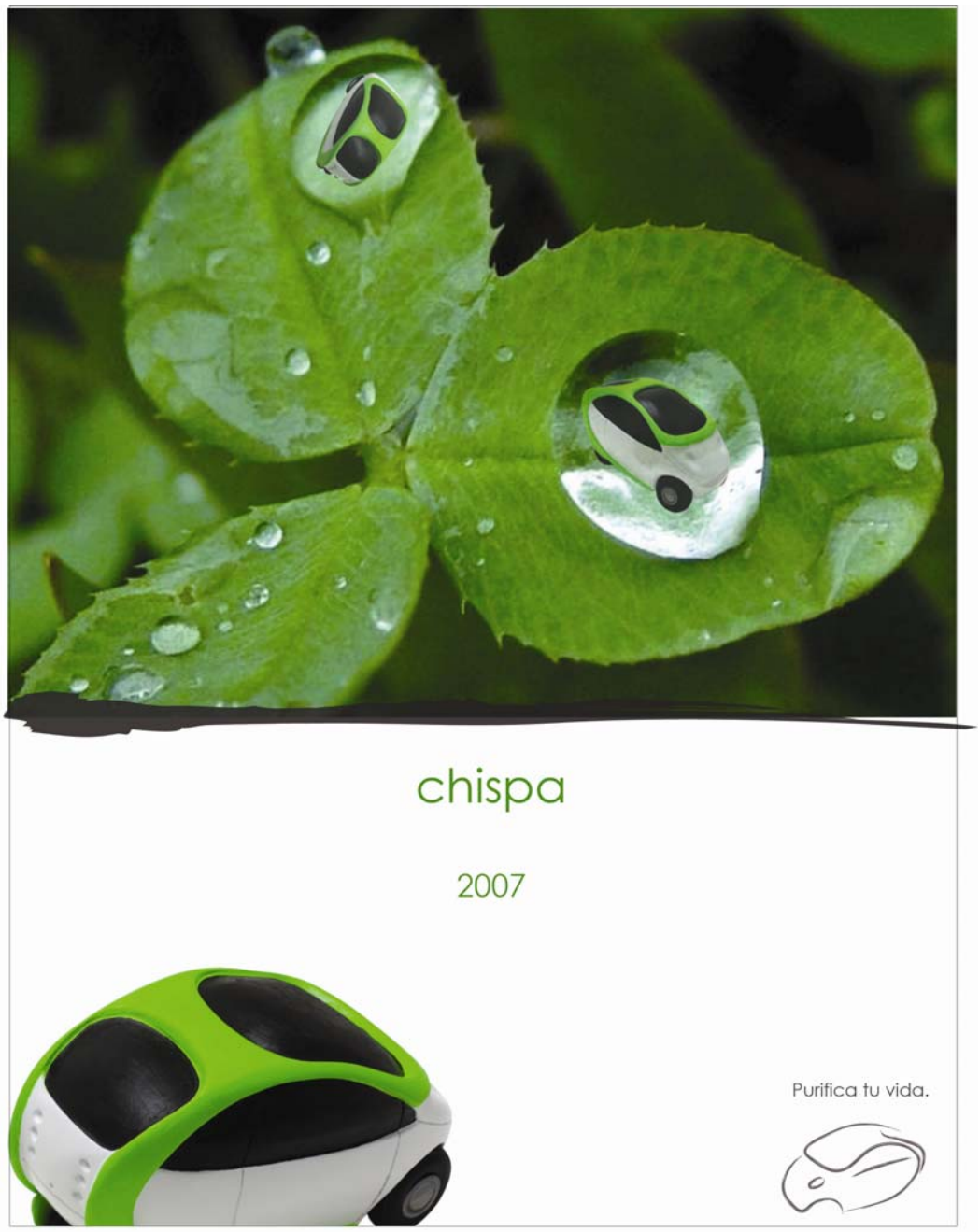


Figure 55: Marketing Ad Two (Carmona, 2006).

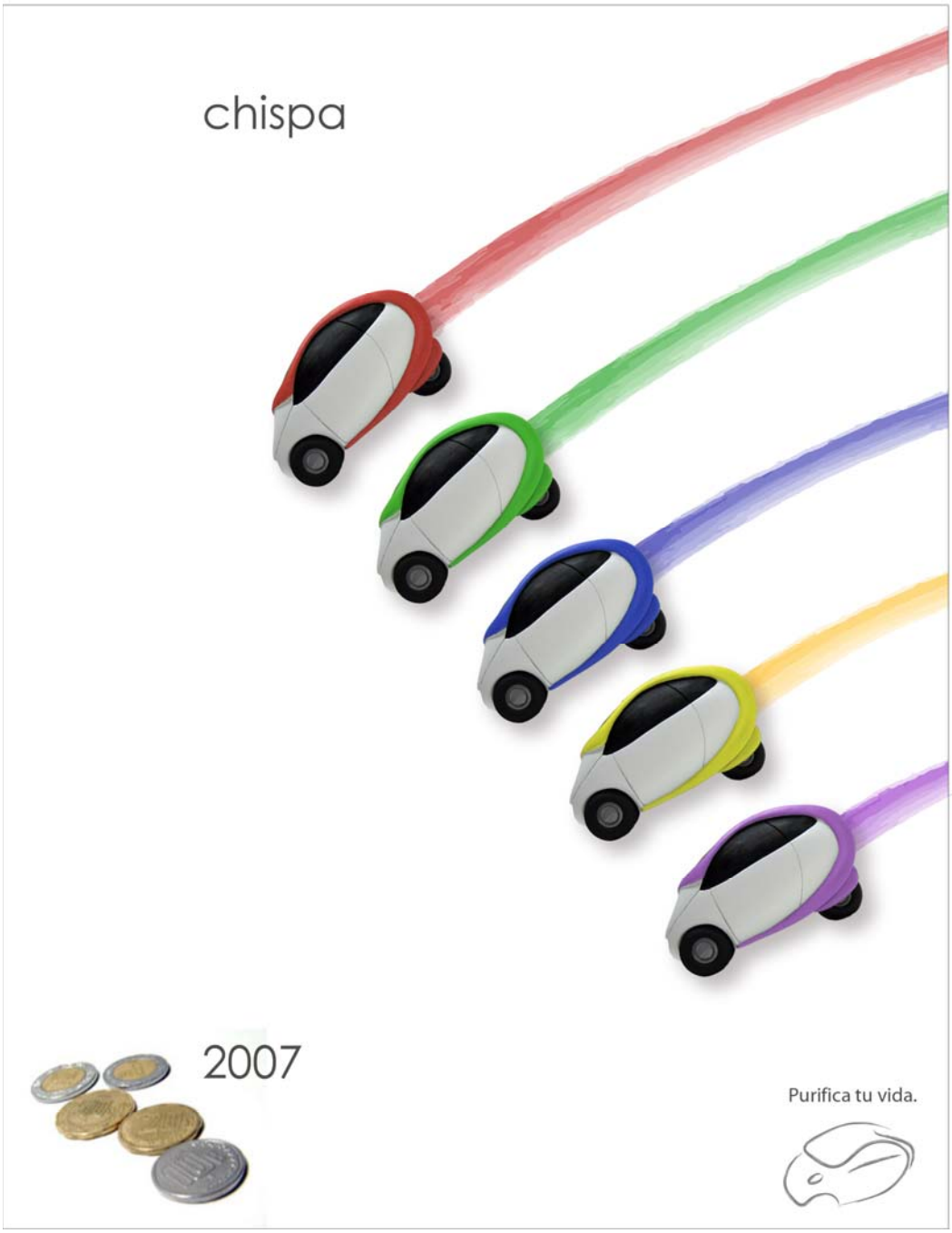


Figure 56: Marketing Ad Three (Carmona, 2006).

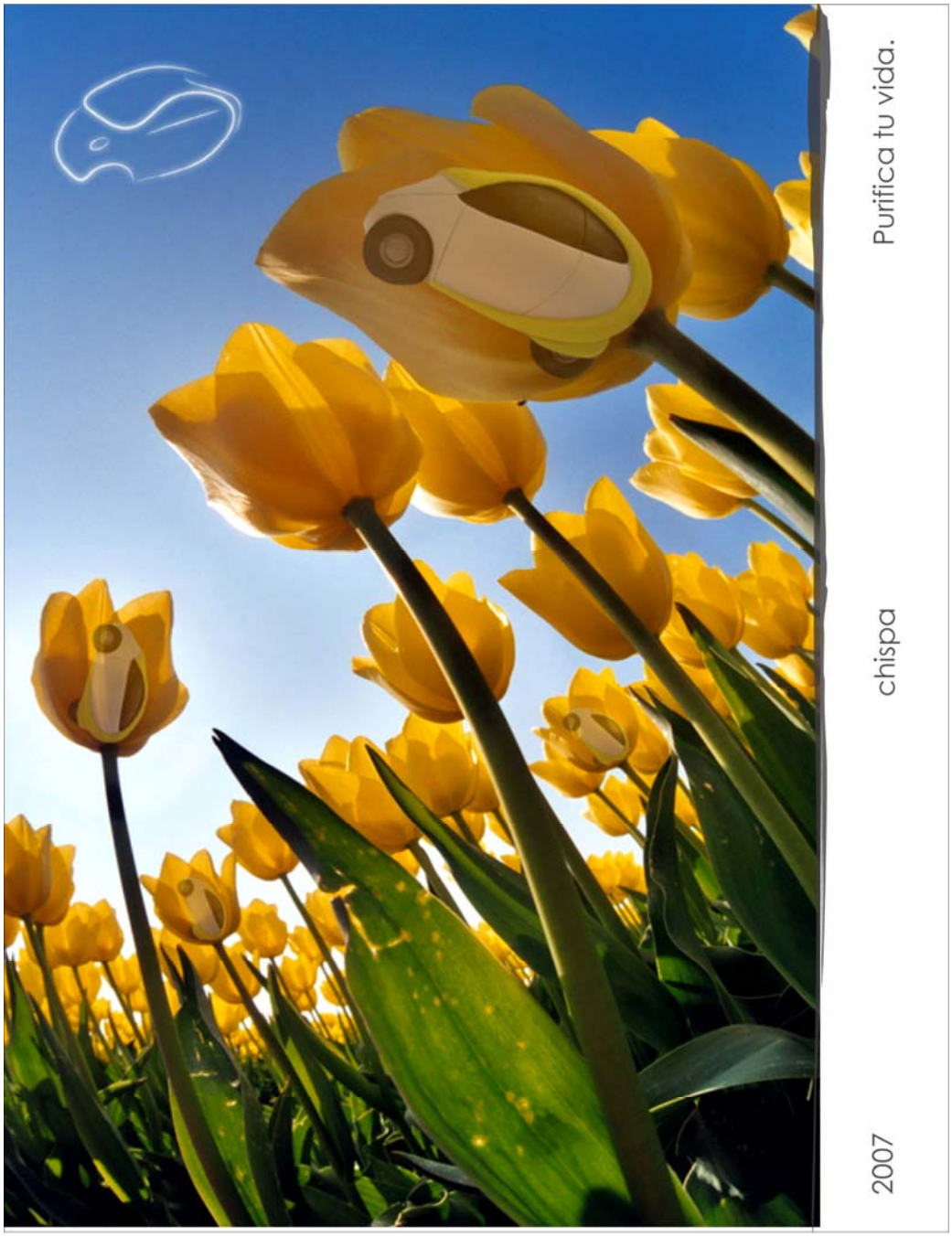


Figure 57: Marketing Ad Four (Carmona, 2006).

Figure 58: Marketing Logo (Carmona, 2006).

-Conduct a finalized presentation with all documentation.

Oral defense on October 19, 2006

-Document recommendations for further design studies.

Refer to Chapter Five, Section 5.2

CHAPTER FIVE: CONCLUSIONS

5.1 SUMMARY OF STUDY

These guidelines can aid designers who are to be given the task to design a new form of transportation for Mexico City in an effort to help the previously mentioned problems caused by the current types of transportation the inhabitants of Mexico City face. These guidelines are a design process, which can be used by a designer as a guide to understand these problems, solve them efficiently and effectively communicate their design.

Phase one of these guidelines is the research phase where analysis takes place. This is where the designers gather the necessary information and knowledge about the problem to help them arrive at a viable solution. The research does not stop at the end of the phase, but continues throughout the project. Phase two is the design development section of the guidelines. This is the synthesis portion of the process where a designer gathers all previously researched information to form and creates the best possible solution. The final phase is the presentation portion of the process. This portion is where the designer presents their best possible solution to the client with visual content that is necessary to understand the final solution.

5.2 RECOMMENDATIONS

The process of building the prototype should be discussed in greater detail and with more guidance. Adding possible steps for creating multiple prototypes could also be examined in greater detail.

The surveying that was done was limiting to only one hundred individuals in Mexico City. More inhabitants could have been surveyed which could vary the presented data.

The actual testing of the vehicle could also be examined to further investigate how the vehicle responds to its environment and if indeed the transportation problems of Mexico City are alleviated. This would require the development and construction of multiple full scale and working prototypes.

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APPENDIX

DEFINITION OF TERMS

Design Related:

Approach: an organized manner, planned in advance, addressing how to set about a task (i.e. Methodology).

Brainstorming: a process for developing creative solutions to problems.

Comparative Product Chart: lists design characteristics of existing products. These charts allow designers to view competition and to see how their prototype design competes with an existing design on the market.

Construction Drawings: two-dimensional representations of a product. They are used to instruct the manufacturer what elements are to be made as well as what they are to look like.

Conceptualization: the act of creating possible product solutions (i.e. Ideation).

Design Methodology: the examining of use of products. Methods identify side effects and safety codes in the early stages of product development.

Exploded View: a diagram showcasing all components of a product and how they fit and work together.

Flow Chart: a chart that shows all the possible paths that may occur during the completion of a product's operation.

Hierarchical Tree Structure: a diagram that allows designers to determine how the components and parts of a product are broken down.

Ideation: the act of creating possible product solutions (i.e. Conceptualization).

Industrial Design: a professional service which develops concepts and qualifications that enhance the value, function, and appearance of products for the benefit of both the manufacturer and user.

Interaction Matrix: a chart that is developed to aid and guide designers showing which parts of a particular product interact with other parts of the same product.

Interaction Table: a table that charts the interaction between a product with the user and its environment.

Morphological Matrix: this chart lays out solutions to main functions of an item which widens the designer with ideas for a solution to a problem.

Performance Criteria: a set if qualitative/ quantitative standards by which alterative and or final solutions will later be evaluated.

Questionnaire/Survey: a series of questions about a specific product that designers conduct.

Time Scheduling/Gantt Chart: a horizontal bar chart developed as a production control tool in 1917 by Henry L. Gantt, an American engineer and social scientist. Frequently used in project management, a Gantt chart provides a graphical illustration of a schedule that helps to plan, coordinate, and track specific tasks in a project.

Mexico City Related:

Aztecs: a people group who has advanced civilization in Mexico before the Spanish conquest in 1519.

Conquistadores: a Spanish term for any of the Spanish conquerors of Mexico.

Economy: the management of the income, expenditures, etc. of a household, government, etc.

Economics: the science that deals with the production, distribution, and consumption of wealth.

Metropolitan: the main city, often the capital, of a country, state, etc.

Netzahualcoyotl: an eastern pueblo of Mexico City where many residents commute from to work in the metropolitan area of Mexico City.

***Pueblo*:** a type of communal Indian village consisting of terraced structures, as of adobe, housing many families.

Tenochtitlan: the capital of the Aztec Empire; it is now the center of Mexico City.

Urbanization: changing from rural to urban, the characteristics of a city.

Vehicle Related:

Battery: a cell or group of cells storing an electrical charge and able to furnish a current (U.S Department of Energy, 2006: 1).

Electric Vehicle: an automobile powered and operated by electricity rather than fuel such as gasoline (U.S Department of Energy, 2006: 1).

Fuel: material from which atomic energy can be obtained.

Hybrid Electric Vehicle: an automobile powered and operated both by electricity and fuel such as gasoline (U.S Department of Energy, 2006: 1).

Electric Traction Motor: the motor of hybrid electric vehicles that converts electrical energy from the energy storage unit it mechanical energy that drives the wheels of the vehicle (U.S Department of Energy, 2006: 6).

Electric Energy Storage System: the battery unit in a hybrid electric vehicle.

Thermal Management System: the proper thermal management of the power and energy storage units of a hybrid electric vehicle (U.S Department of Energy, 2006: 12).

Energy Management and Systems Control: the two or more sources of on-board power in a hybrid electric vehicle (U.S Department of Energy, 2006: 18).

Leaded Gasoline: gasoline in its pure forms that when used causes air pollution.

Human Dimension:

Abduction: the movement of a body segment away from the midline of the body or body part to which it is attached (Pheasant, 1998: 57).

Adduction: the movement of a body segment of segment combination toward the midline of the body or body part to which it is attached (Pheasant, 1998: 57).

Anthropometry: the science of dealing with measurement of the human body to determine differences in individuals, groups, etc. (Pheasant, 1998: 6).

Average: the numerical result obtained by dividing the sum of two or more quantities by the number of quantities; an arithmetical mean.

Center of gravity: that point in a body or system around which its weight is evenly distributed or balanced and may be assumed to act (Pheasant, 1998: 35).

Ergonomics: the study of the problems of people in adjusting to their environment; the science that seeks to adapt work or working conditions to suit the worker (Pheasant, 1998: 4).

Ethnicity: ethnic classification or affiliation.

Extension: the straightening or increasing the angle between the parts of the body, generally defined as the return from flexion. When a joint is extended beyond the normal

range of its movement, the movement becomes known as hyperextension (Pheasant, 1998: 57).

Flexion: bending or decreasing the angle between the parts of the body (Pheasant, 1998: 57).

Functional Dimension: body dimensions take with the body in various working positions (Pheasant, 1998: 8).

Percentile-: any of the values in a series when the distribution of the individuals in the series is divided into 100 groups of equal frequency (Pheasant, 1998: 17).

Popliteal Height: the distance measured vertically from the floor to the underside of the portion of the thigh just behind the knee while the subject is seated with body erect (Pheasant, 1998: 35).

Secular Change: human variation in body since, rate of growth, and development occurring from generation to generation over time (Pheasant, 1998: 164).