Reducing Transportation Energy Consumption by Daily Commuters

MECHENG-589 (F13): Sustainable Design of Technology Systems

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Executive Summary

The current commuting situation is not sustainable. Do you know the average commute to work in the United States is 25.4 minutes each way (1)? This translates to nearly five work weeks of wasted time each year. On top of that, commuter mobility is getting worse which leads to high stress, and vehicle safety is still a major concern. Furthermore, transportation accounts for 71% of the overall petroleum usage in the United States and 33% of the total national CO_2 emissions (2). Approximately 27% of that energy usage and CO_2 emissions is due to commutes (3). Using sustainable thinking and informed design principles, our goals are to relieve the pain of wasted time and money on commuting, to improve commuting health and safety and to reduce the environmental impact of commutes.

We conducted an extensive ethnography plan to find the needs of commuters in the suburban metro Detroit area. We did this with interviews and surveys of traditional commuters, carpoolers and dealerships. We researched ride sharing, futuristic fuel saving technologies, infrastructure concepts and alternative fuels. We also reviewed LCA data on the most common commuting vehicles. From this research we created a stakeholder network and categorized and weighted the commuter needs using a Kano analysis survey. From our research and needs we developed the persona of Dan Williams, a family man living in Troy working in Detroit as a software engineer. He is very busy and thinks his commute is a waste of time but he enjoys where he lives. He also wants more time with his kids and to save money. Requirements for a solution are mainly based on Dan's needs, but do also consider other stakeholder needs, the environment, society and economic feasibility. These were transformed into quantified specifications using ethnographic research and our engineering judgment. Our group generated over 30 different concepts from analyzing the needs and a functional decomposition of a commute. Our top concepts were scored based on how well they met the specifications and the alpha concept won.

We are proposing a shuttle service that provides business and technical professionals with the means to work productively during their commutes. It does this by offering features such as Wi-Fi service, power outlets, noise cancelling headsets, fold-down tables and spacious seats. Our company is properly positioned to succeed since nothing like this is currently offered in the metro Detroit area. In fact, Pontiac, Michigan leads the nation in the number of commuters who drive alone, and has the fewest number of commuters who take public transportation to work (4). We validate this concept using survey results from commuters in the target area. We also use the survey results to find commuters' willingness to pay. To actually start this business, we would need the financial capability from small business investors or other financial lenders. We have conducted an extensive expense sheet of all expected startup and monthly costs to operate the business. We plan to market the product in the target area mainly through radio commercials, flyers and brochures. Lastly, this paper concludes with our informed analysis as to whether this project will lead to a sustainable solution.

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Introduction

Transportation is essential to our economy and quality of life, and currently accounts for 71% of the nation's total petroleum use and 33% of our total carbon emissions (2). Each year in the U.S. 15.07 quadrillion BTUs are required to power light duty passenger vehicles (2). Twenty seven percent of the 2.27 million vehicle miles traveled in the U.S. each year are driven by commuters on their way to and from work (3). Additionally, this situation is getting worse and it's not all due to population growth. Population growth has been responsible for only a quarter of the increase in vehicle miles driven over the last couple of decades. A larger share of the increase can be traced to the effects of a changing urban environment, namely to longer trips and people driving alone (5). Figure 1 shows the increase in vehicle miles traveled relative to the population and the number of vehicles.

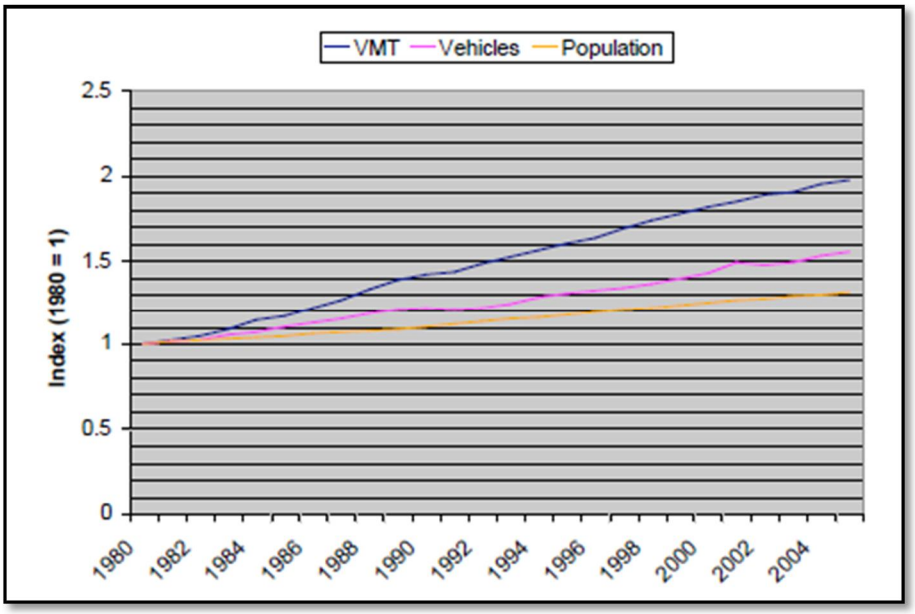


Figure 1 - Trend of vehicle miles traveled, population and number of vehicles

How can this situation improve? Transportation CO_2 reduction can be viewed as a three-legged stool, with one leg related to vehicle fuel efficiency, a second to the carbon content of the fuel itself, and a third to the amount of driving or vehicle miles traveled (VMT) (5). In this paper we will research all avenues related to reducing transportation CO_2 emissions. This includes fuel reducing technologies, alternative fuels, infrastructure changes and shared-ride programs.

Commuting also has several social issues. These include commuter safety, commuter health, commuter mobility and international tensions due to finite fuel resources. Commuter safety, health and mobility are closely related. These areas can be improved using technology, infrastructure modifications or shared commuting. International tension over fuel is closely related to the environmental issues and therefore could be reduced by applying above mentioned avenues for reducing transportation CO_2 emissions.

As designers we must be conscious of the above mentioned issues. The consumer is rarely concerned with environmental or social issues and cares more about their own needs. We have studied

commuters and the stakeholder network around them in order to find their true needs. From these needs we generated some realistic solutions and graded each on their ability to meet commuters' needs. We further refined the winning shared ride concept and developed a business plan around it.

Baseline Description and Future Outlook

As the research team set forth to start find the solutions to reduce the fuel consumption and CO_2 emission owing to the daily commute, it is necessary to find a baseline toto use for benchmarking. Our baseline is set as an individual person commuting an average of 48 miles per day in a 2008 Ford Fusion, a very common midsize sedansedan. The travel mileages, time, fuel usage and CO_2 emissions are the area to be considered for improvement from the baseline. Gasoline prices in absolute dollars are often unstable and on the rise, so there are certain economic benefits to reducing fuel usage.

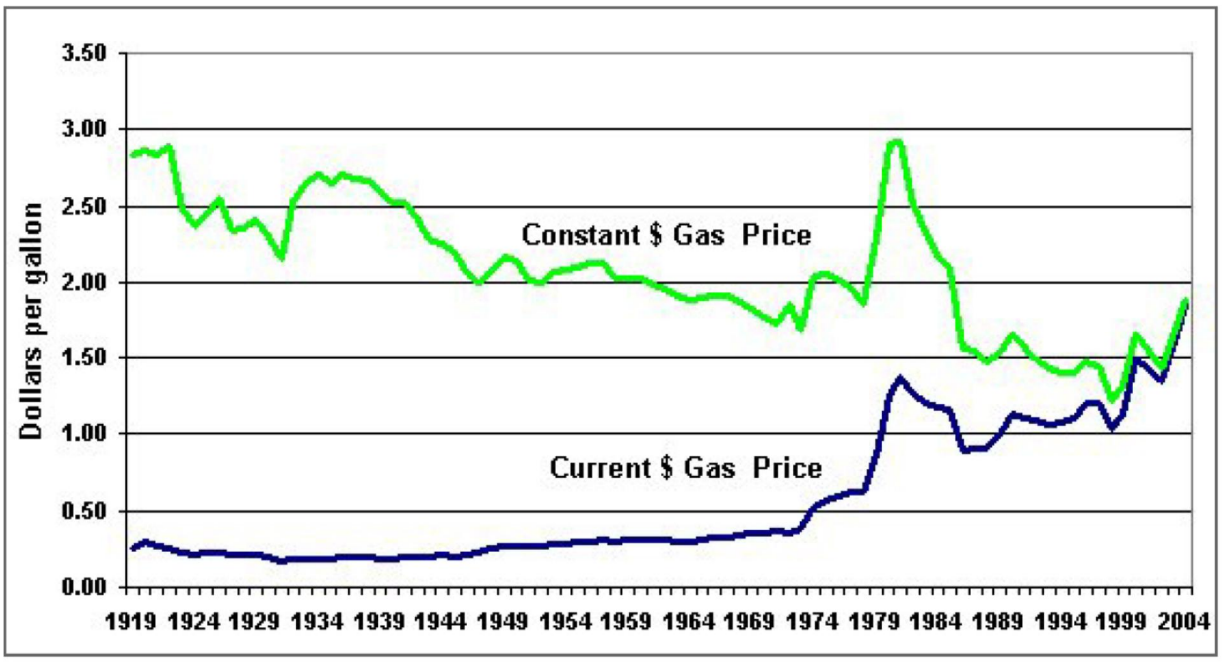


Figure 2 - Historic Gasoline Prices (6)

As to reduce the fuel consumption and CO_2 emission for the daily commuters, currently from automakers, private/public transportation sectors or even states' infrastructure are all actively participating to find the alternatives/solutions for fuel saving technologies :

1. Fuel Savings (CO_2 savings) alternatives:
    a. Autonomy - Autonomous vehicles have the potential to eliminate the usage of 1.9 billion gallons of gasoline, which are wasted in traffic congestion each year in the U.S. through better routing and safer driving. (7)
    b. Vehicle electrification- Several major automakers invest heavily on the technologies of vehicle electrification, including the Hybrid Electric Vehicle (HEV), Plug-In Hybrid Electric Vehicle (PHEV), and Electric Vehicle (EV). Prius from Toyota, Two-Mode Hybrid, and Volt from Chevrolet are among these types of vehicles' with electrification technologies.

c. Alternative Biofuel vehicle - The vehicles that use the non-petroleum based of fuel, as some or complete energy source are as the alternative fuel vehicles. These include the vehicle powered by flex-fuel such as E85, LPG, natural gas, and even the Hydrogen engine. Figure 3 shows the conversion routes from crops to biofuels.

d. Higher efficiency engine technologies - Major automotive companies are under-going the projects to increase the basic thermal efficiency of traditional internal combustion engines. These include the Ecotec engine technology from General Motors (8), EcoBoost engine technology from Ford (9), SkyActive engine technology from Mazda (10), and latest Earth Dreams technology from Honda (11).

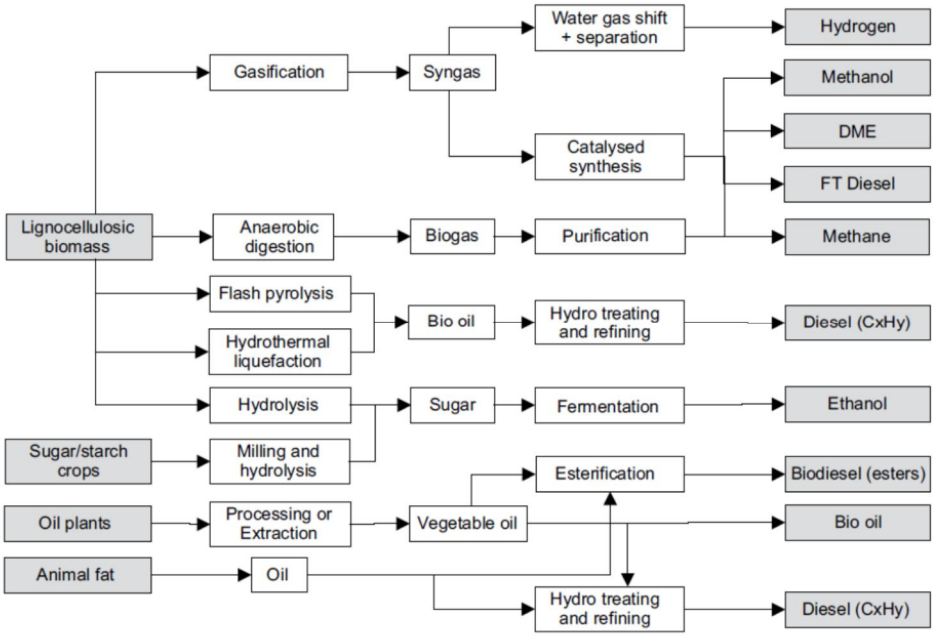


Figure 3 - Overview the conversion routes from crop to biofuels (12)

2. Commuting alternatives

a. Carpooling – Carpooling is gathering the people in one vehicle with the same or approximate travel distance or destination. By having more than one person in the vehicle, which is the ordinary commute pattern in USA, carpooling reduces the overall travel fuel usage. In USA, carpooling represented 43.5% of all trips (13) and 10% of commute trips (14). From this, more than 60% of carpool commutes are family members travel (15).

b. Public transportation – Other than sharing the travel means with specific group or known people, the public transportation is mostly defined to offer the general public on a mass scale, which normally include buses, subway, train, and high-speed rail.

c. Telecommuting – Telecommuting (or Telework) is defined as the employees or workers do not have to report to the central working environment while performing works. According to a Reuter's poll, approximately "one in five workers around the globe, particularly employees in the Middle East, Latin America and Asia, telecommute frequently and nearly 10 percent work from home every day" (16).

    d. Mobile traffic applications -Several Mobile traffic applications, such as Waze app (17), are capable to predict traffic patterns, navigate, and update the route during the trip.
3. Infrastructure changes
    a. Increase the fueling stations for alternative biofuel station – The infrastructure of alternative biofuel stations is still in very earlier stage of development to meet the demand of vehicles using alternative/Bio fuel. According to US Department of Energy, there are 16,274 alternative fueling stations in USA. On the contrary, there are approximate 168,000 gas station in the USA. Thus, the alternative fuel stations are less than 1% compared with the traditional petroleum-based gas stations.
    b. Traffic flow Optimization – Cities' traffic lights play the important role to direct the flow of traffic, and they also induce the idle time for the vehicles while waiting for the red light. Several control algorithms of traffic lights timing to optimize the traffic flow have been published and been applied to the modern cities around the world. (18) (19) (20) (21)

Most information was obtained through online searches, the Department of Energy website, and University of Michigan online library searches. It is understandable that some new technologies may need more time to prove their reliability and be accepted by customers. We also need time to gather more market information to understand what upfront additional costs consumers are willing to accept for hybrid technology, keeping in mind that the costs of fuel saved in using hybrid technology eventually balance out these costs over a variable period of time. For example, as shown in Figure 4, we observe a comparison of the 2013 Ford Fusion Hybrid vs. Non-Hybrid versions (22). It is obvious that the overall fuel economy (MPG) of Ford Fusion Hybrid is significantly improved (46.8 MPG-Hybrid vs. 26.2 MPG-Non Hybrid), but it is also shown that customer will have to pay $3,370 in upfront costs in addition to the cost of a non-Hybrid Fusion. With driving 15,000 miles per year at an estimated fuel cost at $3.27 per gallon, it will take 4.1 years for the owner to get payback for the extra cost.

Meanwhile, there are some safety and legal issues surrounding the technology of autonomous vehicles, such as liable parties in the case of an accident. According to The Security Ledger's report, as stated that data from insurance, we observe that 81% of auto accidents (year? Specify) are caused by operators' errors (23).On the other hand, while autonomous vehicles may be able to contribute to the technology of reducing the fuel consumption by optimizing vehicle operations, they also bring the uncertainty of responsibility in case of accident occurs. More research should also be done on the feasibility of adding special autonomous vehicle lanes on major highways through the Department of Transportation or other government sources, while we will use University of Michigan online library searches to gather much of the needed information, as well as an interview with a GM autonomous vehicle expert.

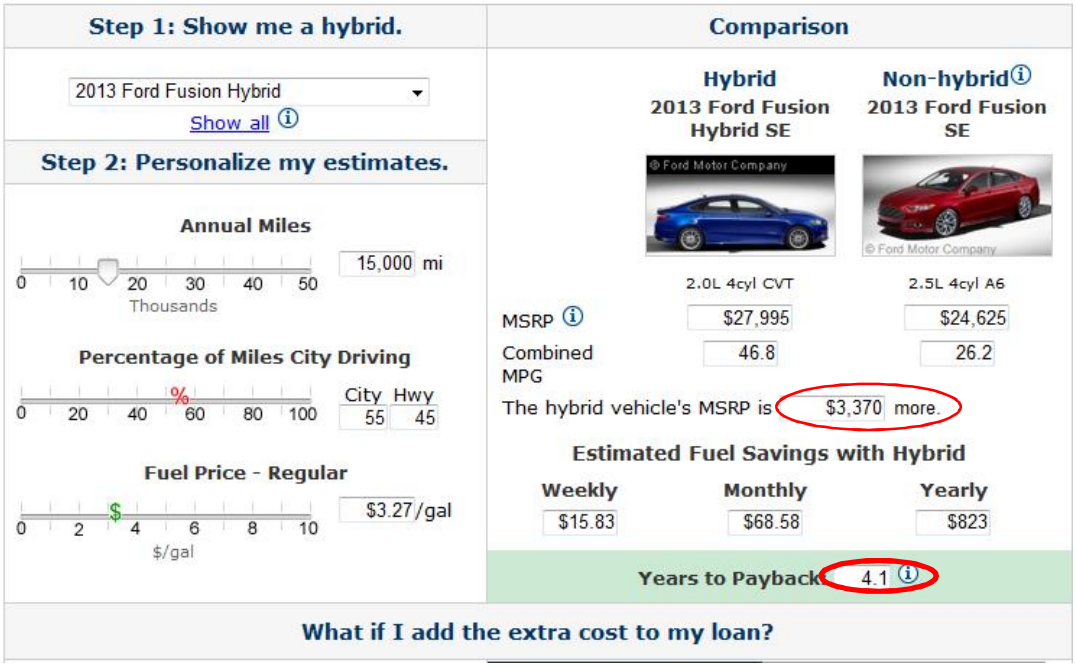


Figure 4 - Ford Hybrid Fusion vs. Non-Hybrid Fusion (22) (22)

Design Ethnography

Frame the Guiding Questions

In this project we are looking for an economically feasible solution from which a business can sustainably run. Ideally that solution will meet the needs of commuters, improve the environmental impact of the commute and improve society as it relates to commuting. To do this, we need to find out answers to the following questions:

- What is the need, pain, or area of opportunity that most impacts commuters lives?
- Who specifically is impacted by the need, pain or area of opportunity?
- What do these individuals value the most in their current commute?
- What alternatives are currently available to commuters that might improve their situation? What about in the future?
- What tradeoffs or constraints come with alternative forms of commuting? Will commuters accept these tradeoffs or constraints?

Define the Who

This study is geared towards suburban commuters traveling in the metro Detroit area. These commuters regularly travel to work in a passenger vehicle and are ages approximately 20 to 55. We will especially focus the study on those whose commute takes longer than 10 minutes because their commutes are more painful. Stakeholders to the above described user may include their employer, their family, other drivers, department of transportation (national and state), local government, insurance companies, lawyers, car dealers, and energy companies. The experts include automotive

OEMs, as well as several national, state and local agencies such as USDOT (US Department of Transportation), NHTSA (National Highway Traffic and Safety Administration), MDOT (Michigan Department of Transportation), and RITA (Research and Innovative Technology Administration). The clients of our solution is the commuters.

Synthesize Existing Knowledge

Through our research we found that commutes to work are dominated by passenger vehicles with only a driver and no one else in the vehicle. We also found that the transportation sector is a major contributor to fossil fuel use and carbon based emissions and greenhouse gas pollution. There is currently a tremendous amount of research being done in the areas of fuel saving technologies for vehicles, and alternative fuels. Some alternative fuels seem very promising to improve the environmental impact, but require both large infrastructure changers and consumer adoption to expensive and new technology. These efforts are huge, but it seems that the trend in vehicle miles traveled per commuter may negate these positive steps. Pontiac, Michigan leads the nation in the number of commuters who drive alone, and has the fewest number of commuters who take public transportation to work (4). This is mainly due to the lack of ride sharing or mass transportation options available to commuters in this area.

Determine Data Collection Methods

We will interview commuters of all types in order to answer the guiding questions for this project described above. However, most of the interviews will be suburban commuters in the metro Detroit area, since the members of this group are most familiar with this zone. Interviews with dealerships and experts can provide additional information that we may not be able to find about consumer purchasing habits as well as future solutions. We also plan to gather survey data from commuters in the target area as well. Once we have the needs from our data collection we will conduct a Kano Analysis survey to categorize and weight the needs. Lastly once we have defined our leading concept we will survey our target area and gain valuable information in order to validate and refine our concept.

Develop Data Collection Structures

Interviews:

- Urban commuter
- Rural commuter
- Suburban commuters
- Carpooler
- Mass Transportation User
- Telecommuter
- Industry expert on vehicle technology
- Automotive Salesman from a Car Dealership

Surveys:

- Commuter Ridesharing Survey
- Kano Analysis of Needs

- Alpha Concept Feedback

Key Interview Questions for a Passenger Vehicle Commuter:
Q1 (Kickoff): Describe your commute to work…
Q2 (Kickoff): Walk me through your commute to work and back home today…
Q3 (Build Rapport): What do you like about your commute?
Q4 (Build Rapport): What do you dislike, is frustrating or concerns you about your commute?
Q5 (Grand Tour): Have you ever tried ride sharing or any other alternatives to your current commute?
Q6 (Grand Tour): How could your commute improve?
Q7 (Grand Tour): What do you see in the future of transportation? What concerns you about it?
Q8 (Reflection): Have you personally made any changes to your commute in order to save time, energy or money in respect to your commute to work?
Q9 (Wrap Up): Thanks for the interview, any closing thoughts or questions for me?

Commuter Ridesharing Survey questions, Kano Analysis questions and Alpha Design Feedback Survey questions can be found in section: Appendix I: Ethnographic Data Collected.

Summary of Ethnographic Data Collected

Note: the results below come from interviews, survey data and our own observations

- What is the need, pain, or area of opportunity that most impacts commuters lives? What do these individuals value the most in their current commute?
  The main area of pain for commuters are:
  1. Cheap commute (low price of gasoline), cheap commute vehicle (relative to any alternative)
  2. Ability to multitask, make use of their commute time or be productive during their commute (this also is the desire to improve their work/life balance as commuting directly reduces their personal time spent at home).
     a. Note: This one introduces safety concerns for passenger vehicle commutes
  3. Short commuting time (care less about distance). However, we have that commuters are willing to sacrifice this for fulfillment of #2

  Other Needs common to most commuters include:
  4. Ability to predict arrival time / commute is relatively consistent
  5. Reliable commute / commuter vehicle
  6. Minimize stress to the commuter, includes easy drive (low attention required). This includes avoiding stop and go, congestion, construction, bad weather or anything else that might slow down their commute.
  7. Flexibility to change departure time
  8. Adequate level of seat comfort and individual space
  9. Minimized safety risk
  10. Flexibility to go out to lunch or leave workplace at odd hours for an emergency
  11. Not having to drive or pay attention during their commute

12. Ability to make personal or business related phone calls
13. Quiet ride when need time to think

Some commuters have these desires

14. Personal/alone time and freedom in their commute
15. Multiuse commute to run errands like grocery shopping or car maintenance
16. Enjoy scenic drive
17. Ability to eat breakfast or snacks during commute
18. Entertainment and comforts such as music, audio books, NPR or talk radio, coffee
19. Conversations with passengers

- Who specifically is impacted by the need, pain or area of opportunity?
  There are relationships between distance and congestion with the strength of the needs described above. Some of the needs such as safety, reliability and consistency are base needs to all commuters. However other needs such as the ability to be productive during their commute are more prevalent for those who have a longer commute. Those who need to reduce stress on their commutes typically travel through highly congested areas or other forms of stop and go.

- What alternatives are currently available to commuters that might improve their situation? What about in the future?
  Commuters within our scope currently do not currently have many options. Most of them live too far to consider walking or biking to their destination. Mass transportation of all kinds is either not offered or only offered for portions of their commute. Due to the commuter's need of a flexible schedule carpooling is often difficult to organize. Additionally it is difficult to find willing carpool members. One option they have is to invest in an efficient vehicle such as a hybrid, but this is often too expensive. Most of the commuters could downsize their vehicle but like the luxuries offered in a larger vehicle. Additionally they have the option of moving closer to their destination, but often the destination is not located in a desirable area.

- What tradeoffs or constraints come with alternative forms of commuting? Will commuters accept these tradeoffs or constraints?
  Alternative forms of commuting often come with sacrifices in time, comfort, convenience, flexibility in scheduling and sometimes personal time/freedom. Even with these, several commuters are willing to share their ride in order reduce their expense. There is a definite relationship between cost savings and the above mentioned sacrifices, but this does not apply to everyone.

Kano Analysis of Commuter Needs:

After the initial interview, a survey was sent to the interviewees to understand the priority of the needs they listed. That survey was used to do a Kano analysis of their needs. The survey questions can be found in the section: Survey - Kano Needs Analysis Questions.

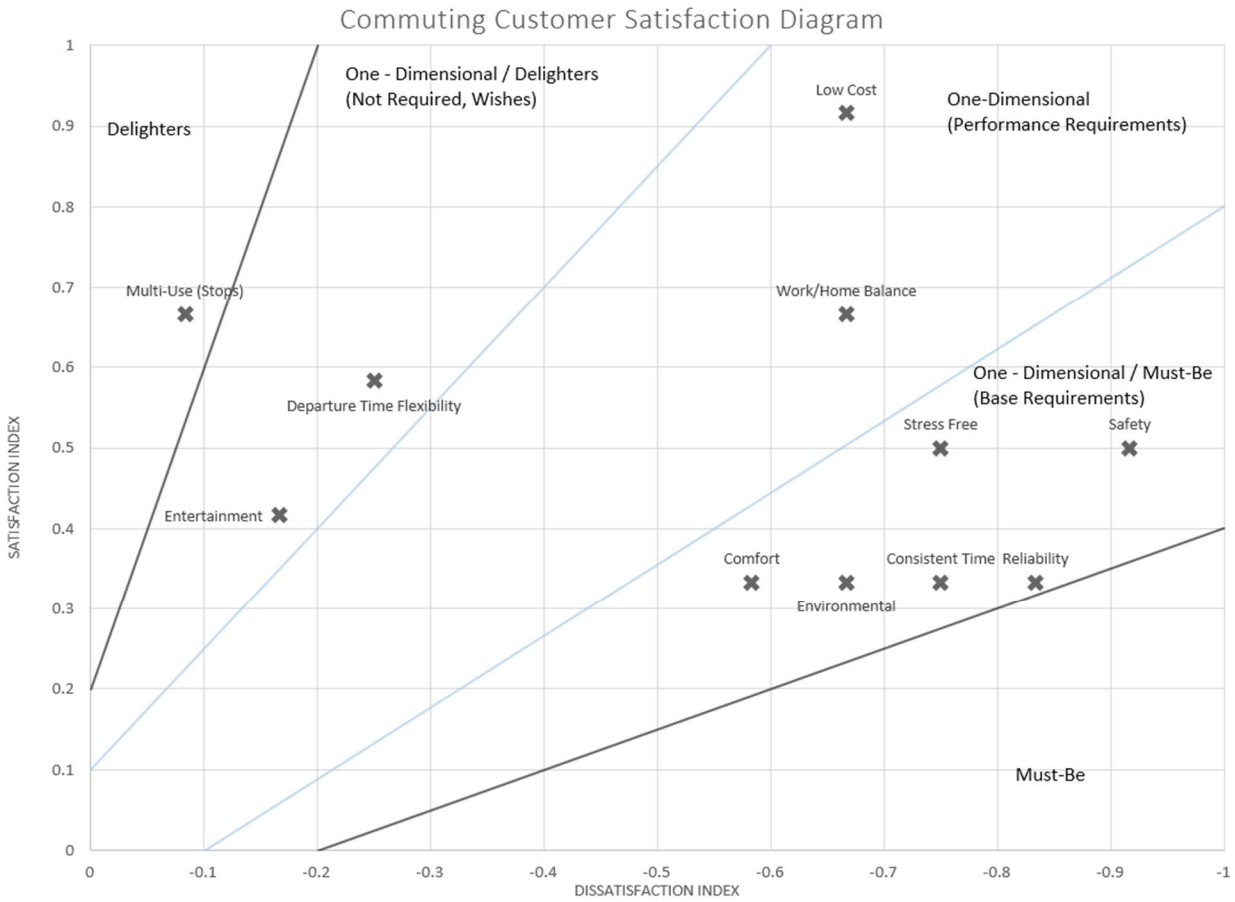


Figure 5 - Commuting Customer Satisfaction Diagram from Kano Analysis

Persona

A persona was developed based on survey feedback, background research, and Kano analysis. The persona is described below.

Name: Dan Williams
Gender: Male
Age: 32
Family: Married to Julie (31), 2 kids (Ben 2 years, Sara 6 months)
Residence: Homeowner in Troy, MI.
Occupation: Software engineer
Salary: $85,000
Vehicle: 2008 Ford Fusion

City	20 mpg (11.8 liters/100km)20 mpg (11.8 liters/100km)20 mpg (11.8 liters/100km)20 mpg (11.8 liters/100km)
Hwy	28 mpg (8.4 liters/100km)28 mpg (8.4 liters/100km)28 mpg (8.4 liters/100km)28 mpg (8.4 liters/100km)

Combined	23 mpg (10.2 liters/100km)
Class	midsize sedan
Engine	4 cylinder 140.355 cubic inches (2.3 liters)
Transmission	Lock-Up/Automatic/5-Speed
Fuel	Regular Gasoline

Table 1 - Vehicle Specification and Fuel Economy Data (24)

Daily commute assuming no accidents, normal traffic flow:
Morning: Troy, MI to Detroit, MI. 24 miles and 35 minutes
Evening: Detroit, MI to Troy, MI. 24 miles and 45 minutes
Worst commute: 2 hours driving home on a Friday afternoon in the summer after an accident occurred.
Best commute: 25 minutes after speeding on empty roads at 5:30am

Background: Dan is tech savvy and concerned about the environment, but his family and work obligations prevent him from spending much time focusing on improving his environmental footprint. Dan is very busy and feels like his commute is a waste of his time, but a necessary evil. He works in Detroit, but does not want to live there due to the safety concerns and lack of city services. He likes living in Troy because of the spaciousness of home lots, tight community feeling, safe neighborhood, and great schools for his children. He wishes he could find a job in Troy to cut his commute time and allow him to spend more time with the kids, but the best financial opportunity for him currently is in Detroit.
Ben's wife, Julie, drives a 2010 Chevrolet Equinox and works as a teacher in Troy.

Commute Needs: Dan's time is the biggest factor, so he would love to have the shortest commute possible or no commute at all. He wants his commute to be less stressful and more consistent day-to-day. Multi-tasking during the commute would also be a big plus. Dan has a mortgage to pay, so he would like to cut down on commute costs. Dan would be willing to sacrifice things such as comfort or even a small amount of money if it meant that he could spend more time with his family. However, he is not willing to sacrifice his productivity at work because he sees himself moving up in the company, where he will earn more money which will benefit his family. He also does not want to add any extra hassle or inconvenience to his life.

Project Requirements and Engineering Specifications

We categorized the list of Commuters' needs and desires in section Summary of Ethnographic Data Collected into three categories: Performance Needs (weighted at 9 points), Base Needs (weighted at 3 points) and Not Required (0 points).

Performance Metrics

Performance needs are those most important to our persona. The performance needs for our persona represented as requirements and specifications are shown below in Table 2. The persona's customer satisfaction will increase linearly with greater fulfillment of these needs.

Requirement	Target Metric	Weight
The commuter's cost will be minimized	Overall customer cost of the commute is less than 90% of the Baseline: (< $220/month)	9 points
The commuter is able to make productive use of their commuting time (examples include working on a laptop or sleeping)	The following ratio will increase by more than 50% compared to the Baseline: (Commuting Productive Time)/(Commuting Time)	9 points

Table 2 - Commuting Product Performance Requirements & Specifications

Note: Calculation for baseline commute cost is based on KBB reported for a 2013 Ford Fusion SE Sedan 4-door as shown in Figure 6 below.

- Miles Per Gallon for Commute: 26.88 MPG = 0.14 $*$ 20 MPG + 0.86 $*$ 28 MPGCosts:

  \$1469.75 = $\frac{48\frac{mi}{day}}{26.88MPG} * 3.50\frac{\$}{gal} * 235days$
- Total Cost of commuting per month:

  \$220220 = $\frac{\$1469.75+27\%*\frac{1}{5}(\$14633+\$4075+\$1432+\$2061+\$2490+\$2430)}{12}$

Figure 6 - KBB 5-Year Cost to Own Ford Fusion (25)

Base Metrics

Base needs are common amongst most commuters. These needs must be in the product, but customer satisfaction will not increase with greater fulfillment of the need. The base needs for most commuters represented as requirements and specifications are shown below in Table 3.

Requirement	Target Metric	Weight
The overall commuting concept will not significantly increase the commuting time.	The average commuting time will not increase more than 20% compared to the baseline: <42 min (Morning), <54 min (Evening) Note: Baseline = 35 min (Morning), 45 min (Evening)	3 points

The commute time must maintain a regular level of consistency	The commute time from day to day will not fluctuate by more than 20% from the average (not including weather and other natural disasters)	3 points
The commute must maintain an adequate level of safety	Vehicle is structurally sound and equipped with standard safety features for all passengers including airbags and seatbelts.	3 points
The commute will provide an adequate level of comfort	Commuter Satisfaction Index rating (1=Worst, 5=Best) of 4 or better (Baseline is 3)	3 points
The commute will reduce commuting stress	Commuter Satisfaction Index rating (1=Worst, 5=Best) of 4 or better (Baseline is 3)	3 points

Table 3 - Commuting Product Base Requirements & Specifications

Sustainability Metrics

Environmental and social considerations have a low impact on consumer purchasing compared to product performance related to customer needs. However, for a sustainable future they must be included in the product if at all possible. Social requirements were captured in the base needs above for example safety and commuter stress reduction. Through our streamlined LCA analysis of the baseline as well as other research on the topic we have developed the following environmental requirement and engineering target for our product:

Requirement	Target Metric	Weight
(Environment) Reduce fuel consumption and CO2	Reduce total vehicle miles traveled by customers by 10% or more Reduce energy consumption and CO2 emissions per commuter by 10% or more	6 points

Table 4 - Commuting Product Environmental Requirements & Specifications

Workplace Employer Metrics

Through consideration of our stakeholder network along with ethnographic research, we found that the employer of the commuter should be considered for the design of a commuting product.

Requirement	Target Metric	Weight
Commuting product does not impact work performance	Employer Satisfaction Index rating (1=Lowest Impact, 5=Highest Impact) of 2 or lower on commuting product impact to employee's work production	6 points

Table 5 - Commuting Product Employer Requirements & Specifications

Sustainability Evaluation of Baseline

Stakeholder Network for Suburban Commuters

The stakeholder network for suburban commuters is described in the section: Define the Who, but can also be seen in Figure 7 - Suburban Commuter Stakeholder Network below.

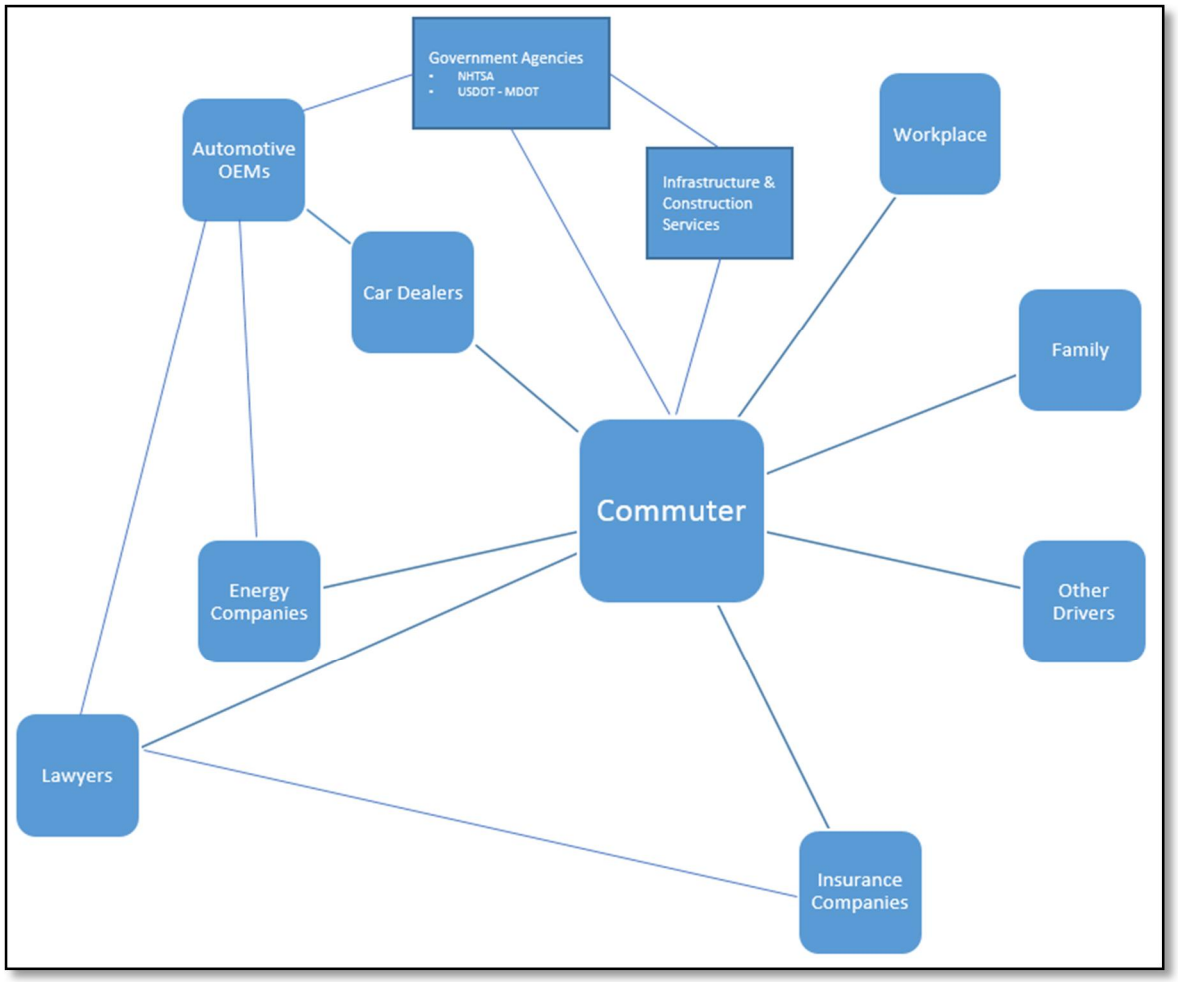


Figure 7 - Suburban Commuter Stakeholder Network

Environmental Impacts of the Baseline

The baseline is a based on the persona, who commutes daily in a 2008 Ford Fusion, which is a mid-sized car. The manufacture, use, and disposal are considered in the streamlined life cycle analysis below. The data for this analysis was taken from an LCA on a mid-size vehicle in the United States (26). Since commute miles make up 27% of the vehicle miles traveled in the U.S., the life cycle analysis was scaled to 27% of the original values in order to allocate the energy and CO_2 emissions appropriately to the commute (2). As shown below, the largest impact on energy and CO_2 emissions is in the use phase. This is what we expected to find and is the driving force behind our project selection.

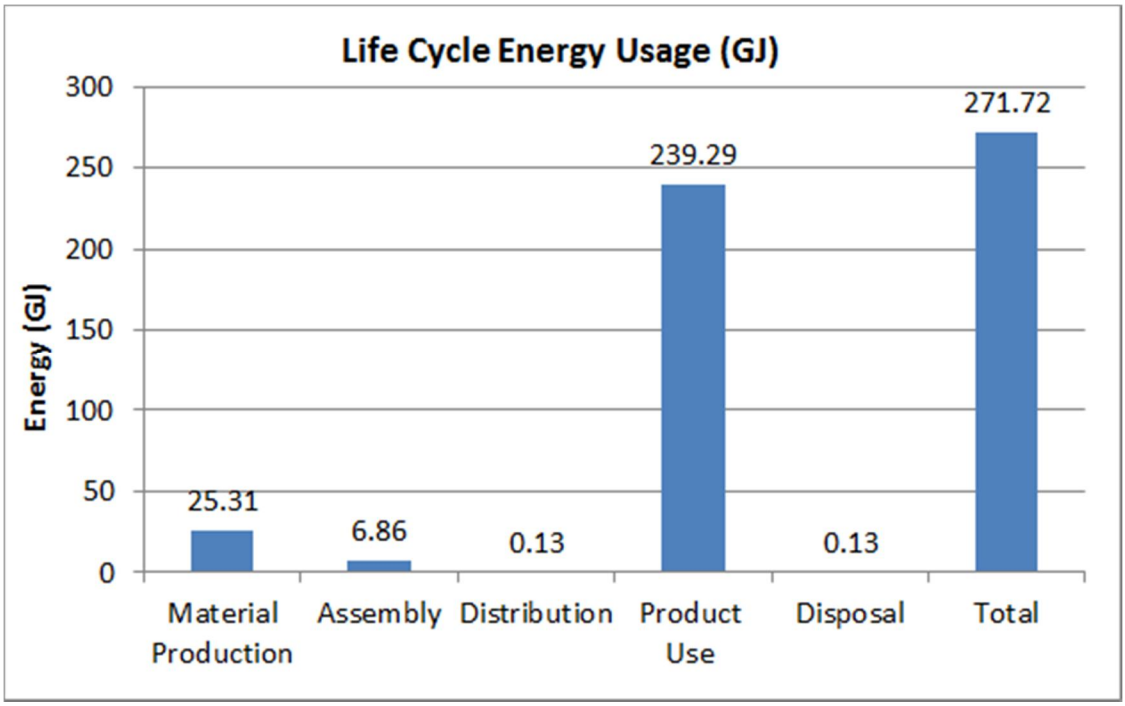


Figure 8 - Life Cycle Energy Usage of an average U.S. Commute with a Midsize Passenger Vehicle (26)

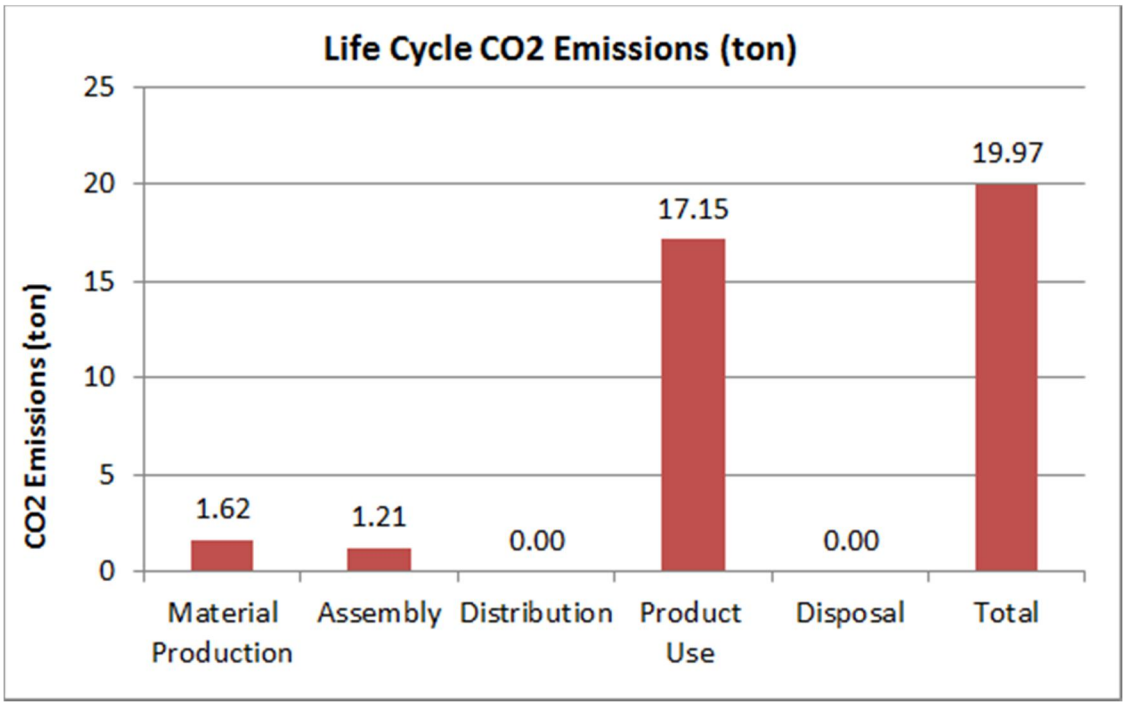


Figure 9 - Life Cycle CO2 Emissions of an average U.S. Commute with a Mid-Size Passenger Vehicle (26)

The material mass distribution for the mid-size vehicle studied is shown below. This mass distribution was used to estimate energy and CO2 emissions from the production of the specific quantities of materials listed below.

Material	Present
	Gasoline ICEV, mass (kg)
Ferrous Materials	886
Copper	9
Zinc	7
Lead	10
Aluminum	81
Magnesium	10
Glass	35
Fluids	54
Rubber	54
Plastics	100
Other	78
Total	1324

Figure 10 - Material Distribution used in LCA of mid-size vehicle (26)

Assumptions related to the energy used to assemble the vehicles were based on the energy mix in the United States. The energy used to distribute the vehicles as well as the energy incurred during the use phase were based on U.S assumption as well. The CO2 emitted during for distribution and disposal was so small that it was neglected in this LCA (26).

Social Impacts of the Baseline

The social impacts of commutes were also evaluated. There are a large number of ways a the vehicle design and manufacture can impact society, from the way workers are treated in the locations components are manufactured to the toxicity and sustainability of the materials and processes used to make components in the vehicle. Since social impact data is very limited, we chose to limit the scope of the social LCA to the commute itself. We do not plan to focus on manufacturing locations, methods, or materials for our project.

The major social issues we identified surrounding commute in a motor vehicle are commuter safety, commuter mobility, commuter health, and international tensions due to dependency on oil. The issues are scored in the chart below.

Social Issue	Score (1=worst, 3=best)	Score Justification
Commuter safety	2	In 2012, there were 33,561 deaths in the U.S. due to motor vehicle crashes. This number has gone down over time, especially in terms of VMT, but is still too high. There are 5.5million car crashes in the U.S. each year.
Commuter mobility	2	U.S. drivers spend 36 hours per year, on average, stuck in congestion.
Commuter health and stress	1	The stress of commuting, especially long distances, can cause people who drive further to die younger than their colleagues. Obesity is also linked to vehicle miles travelled.
International tensions due to national oil dependency	1	The U.S. economy is dependent on oil and uses the military to protect oil sources and trade routes, which has lead to conflict and could lead to future conflict. Reducing dependency on oil reduces the risk.

Figure 11 - Social Life Cycle Analysis Invalid source specified.Invalid source specified.Invalid source specified.Invalid source specified.Invalid source specified.

Concept Generation

Concepts were generated in two ways: 1) by focusing on the persona's most important needs and then brainstorming solutions and 2) by creating a functional decomposition. The functional decomposition we created may not be a perfect representation of the system, but thinking through the inputs that change a driver's behavior as well as thinking through losses in the system, led us to several concepts, specifically those related to mobile applications and ride sharing. The full list of 30+ concepts is shown in Appendix II: Concept Generation. The functional decomposition is shown below.

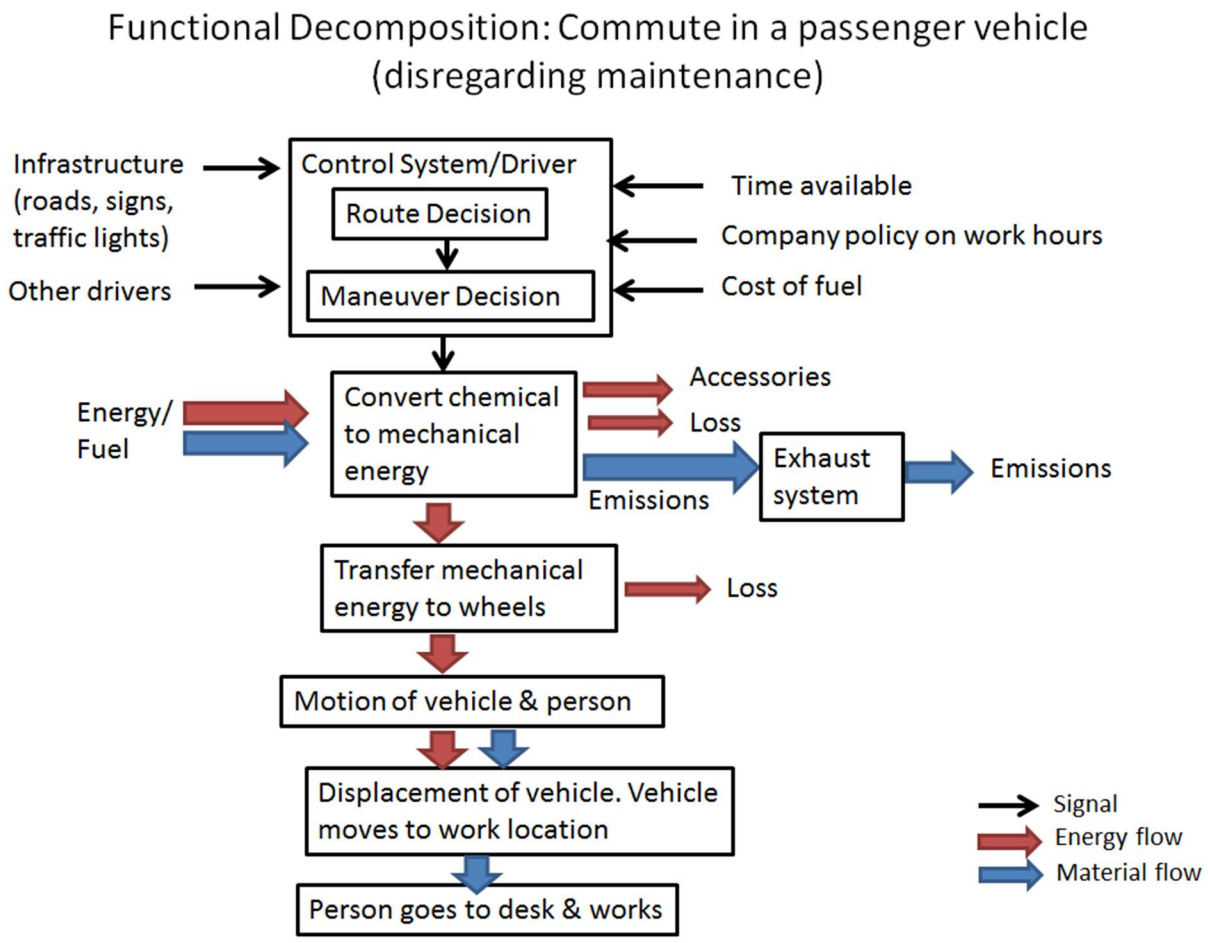


Figure 12 - Functional Decomposition of a commute in a mid-size passenger vehicle

The concepts we generated generally fell into four different categories: company policy changes on work hours, ride sharing, mobile applications, and vehicle fuel efficiency improvements. Because most of the fuel efficiency improvements only addressed one need, the cost of the commute, we ruled them out early in the concept selection process, so that category will not be discussed here.

Company policy has a significant impact on commuters. Rigid company policies that require specific start times and specific hours worked per day cause commuters to all travel at roughly the same time of day, leading to congestion. One company policy change that seemed very promising is telecommuting a minimum of 5 days per month. Telecommuting is only possible for workers who have good internet connection and telephone service at their homes as well as a job that can be done remotely. The worker must also be able to complete their tasks without direct supervision. The benefits of telecommuting for the employee are: reduction or elimination of fuel cost for the commute, improved safety because the worker didn't have to endanger himself on the road, flexible work hours, lower total time spent commuting+ working, ability to multitask at home, and reduction or elimination of stress related to the commute. The employer could be recognized by the DOT and EPA as one of the Best Workplaces for Commuters. This recognition allows the employer to save money on payroll taxes if they provide commuter resources for their employees, reduce commute trips by at least 6%, and ensure that

at least 14% of their work force is not travelling to work alone in a vehicle [19]. If the employee is happier about his work life balance, he will also be more engaged at work, improving his productivity. The benefits for the environment and society are: the reduction of fuel energy used for commutes, reduction in commute related CO2, reduction in congestion due to fewer vehicles on the road, improved safety due to fewer vehicles on the road, and perhaps longer lasting roads due to fewer vehicles travelling on them. The possible negative effects of this change on the persona could be: a reduction in work efficiency due to distractions at home, larger home energy bills, loneliness due to extended periods of time alone, and possibly fewer opportunities at work due to less face time with managers and colleagues. To fully understand the impact on the environment, an energy analysis needs to be done to understand the effect of displacing commuting energy and CO2 emissions and replacing it with increased home energy usage. This idea was a result of brainstorming based on the persona's needs and desires for increased safety, reduced stress, and better work/home life balance.

Our top ride sharing idea came from examining the driver inputs on the functional decomposition and from considering the highest priority needs of the persona. The persona needs better work-life balance, but is not going to be able to reduce his work hours and can't easily change the distance he lives from work. If he had an option to reduce his total work + commute time without reducing the work he completed in a day, then he would be happier. The persona sees the commute as a waste of time, so the way to make him happy is to make his commute more productive by allowing him to work on the commute. That is where the idea for a shuttle service was born. The service would pick up workers from their homes and drop them off at work in the morning and then reverse the procedure in the evening. The shuttle would have business friendly features such as noise cancelling headphones for conference calls, Wi-Fi for reliable internet service, and some breakfast and snack options to further save the commuter's time. This would only work if the cost to the employee was less than the cost of gas for his current commute, the employee's productivity did not decrease, and if the employer agreed to allow the employee to spend less than 8 hours physically in the office. The shuttle service would need to make money, so there would have to be enough commuters travelling in the same general direction at about the same time of day to pay for the cost of the shuttles, gas, drivers, and overhead.

The benefit of a shuttle service to the employee is the ability to better balance work life and home life by reducing overall work + commute time without reducing work completed. The employee's commute would be more productive and he wouldn't have to stress about the commute, because someone else is driving. The employee's commute cost would likely go down and employees like our persona would consider getting rid of the second car in the two car household, saving the employee even more money. The benefit to the employer is that they can try to get the Best Workplaces for Commuters status and the tax benefits that go with it. They may also get more work time out of the employee if he is spending his entire commute working, but is able to spend less overall time commuting+ working. If the employee is happier about his work life balance, he will also be more engaged at work, improving his productivity. The benefits to the environment and society are lower total vehicle miles travelled, fuel burned, and CO2 emitted as well as less congested roads and fewer stressed-out drivers. Possible negative side effects are that shuttle passengers may get carsick, reducing their ability to work and in

the long term, fewer vehicles may be needed if families reduce the number of vehicles they own, which could mean fewer jobs in the auto industry.

The third category of concepts is applications for mobile devices. Mobile phone applications would generally be the quickest and easiest changes to implement, making it an area of interest for the team. One mobile phone application would use Google maps, current user speed and location, and user speed and location history to predict the best route for the user. It also predicts traffic light behavior based on user history data at a given location and uses the traffic light data in the routing algorithm. The best route is defined by the user as either the fastest route, shortest route, or best route for fuel economy. The application will navigate the user to the desired destination using real-time routing updates if required. This application is similar to the Waze application, but predicts traffic light patterns and navigates the driver along best routes that are updated in real time. The benefits to the user are reduced drive time and/or better fuel economy. If enough people use the application, some environmental and social benefits are that fuel usage and CO2 emissions would be reduced and congestion would be reduced. There is a possible safety concern of the driver looking at the phone frequently to understand the updated route, which could potentially lead to an accident. Another possible negative side effect is that re-routing the driver too frequently could be annoying to the driver, so there would have to be some hysteresis between route changes.

Concept Selection

As mentioned above, over 30 concepts were considered as part of this project. Prior to conducting a detailed concept selection process to find our alpha concept, we first narrowed down the list. We eliminated all infrastructure based concepts (including workplace satellite offices) since our group's focus was more on a more near-term implementation project. Additionally, we eliminated all concepts that were simply technology improvements in the vehicle aimed at fuel efficiency gains since these concepts were completely missing the mark in improving the commuter's work/life balance. From there we used engineering judgment to eliminate topics that we simply did not believe would be successful in the market or were not complete concepts. After this filtering process, we were left with 6 concepts to evaluate. These concepts are:

- Shuttle service provided to the commuter by an independent shuttle bus service. The shuttle would be equipped with Wi-Fi, sound deadening headsets, tray table, etc. The employer may receive a tax incentive under section 132 (f) of the federal tax law if they subsidize the cost to their employee (27).
- Telecommuting policy in place allowing the employee to telecommute up to 5 days per month under circumstances granted by the manager of the employee. The employer may receive a tax incentive under section 132 (f) of the federal tax law (27).
- Company policy allowing the employee with the option of 4 10 hour working days per week.
- Incentives to encourage employees to work earlier hours (such as 4AM to 1PM). Incentives may include a dedicated locker (and shower), dry-cleaning and free breakfast. The employer may receive a tax incentive under section 132 (f) of the federal tax law (27).

- A carpool incentive program offered by the employer. Employees carpooling may receive extra vacations days for example. The employer may receive a tax incentive under section 132 (f) of the federal tax law (27).
- A phone app to find the best route based on speed, traffic lights, and distance to destination

We used a 3-9 weighting scale for importance of each of the specifications. Performance metrics were weighted with 9 points for each specification since these are most important to the persona. The concepts were evaluated against a 1-5 scale of meeting the specification, where 1 is poor and 5 is excellent. The rating of the concept multiplied by the weighting of the category resulted in the score that the concept receives for the specific engineering target. Table 6 shows the ratings of the concepts against the persona's performance based specifications. Likewise the concepts were graded against the sustainability and employer metrics, only these had a weighting of 6 points. The concept selection against these metrics can be seen in Table 7. The base metrics were weighted with 3 points for each specification and the scores are found in .

Concept	Overall customer cost of the commute is less than 90% of the Baseline: (< $220/month)	The following ratio will increase by more than 50% compared to the Baseline: (Commuting Productive Time)/(Commuting Time)
Shuttle service	36	36
Telecommuting policy	27	45
4 10 hour work days per week	27	27
Incentives to encourage employees to work earlier hours	27	27
Carpool incentive program	36	27
phone app to find the best route	18	18
Baseline	18	18

Table 6 - Concept Selection based on Performance Metrics

Concept	Reduce total vehicle miles traveled by customers by 10% and reduce energy consumption and CO2 emissions per commuter by 10% or more	Employer Satisfaction Index rating (1=Lowest Impact, 5=Highest Impact) of 2 or lower on commuting product impact to employee's work production
Shuttle service	30	30
Telecommuting policy	24	6
4 10 hour work days per week	24	12
Incentives to encourage employees to work earlier hours	24	12
Carpool incentive program	30	30
phone app to find the best route	18	30
Baseline	18	30

Table 7 - Concept Selection based on Sustainability and Employer Metrics

Concept	The average commuting time will not increase more than 20% compared to the baseline	The commute time from day to day will not fluctuate by more than 20% from the average	Vehicle is equipped with standard safety features for all passengers including airbags and seatbelts.	Comfort - Commuter Satisfaction Index rating (1=Worst, 5=Best) of 4 or better (Baseline is 3)	Stress - Commuter Satisfaction Index rating (1=Worst, 5=Best) of 4 or better (Baseline is 3)
Shuttle service	6	6	15	9	12
Telecommuting policy	15	15	15	15	12
4 10 hour work days per week	15	12	15	12	9
Incentives to encourage employees to work earlier hours	15	15	15	12	6
Carpool incentive program	6	6	15	9	6
phone app to find the best route	12	9	15	12	3
Baseline	12	9	15	12	3

Table 8 - Concept Selection based on Base Metrics

After scoring the concepts against all of the engineering targets, the scores were summed and the concepts could then be ranked in order. As can be seen, the shuttle service has the most likelihood of meeting the needs of the persona, and thus is our selected concept for this project.

Concept	Total
Shuttle service	180
Telecommuting policy	174
4 10 hour work days per week	153
Incentives to encourage employees to work earlier hours	153
Carpool incentive program	165
phone app to find the best route	135
Baseline	135

Table 9 - Concept Selection Results

Alpha Design

Our alpha design is of a shuttle service to transport commuters from their homes to their workplaces and back while allowing them to work productively during their commute.

How it works:

The shuttle service is an independent business to shuttle customers from their homes to their places of work. The customer schedules pick up and drop off times via a mobile phone app or through website. Our proprietary routing algorithm computes the best routes for all shuttles. Next, a text or email is sent to alert the customer 10 minutes before the shuttle arrives. While on the shuttle, the commuter works efficiently due to features we added to enable working on-the-go. The features will be described in depth later. The shuttle continues to pick up several other passengers in the same neighborhood who are travelling to nearly the same place. Passengers are also picked up along the route to the office. The shuttle drops off each customer at their desired destination and continues the process as required and as determined by the proprietary routing algorithm. In the afternoon, the shuttle picks up passengers at businesses at the scheduled times and drops them off at their homes, all within a short distance from each other. A high level process flow chart is shown in: Figure 13 - Shuttle Service Flow Chart.

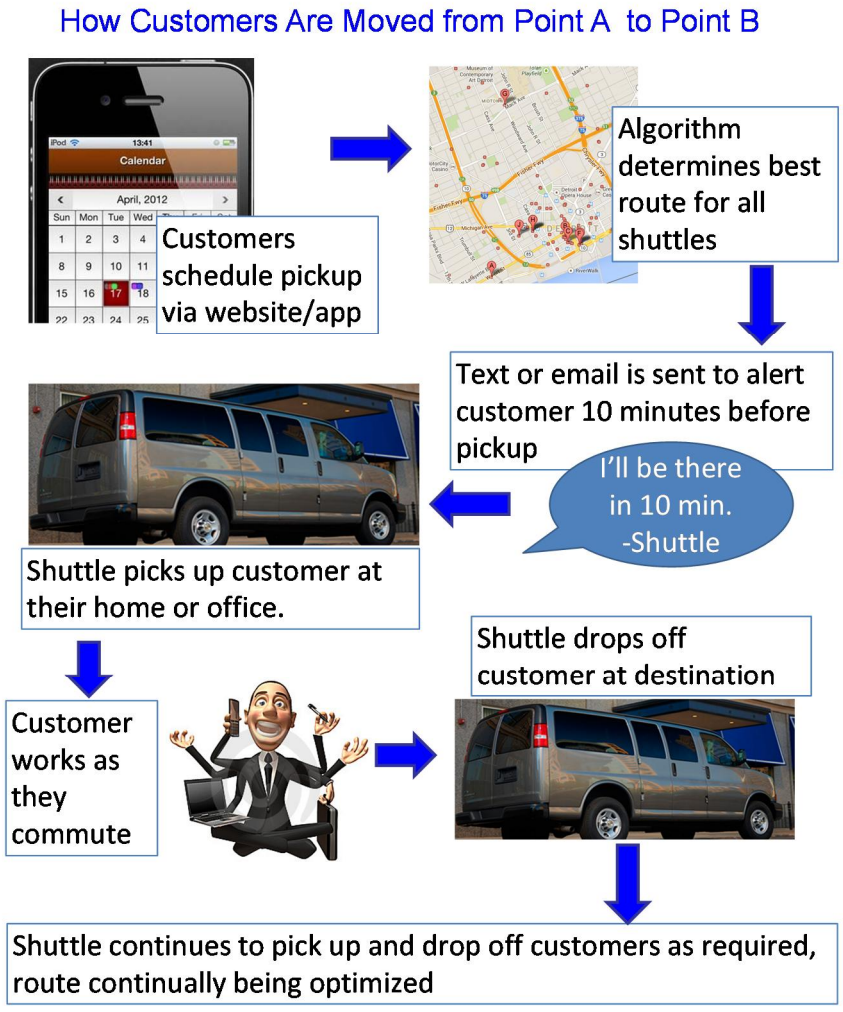


Figure 13 - Shuttle Service Flow Chart

Figure 14 below is a functional diagram of the shuttle service. The diagram breaks down the task of reducing commuter fuel consumption and improving work life balance, without compromising the

quality of the customer's work, into essential functions. The green boxes show our initial concepts which provide the essential functions listed.

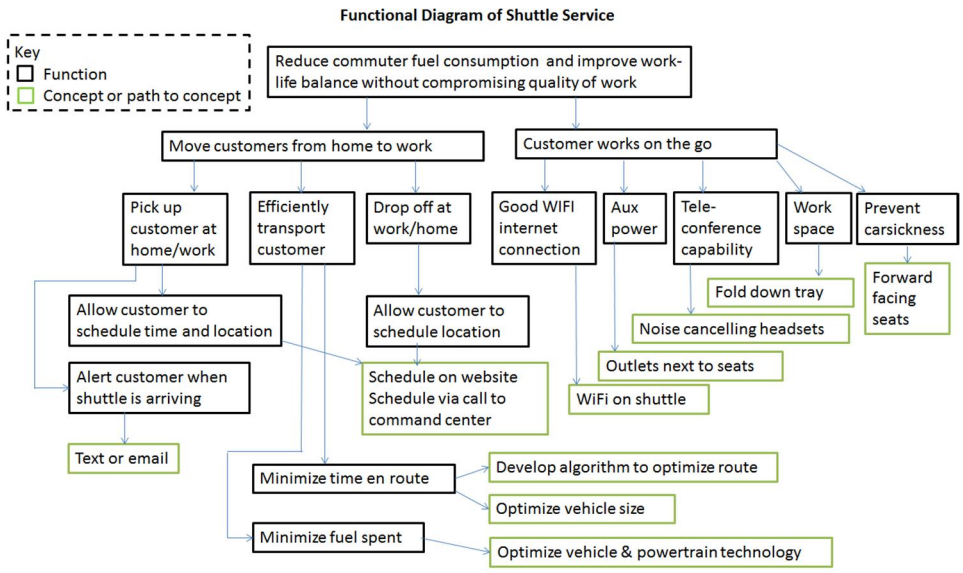


Figure 14 - Functional Diagram of Shuttle Service

Interior Shuttle Features to help the customer work on-the-go:

This shuttle will have special features which are required to help the customer maintain the same level of productivity that they would at their desk. The features are outlined in Figure 15.

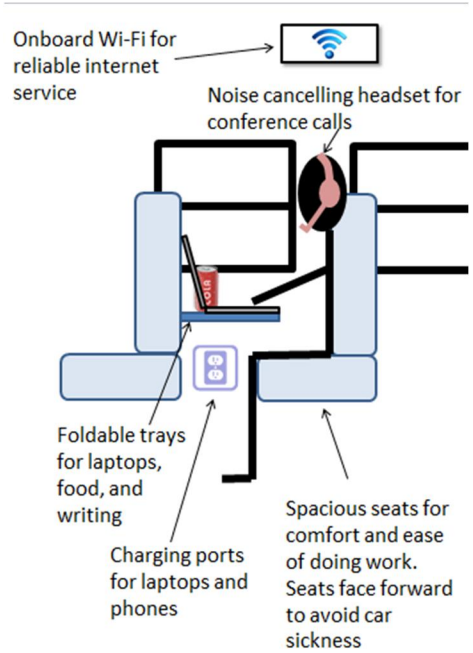


Figure 15 - Shuttle features which enable the customer to work on-the-go

Initial estimates at fuel savings (environmental impact):

Our initial estimates at fuel savings per passenger are shown below for one leg of their daily commute. The initial results show that the solution makes sense in terms of reducing fuel consumption, and therefore CO2 emissions, if there are even two passengers on a twelve passenger van as long as each passenger does not add to the total commute distance by more than half a mile (one way). This analysis does not take into account the fuel economy penalty associated with the additional accessory loads required for interior work productivity features nor does it include the fuel economy penalty associated with the additional mass of the customers. Even so, if just three passengers rode on the 12 passenger bus, the fuel used per passenger would be a 41% savings over the baseline. This tells us that the shuttle service shows a promising environmental improvement, but further, more detailed calculations need to be carried out to confirm fuel savings per passenger. Initial calculation results are shown in: Appendix III: Alpha Design Fuel Economy Calculations.

Method and Assumptions:
Baseline: 2008 Ford Fusion (20mpg city/28mpg highway)
Shuttle: 12 passenger 2014 Chevy Express (11mpg city/17mpg highway) [20]
Both vehicles get the EPA label city and highway fuel economy.
Baseline commute is 24 miles, 14% is city driving and 86% is highway driving, which is based on the persona's commute.
Each additional shuttle passenger adds 0.5 miles of city driving, which adjusts both the total miles driven and the average fuel economy of the shuttle.
Average fuel economy is calculated by taking city mpg * city miles driven + highway mpg * highway miles driven
Total fuel used = Total Miles Driven/Average fuel economy
Fuel used per passenger=Total fuel used/number of passengers

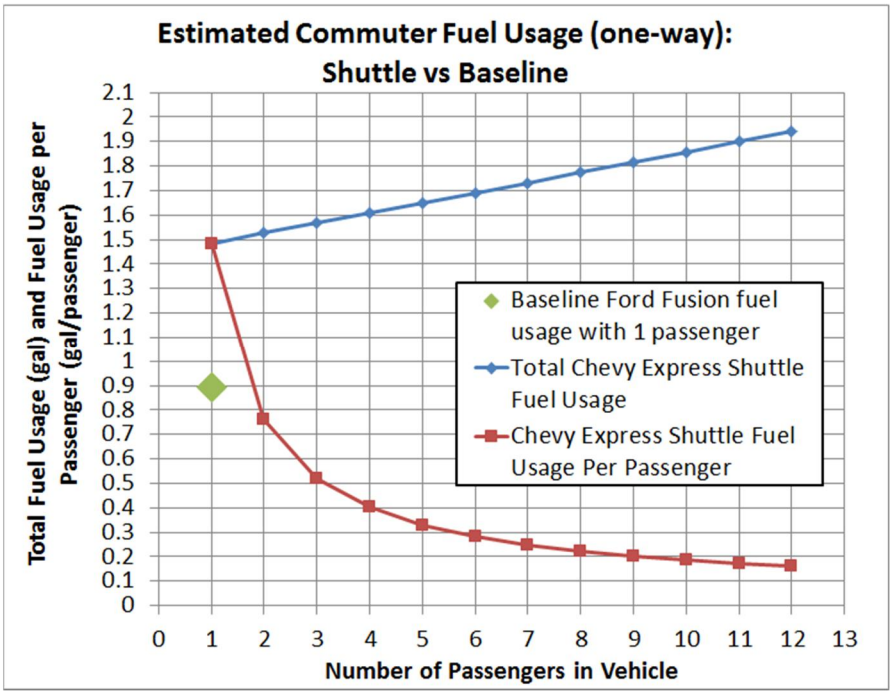


Figure 16 - Estimated Commuter Fuel Usage: Shuttle vs Baseline

Alpha Design Feedback

We created a survey to get feedback on our alpha design. We began the survey with generic questions about the person's daily commute and what they thought about ride sharing. Then we showed the survey taker Figure 15 and short description of the service before asking more specific questions related to the product itself. We were trying to elicit feedback on the design features, the likelihood that the person would use the service, what they would be willing to pay, and what they liked and disliked about the service. The survey questions and a summary of the responses are shown in the section: Survey – Alpha Design Feedback & Results. We received 29 survey responses, the results of which are discussed below.

Survey Results

A summary of the numerical responses are shown in Table 10. The average survey taker works 8.4 hours a day and commutes 20.2 miles in 34.3 minutes each way at a gas mileage of 25.7mpg. Seventy five percent of the survey respondents said they would consider taking the service, which is encouraging, but many noted that their continued use of the service would depend on how the service was implemented. The people who responded "No" also commented that their commute was already short, so the service wouldn't be beneficial for them.

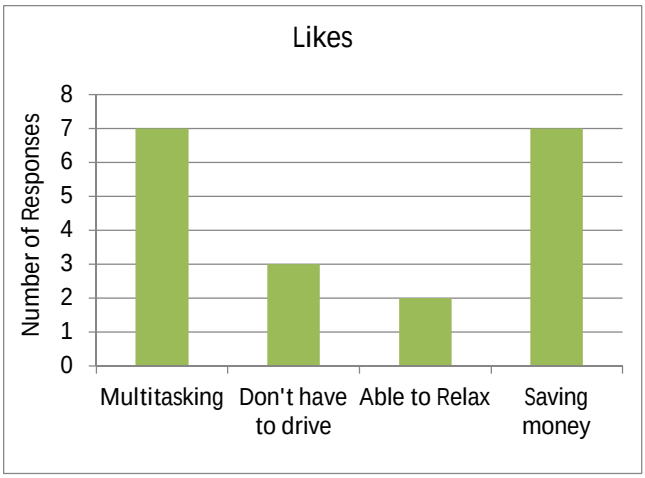
Survey Numerical Response Summary								
	How many hours a day do you work on average? (hours)	How far is your daily commute to work? (miles)	How long is your daily commute to work? (min)	What percent of your current commute is city driving? (%)	What gas mileage do you typically get on your commute? (mpg)	How many times a week do you think you would use the service?* (days)	Approximately how much per month would you be willing to pay for your shuttle?* ($)	If the shuttle increased your commuting time, how much additional time would you tolerate?* (min)
Average	8.4	20.2	34.3	51.0	25.7	4	108.2	21.8
Maximum	10	52	110	100	50	5	250	60
Minimum	6	2	7	5	15	2	30	5
Std Dev	0.7	14.2	23.2	37.7	9.0	1.2	49.6	8.7

* Survey takers who responded that they would ride the shuttle 0 times/week or pay <$10/month for the service were thrown out

Table 10 - Survey Numerical Response Summary

Likes and Dislikes

The survey takers commented on their likes and dislikes about the service. Their comments were categorized and shown Figure 17. The highest ranked positives attributes were the ability to multitask and ability to save money, which validates the purpose of our shuttle service: saving time and money. The biggest dislikes were the reduced flexibility and increased commute time. We were concerned that these two items might be an issue, but the fact that 75% of our survey takers were willing to try out the service means they prioritize multitasking and saving money above flexibility and time on the road as long as they get the service they expect. It is highly critical that the service is implemented well.



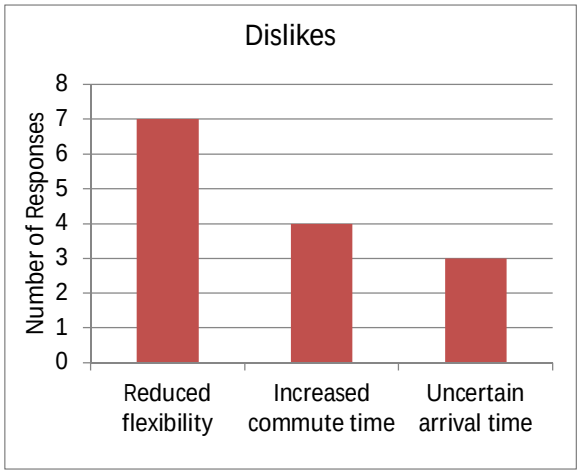


Figure 17 - Survey Respondents' likes and dislikes about the shuttle service

Shuttle Service Performance

We asked the survey takers to rate the importance of various aspects of the shuttle services. The results showed that the quickest drive to work is very important. Also ranking as important are: known arrival time, cheapest ride to work, and more options for pickup and drop off times. From this we have confirmed that the customer wants flexibility, convenience, consistency, and low cost and they do not want their time wasted. The results of the survey can be found in Appendix I: Survey – Alpha Design Feedback & ResultsSurvey – Alpha Design Feedback & Results.

We asked the survey takers to input the additional commute time they would tolerate and the average came in at 21.8 minutes, so we will aim to minimize the additional commute time, with the goal that no commuter exceeds their normal commute time by more than 22 minutes. The results of this survey question are shown in Table 10.

Shuttle fee pay period

We found that 56% of our survey takers would prefer to pay per month. Originally we thought we would charge per ride, but a monthly pay rate would bring more stability to our revenue as well as please the customer, so we will charge a monthly fee.

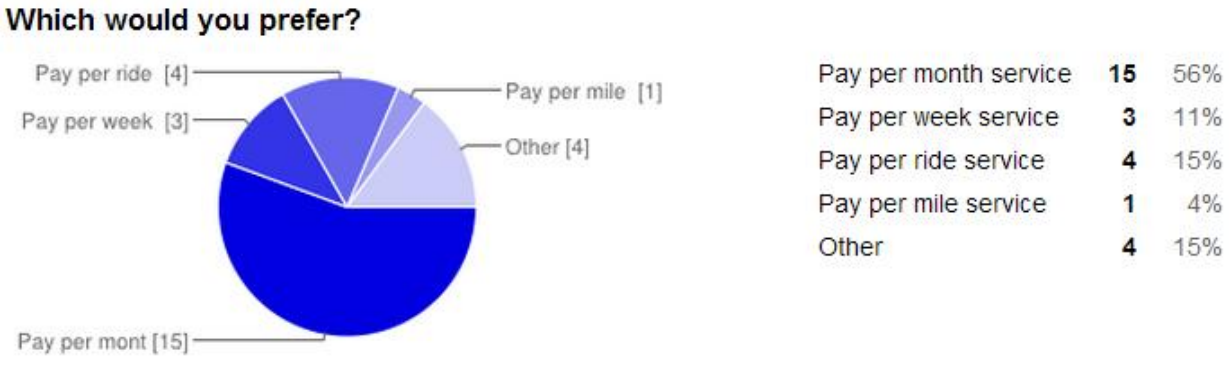


Figure 18 - Fee payment frequency preference

Shuttle pickup location

The shuttle pickup location is a tradeoff for the customer. The closer the pickup location is to the customer's home, the longer the overall ride will take. We wondered if customers preferred the convenience of being picked up at home or the convenience of a shorter commute more. We gave the survey takers 3 options: pick up from home, pick up from a neighborhood pickup zone, or pick up from the nearest park and ride. The survey results show that 39% of people preferred to be picked up at home. While not a majority, it is still 10 percentage points higher than the next highest response, so we will start our business by picking people up from home. We could re-evaluate this after a few months of operation to see if this is the best option for our business.

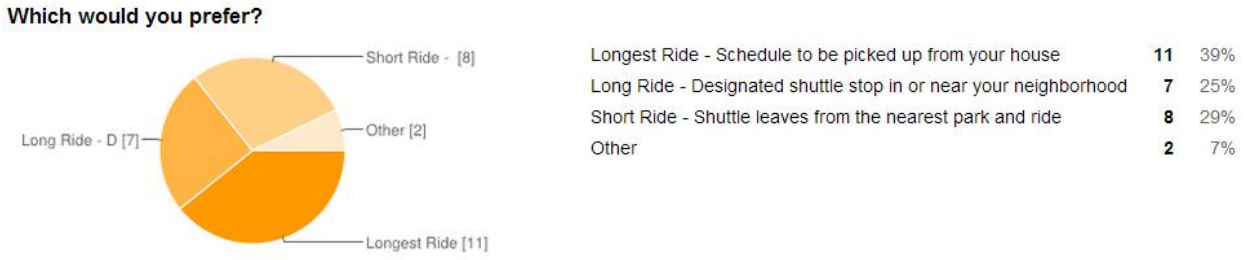


Figure 19 - Shuttle pickup location preference

Shuttle pickup frequency

Another design tradeoff is the frequency with which people are picked up from their homes versus the cost of the service. As a business, we have to charge more for more pickup options because it will cause us to purchase smaller shuttles and have more of them travelling a longer distance than one large shuttle bus. We gave the survey takers the option of one pickup time (the cheapest option), 3 pickup times (more costly), and scheduling the shuttle for the customer's desired time (most expensive). When cost is a factor, 54% of people chose the second option, 3 pickup times. 32% of people chose the cheapest option, just one pickup time. When cost is not a factor, an overwhelming 78% of respondents chose the third option. We interpret this to mean there is a balance between cost and convenience and the customer desires a choice in their scheduled time. We plan to start out with designated pickup times, but would continue to optimize the algorithm to allow more flexibility in scheduling as a customer satisfaction improvement as the business grows.

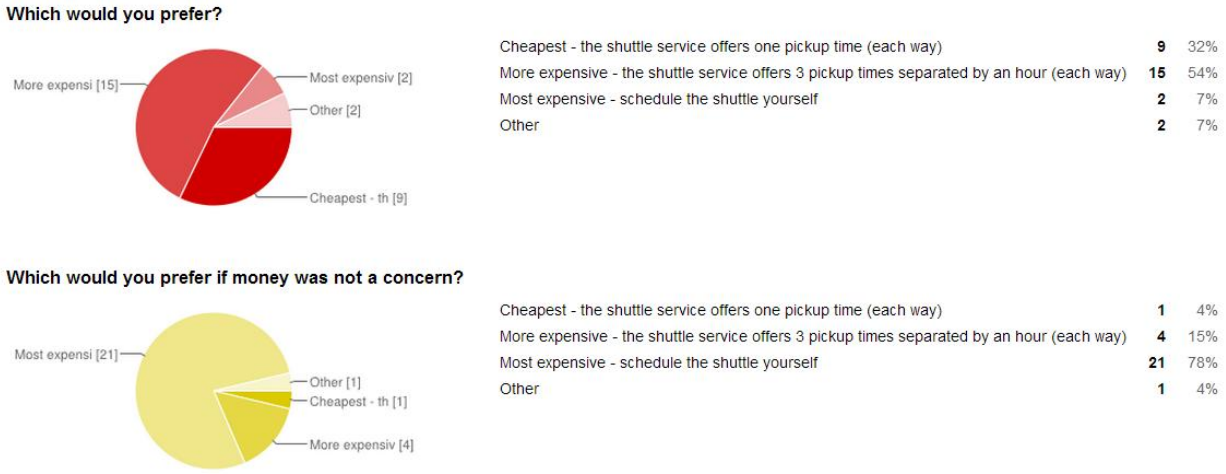


Figure 20 - Shuttle pickup frequency preference both considering and not considering cost

Shuttle Features

We asked the survey takers to rate the importance of each of the shuttle's features to help us understand what is high priority to the customer. Items that were ranked as important were: fast Wi-Fi, comfortable seats, enough space to work on a computer, seat preference (aisle or window). Moderately important features are: undisturbed conference calls and quiet atmosphere. Features of little importance or unimportant are: individual air (A/C or heat) control and cheap food availability. Now we know that we should focus on a good internet connection and comfortable seats and spend less time worrying about food service and individual climate control. The results of the survey can be found in in section: Survey – Alpha Design Feedback & Results.

Final Concept Description

Our concept is similar to the alpha design with a few changes. We are starting this as an independent business without the partnership from large companies because we would like to see where the customers come from first. We would try to partner with companies whose customers we shuttle the most.

Based on survey feedback we have made the following changes and refinements:

- A customer's shuttle commute time will be no longer than 22 minutes more than the customer's regular commute time. That generally means about a 50 minute commute for the Troy- Detroit commuter.
- The payment frequency will be monthly, so the customer will be charged a monthly fee and will be able to schedule pickups after the fee has been paid. This will be automated, so the customer can automatically charge a credit or debit card and continue their same monthly schedule without having to go online if that is the customer's preference.
- The shuttle pick up location is the customer's home. This was confirmed through survey feedback.

- The customer will be allowed to select one of three pickup times based on their location. After the customer enters their home and work locations, the algorithm will select three 30 minute windows for the customer to choose from for each leg of the commute. Customer morning pickup time options will be roughly in the 6:30-7:30 hour, 7:30-8:30 hour, and 8:30-9:30 hour. Customer evening pickup times will be roughly in the 3:30-4:30 hour, 4:30-5:30 hour, and 5:30-6:30 hour. We expect the algorithm to get better over time, allowing pick up windows to be narrower.
- There will not be food offered initially on the shuttle. The customer did not demand it based on survey results and we will not complicate the business with food offerings at this time. That will be a potential customer satisfaction improvement as the business grows. We can learn what the customer desires by asking the customers who take the shuttle for their preferences.

The service area, shuttle van, and service description are provided in detail in the following paragraphs.

Service Area

We have defined the initial shuttle service area as the city of Troy and the area of Detroit bordered by M10, I-75, and I-375. There are a number of large corporations in both areas as well as commuters who live in these areas, which is further described in the business plan. The service areas are shown in Figure 21Figure 21Figure 21 and Figure 22Figure 22Figure 22.

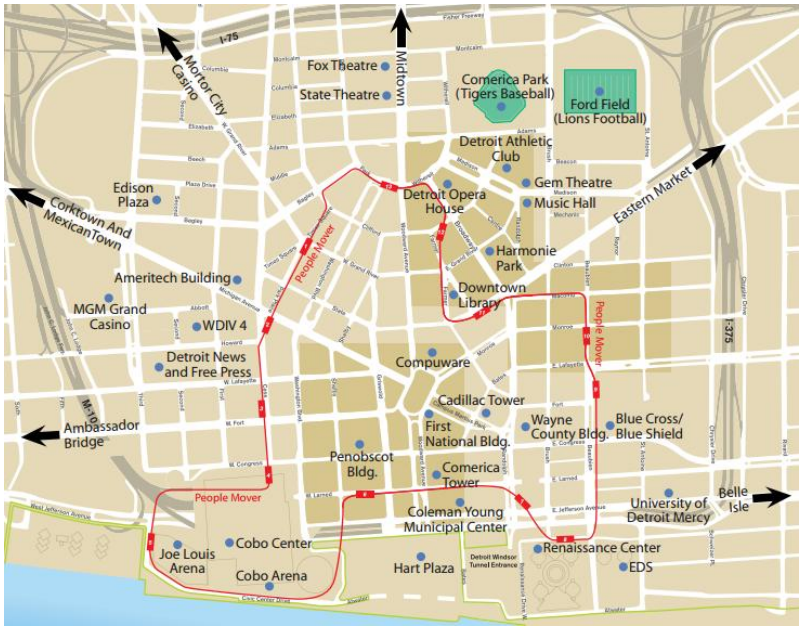


Figure 21 - Detroit Service Area: Roughly 1.1 miles x 1.1 miles (28)

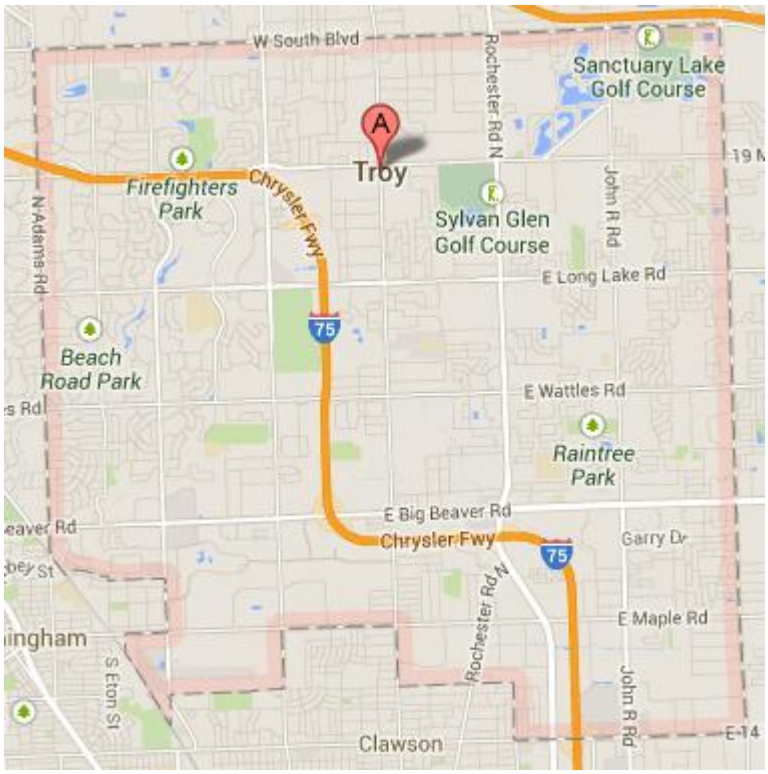


Figure 22 - Troy Service Area: Roughly 6 miles x 6 miles (29)

Shuttle Description

The shuttle will be a 2014 Chevrolet Express 3500 12 passenger van with 11 seats arranged as shown in Figure 23. The Express was chosen because of its fuel economy. Many commercial vans we researched exceeded the EPA mass requirement for reporting fuel economy, but the Express gets 11mpg city and 17mpg highway, which we found to be the best in the 12 passenger van category (30). We chose a van as opposed to a large bus because we wanted to meet the customers' desire to be picked up at home. A van will maneuver the suburban streets better than a bus and will get better fuel economy doing that. More vans can be purchased for the price of a bus, so multiple people can be picked up in multiple areas of the city at the same time.

All features described in Figure 15 of the alpha design still exist in the final design. Locations of tray tables, seats, headsets, and Wi-Fi router are shown in Figure 23. We selected the Verizon Jetpack 4G LTE Mobile Hotspot MHS291L for the shuttle Wi-Fi because of Verizon's excellent service in the area and because of their 50GB per month plan which allows 10 users to access the internet (31). Further optimization of both the vehicle and vehicle interior could be done to improve fuel economy, seat spacing, and location of features. We planned to run a sensitivity analysis to diesel versus gasoline engine but were not able to find diesel engine fuel economy for large vans.

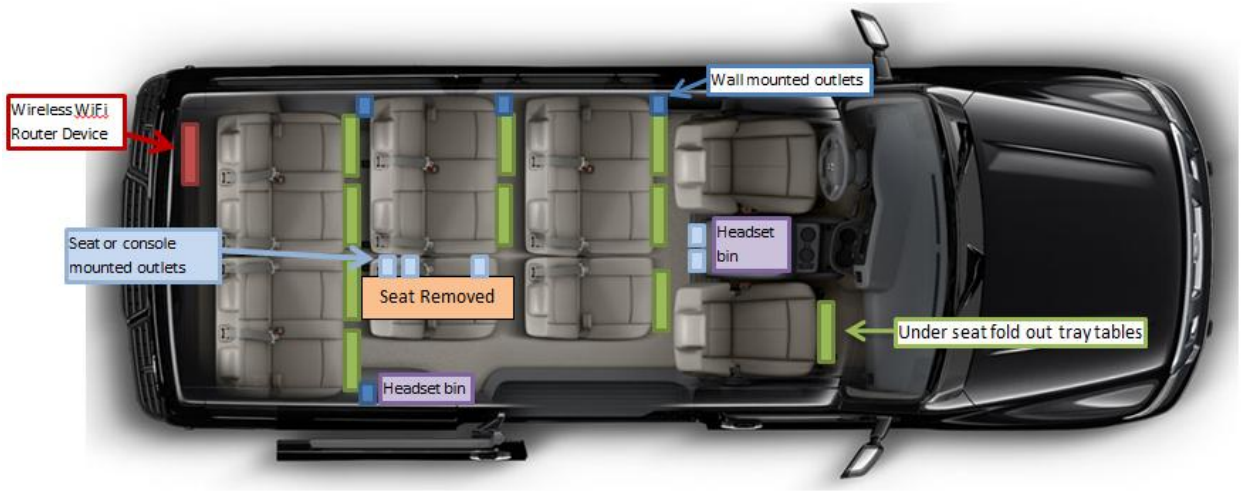


Figure 23 - Shuttle Seating and Feature Configuration (32)

Shuttle Service Functionality

Only small tweaks were made to the functional diagram in between the alpha design and final design based on customer feedback. As shown in Figure 24, the scheduling was changed to 3 optional windows per leg of the journey. Also, all scheduling is done through mobile application or through the website, because we could not afford to pay for an additional person to man the phones at a call center.

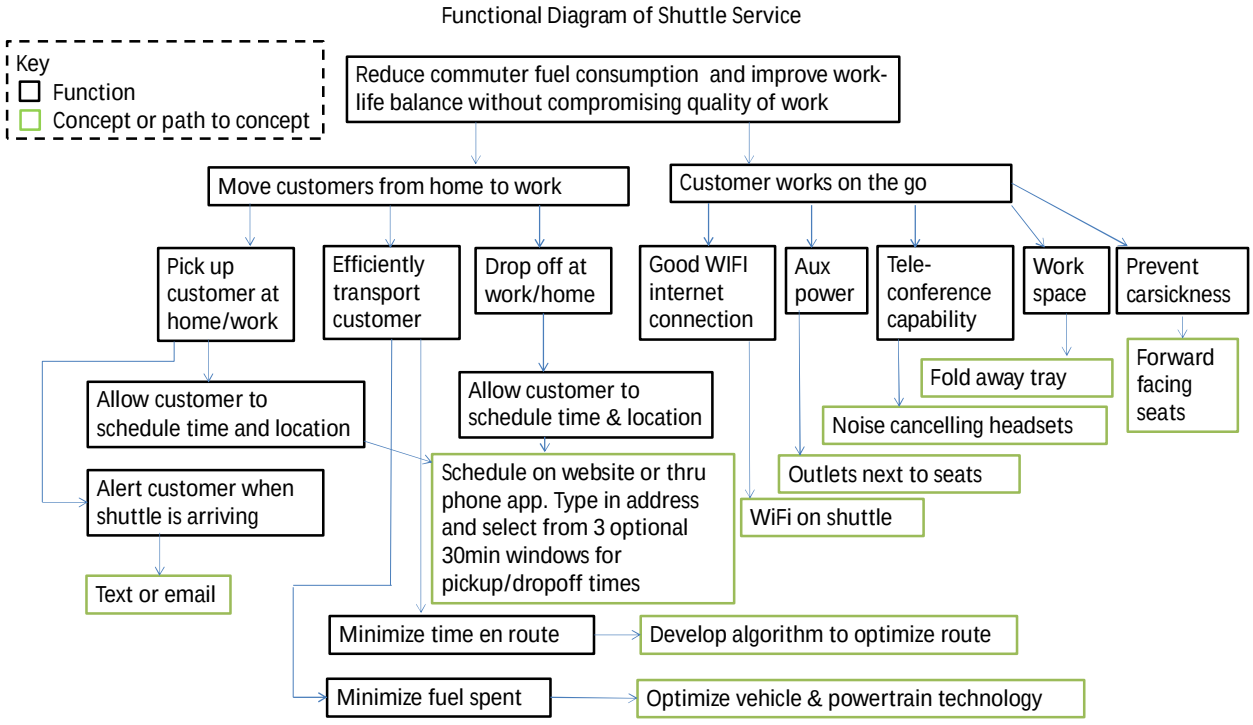


Figure 24 - Final Functional Diagram of Shuttle Service

The updated flow chart for the shuttle service is shown in Figure 25. The flow chart was updated to show that the customer has 3 selections for pick up times for each leg of their journey. The flow chart also shows that the process is continuous until the shuttle is no longer needed, meaning that additional customers may be picked up along the way and dropped off along the way. Customers may be picked up in Detroit after Troy customers were dropped off and customers may be picked up in Troy after Detroit customers are dropped off. The more passenger throughput the shuttle gets, the more money the service makes.

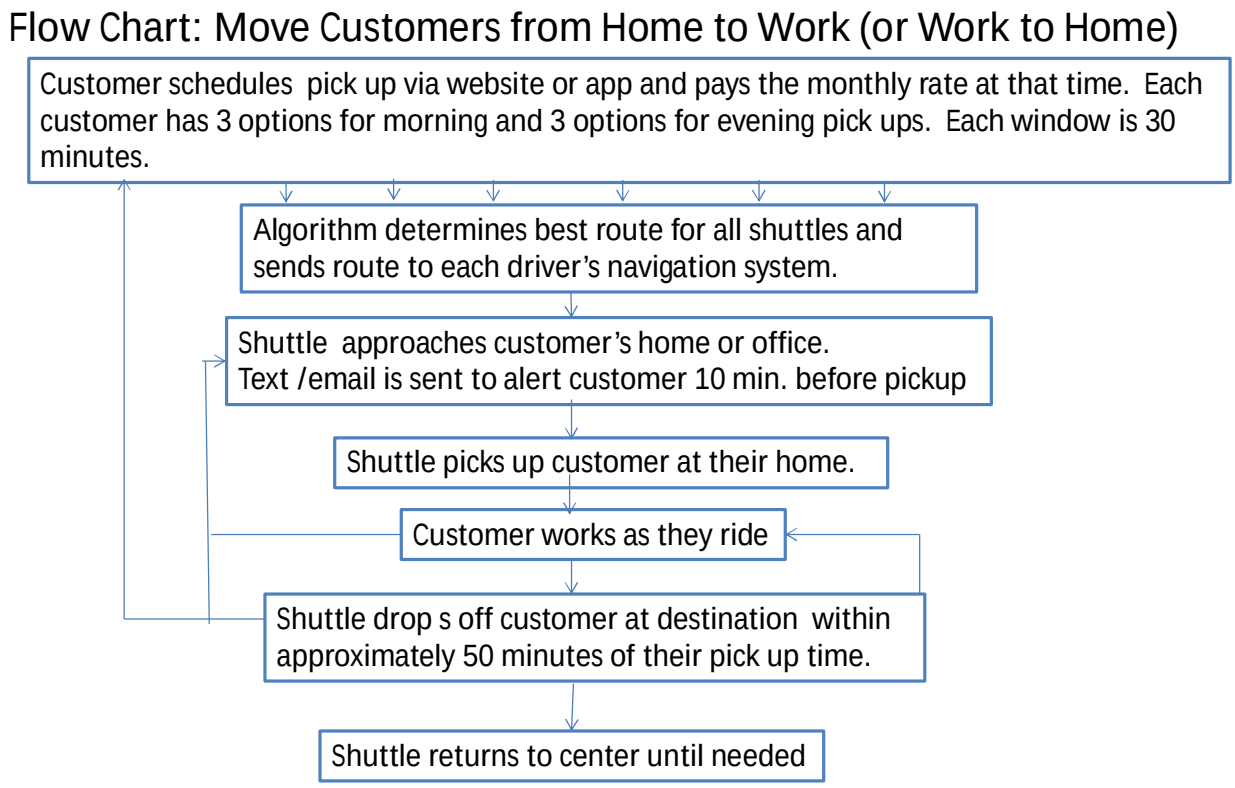


Figure 25 - Final Shuttle Service Flow Chart

-

Fuel Economy, CO2 Emission, and Cost Sensitivity Analysis

Because we aren't able to accurately predict how the shuttle service will operate and what all the costs will be, we decided to do a sensitivity analysis to additional shuttle distance per passenger, number of shuttles, number of passengers per shuttle, and the price of gasoline. The analysis encompasses additional fuel usage, CO2 emissions, and estimated effect on our breakeven rider fee as well as overall startup costs. From this analysis, we are able to finalize the number of shuttles and number of passengers per shuttle. We are also able to quantify some of the uncertainty in the business. Figure 26 shows the fuel usage sensitivity to number of passengers and also to the number of additional shuttle miles added per passenger. Figure 27 shows the CO2 emission sensitivity to number of passengers and also to the number of additional shuttle miles added per passenger. Figure 28 shows the sensitivity of

the break even fee, or the fee we would have to charge in order to break even on a monthly basis, to several factors, such as number of passengers per shuttle and additional miles per passenger. Figure 29 shows the total startup cost sensitivity to the same factors. The baseline in the cost analysis is a 5 shuttle business with 10 passengers per shuttle. Each passenger adds an additional 0.5 miles one way. Gasoline is assumed to be $4.00/gallon in the baseline. Further cost analysis is shown in the business plan and calculations can be found in Appendix IV. Fuel economy and CO2 calculation tables are shown in Appendix III.

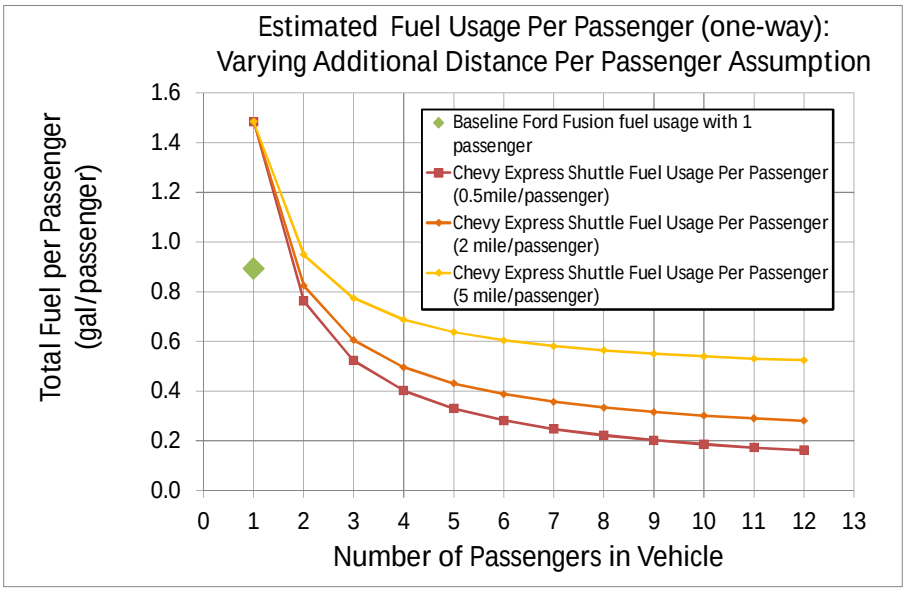


Figure 26 - Sensitivity Analysis: Fuel usage per passenger as additional shuttle commute distance per passenger increases

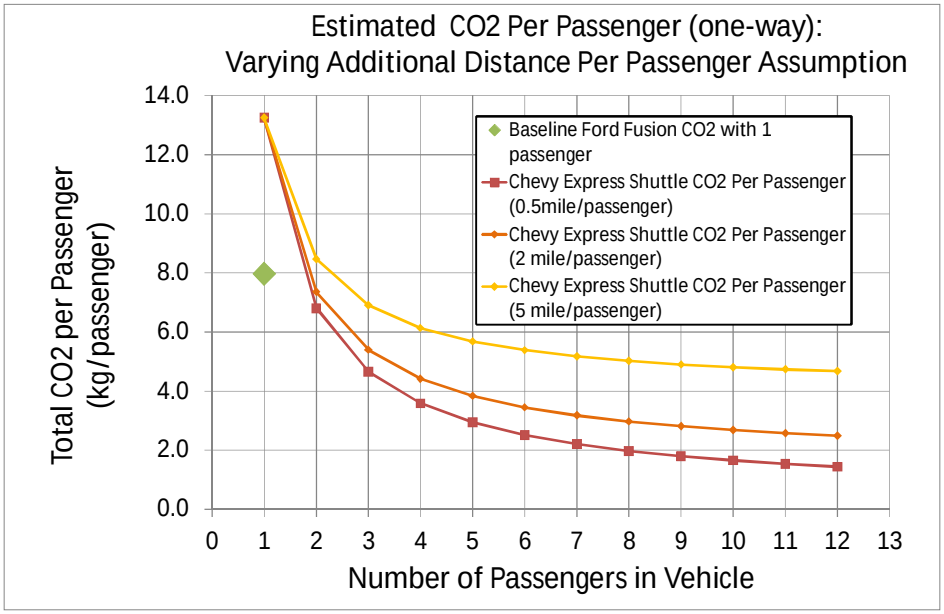


Figure 27 - Sensitivity Analysis: CO2 per passenger as additional shuttle commute distance per passenger increases

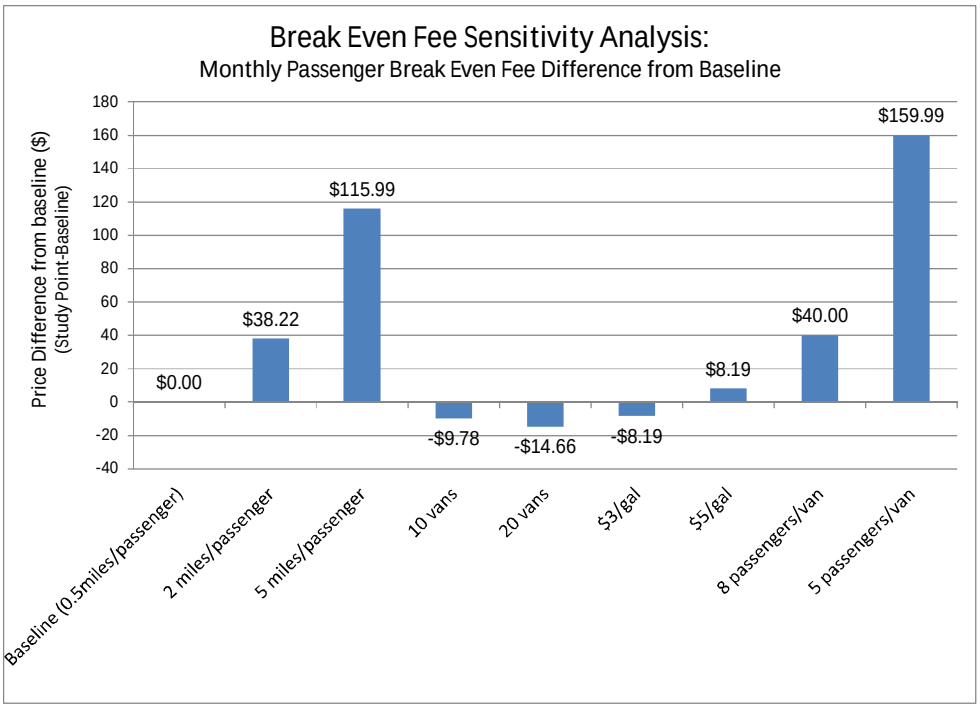


Figure 28 - Break Even Fee Sensitivity Analysis

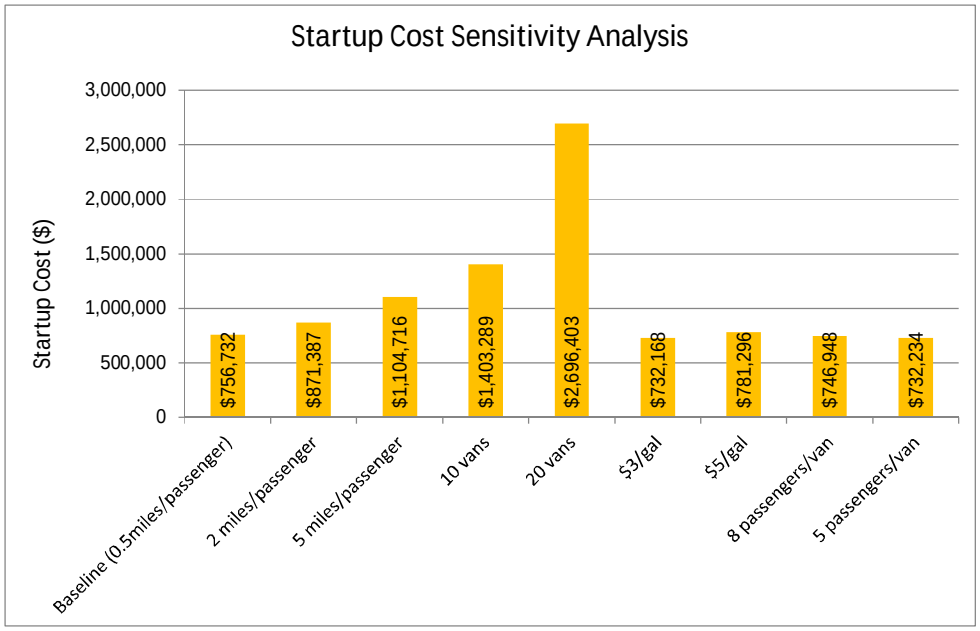


Figure 29 - Startup Cost Sensitivity Analysis

Number of Seats per Shuttle

In terms of fuel and CO2 saved per passenger, the curves in Figure 26 and Figure 27 begin to level out after about 6 passengers, so for environmental reasons, we want at least 6 passengers per van. Figure 28 shows that there is a huge difference in the breakeven fee we'd have to charge based on number of seats per shuttle, so we need to make sure the shuttle is packed. That is why we chose to put 10

passengers in a 12 passenger shuttle. We removed one seat as shown in Figure 23 to provide the customers with extra space for comfort and ease of entry, to try to meet their desire for comfortable seats.

Sensitivity to number of Shuttles

The break even monthly fee would drop by $9.78/month/passenger and by $14.66/month/passenger if the number of vans was doubled and quadrupled, respectively, as shown in Figure 28. However, the startup costs increase by $1.4 million and $2.7 million for the same increase in shuttles. This does not take into account reduced distance travelled per customer. We were not willing to invest in more shuttles the first year because of the small pay out and the infancy of the route optimization algorithm, so we will stick to 5 shuttles until we have money to invest more into the business.

Sensitivity to additional distance per passenger

We are not able to predict the additional shuttle distance per passenger, so we studied the sensitivity to fuel usage and cost. In a 10 passenger van, the fuel and CO2 increases by about 0.08gal/passenger/mile and 0.7kgCO2/passenger/mile as shown on Figure 26 and Figure 27. This corresponds to an approximate $26 increase in the monthly shuttle fee per additional mile travelled per customer each way as shown on Figure 28. This confirms that the algorithm needs to be efficient in routing the shuttles in order to keep distances to a minimum and costs down.

Sensitivity to price of gasoline

Gasoline prices are uncertain, so we studied gasoline at $3/gallon and $5/gallon and compared it to the baseline at $4/gallon. The results are that the break even fee would have to increase by more than $4/month for each additional dollar per gallon cost increase. If the cost of gasoline goes down one dollar per gallon, then we would make an additional $4 per month per passenger. This is shown in Figure 28.

Overall, the break even fee is highly sensitive to number of miles added per passenger and number of passengers per shuttle. The total startup cost is most sensitive to the number of shuttle vans in the fleet.

Business Plan

Company Description

Primary Business:

Motor City Shuttle is a transportation service for commuters in the metro Detroit area.

Mission Statement:

Our goal is for our customers to save time, money and be productive during their daily commutes.

Business Philosophy:

We at Motor City Shuttle are focused on relieving the pain of a stressful commute that takes away otherwise productive time in your busy schedule. We do this by providing amenities such as spacious and comfortable seating, power outlets, tray tables and WI-FI service for the business professional on the go. Our company smartphone app or website allows you to schedule a pickup from several set time options and our shuttle service will notify you when we are in the area and will pick you up from your house.

Market Analysis

Southeast Michigan is home to more than 300,000 businesses, is 9th in the nation with 20 Fortune 500 companies, has the 6th fastest growing economy in the nation and has a population of over 5 million people (33). Regionally, an estimated 2,034,800 workers commuted to work every single day between 2006 and 2010 (34). As can be seen below in Figure 30, this area is home to many different business sectors.

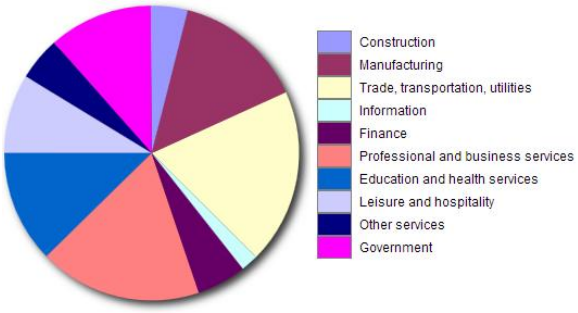


Figure 30 - Labor Force Distribution in Detroit (35)

Our target customers are those working in professional and business services, finance and the information sectors. However, the shuttle applies to anyone that regularly does work on a laptop or tablet which may also include commuters working in education, health, government, manufacturing, construction or other services.

Michigan also leads the nation in the percentage of commuters that drive alone with 84.3% (36). This is a very large market to explore in terms of potential customers given our positive feedback from our alpha design survey. Furthermore, as can be seen in Figure 31, our target commuting areas of Troy and Detroit rank in the top five of southeast Michigan in largest daytime population change. As the business

grows, we will serve other communities in the area with high population densities and businesses including: Southfield, Dearborn, Ann Arbor, Warren, Sterling Heights, Pontiac, Livonia, Royal Oak, Flint, Saginaw, Lansing and Windsor.

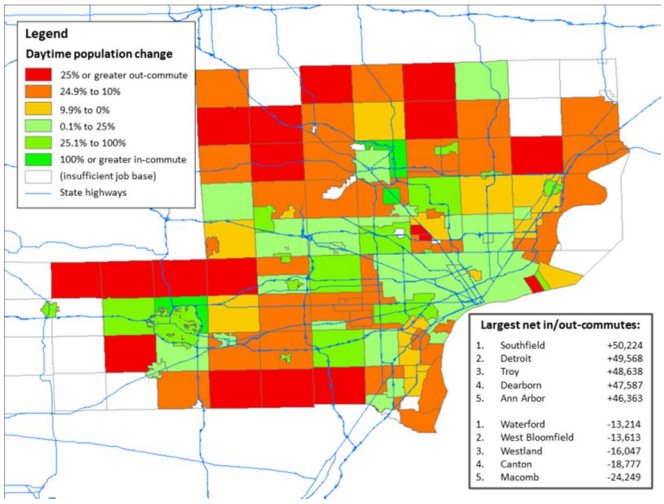


Figure 31 - Daytime population change southeast Michigan (37)

The largest competition to our shuttle service is commuters' choice to drive themselves. Other competition includes shared ride options. Among shared ride services, the SMART public transportation bus is the largest in terms of riders in the area. Michivan is another shared ride service in which commuters with similar routes sign up to share the fees for a vanpool service (38). Michivan serves many commutes in the area including Troy to Detroit (39).

Motor City Shuttle presents many advantages over the above mentioned competition. Some advantages are listed below:

- Pickup from customer's home
- Three pickup times
- Comfortable and spacious seating
- Amenities to allow customers to work productively during their commute
- Price that consumers are willing to pay

Some weaknesses compared to the competition include:

- New Company, Inexperienced
- Inflexible Schedule (compared to commuter vehicle)
- Increased Drive Time (compared to commuter vehicle)
- Inconsistent arrival time (compared to commuter vehicle)
- Price is High (compared to cost of commuting in a mid-size car or public transportation)
- Low profit margin for business

Barriers to start this business include:

- Obtaining investors
- High capital costs
- High monthly costs
- Successful marketing (consumer acceptance and brand recognition)
- Whether the product actually meets customer needs

Product Description

Based on the customers' need to save time and money, we are providing a shuttle service that picks the customer up at home, drops them off at work, and lets them work efficiently on the commute. The shuttle also provides the same service from work to home. The customer is able to use features such as high speed internet provided through in-vehicle WiFi, tray tables for work space, auxiliary power outlets for electronic devices, and noise cancelling headsets for conference calls to work efficiently during the commute. The customer will no longer waste time driving, because they can multitask and no longer frustrate themselves driving, because our shuttle drivers are handling the stressful drive for them.

The shuttle service is much faster, reliable, and more business friendly than public transportation. It is less stressful than commuting on an individual basis and allows the customer to spend less total time working + commuting because they can multitask. There are no shuttles with the same amenities in Metro Detroit, but if there were, they would not have the connectivity and advanced routing algorithm that our service has.

Our idea is still in the early design stage. The routing algorithm, website, mobile application, and shuttle communication method need to be developed and details of the shuttle interior modifications need to be ironed out. Prototypes need to be built, drivers need to be hired, and trials need to be performed. This service would apply to the shuttle van's use phase and an end of life strategy needs to be outlined. The use phase of the shuttle will be determined by the quality of maintenance and miles driven. The shuttle will replace some of the use phase of commuter vehicles, possibly allowing two car families to become one car families, or at least allowing the commuter vehicle ownership time to increase.

We validated our concept through a survey. We found that 75% of survey takers were interested in trying our alpha concept. As shown in Figure 17, we received feedback from 7 people that they liked the ability to multitask on the commute and 5 either liked the idea of relaxing or not having to drive themselves to work. Positive comments, such as, "I like that I have time to relax, make calls, someone else can get frustrated with the driving," validate the potential of this idea. These comments and all survey results can be found in Appendix I: Survey – Alpha Design Feedback & Results.

Marketing Strategy

Market Penetration Strategy:

According to our alpha survey results, we will charge a price that commuters are willing to pay at $214 per month. We will target Troy to Detroit and vice versa commuters similar to our persona as our first customers. With limited seating on the shuttles, this business provides a low profit margin and with this we expect it will take time to grow the business.

Communication Strategy:

We will market the shuttle via peak commuting time radio commercials and flyers and brochures delivered to companies and placed on cars in the target area. After startup, we will try to develop relationships with large companies such as GM and Compuware whose employees we shuttle. Specifically, we plan to educate them on benefits that shared rides can bring to their organizations. Benefits to employers include improved employee recruitment and access to labor markets, competitive advantage in tight labor markets, improved employee retention and reduced employee turnover expenses, enhanced productivity and work environment, tax savings, reduced demand for employee parking, additional flexibility to grow and expand and national recognition as a community leader (40). In turn, they may elect to subsidize some of the shuttle service expense for their employees, a tax write-off for them, which will lead to increased business and perhaps higher profit margins (allow for increased fees) (27). We will also contact other organizations to assist in getting our name out there. This includes trying to get on popular commuting websites such as the Michigan Rides service (https://mirideshare.org/en-US/https://mirideshare.org/en-US/) which offered by SEMCOG (Southeast Michigan Council of Governments), Commuter Choice (http://www.commuterchoice.com/http://www.commuterchoice.com/), and Best Workplaces for Commuters (http://www.bestworkplaces.org/http://www.bestworkplaces.org/).

Growth Strategy

After considering the initial investment, all profits will go towards more shuttles. Relationships with employers will be developed to bring in customers and to subsidize the cost. Once we have enough shuttles to meet the demand for Troy to Detroit, we will strategically expand our commutes to other areas in southeast Michigan. Once we have a healthy profit margin and recognition, we will seek to expand our market to other transportation services and may purchase an airport taxicab service company.

Business Costs & Outlook

Our prototype costs would be around $16,500 as shown in Table 11.

Prototype Costs	
Shuttle	3500
WiFi Device	50.00
Tray tables	200.00
Add A/C and Power Outlets	150.00
Noise cancelling headsets	900.00
Website and App Design	5,000.00

Route algorithm development	5,000.00
WiFi service	355.00
Gas	1,000.00
Insurance	280.00
Website hosting	10.00
Total	16445

Table 11 Prototype Costs

Our fixed startup costs, monthly costs, and revenue are shown in Table 12 for the first year of business. We are able to make a monthly profit charging the customer $214/month and assuming the shuttles are full with 10 passengers per vehicle. The payback period, assuming no return on investment to the investors, is 28 months. If we only get 6 passengers per vehicle on average and each passenger adds 2 miles additional distance, then we cannot make money as shown in Table 13. The sensitivity analysis shows us that we need additional sources of revenue, such as government or corporate subsidy. We could raise the fee for the customer, but we do not want to miss our target of $220/month or 90% of the baseline's monthly gasoline cost.

Startup costs	**Cost ($)**		**Monthly costs**	**Cost ($)**
Prototype Costs	$16,445.00		WiFi service	$1,775.00
Company Registration Fee	$25.00		Driver Pay & benefits	$16,800.00
Shuttle Van	$175,000.00		Gas	$9,207.69
WiFi Device	$250.00		Maintenance	$8,977.50
Tray tables	$2,000.00		Insurance	$1,400.00
Add A/C and Power Outlets	$750.00		Our income	$3,780.00
Noise cancelling headsets	$4,500.00		Route Algorithm continued optimization	$500.00
Website and App Design	$20,000.00		Website hosting	$10.00
Route algorithm development	$10,000.00		Corporate Income Tax (CIT)	$75.60
Radio Advertising	$20,000.00		Federal Income Tax	$289.17
Company Flyers and Brochures	$1,500.00		Monthly cost before overhead	$42,814.96
Smart Navigation System	$1,000.00		Overhead	$2,140.75
TOTAL FIRST YEAR FIXED COST	$235,025.00		TOTAL MONTHLY COST	$44,955.71
Revenue				
Rider fee	$53,500.00			
TOTAL YEARLY REVENUE	$642,000.00			

Table 12 Cost/Revenue Sheet

10 passengers/vehicle at 0.5miles/passenger			6 passengers/vehicle at 2 miles/passenger	
Fixed Cost	$235,025.00		Fixed Cost	$232,125.00
Monthly Cost	$44,955.71		Monthly Cost	$44,955.71
Monthly Revenue	$53,500.00		Monthly Revenue	$32,100.00
Monthly Profit	$8,544.29		Monthly Profit	-$12,855.71
Months to Payback	28		Months to Payback	-18

Table 13 Payback time for best case and worst case scenario

Additional Reflections on Project Outcome

Project Sustainability Evaluation

Sustainable design is a methodology that intends to balance environmental, social, and economic needs. These three goals need to be considered while conducting lifecycle assessments for any product. Nevertheless, it is very possible that a product can somehow become un-sustainable since there are still several factors that may impact the project environmentally, socially, and even economically.

Environmental impact is related to economic impact for any product. As seen in Figure 16, benefits of fuel usage saving begin when more than two people use the shuttle service for their commutes. It is also notable that if only one person uses the shuttle most of the time, both economic and environmental sustainability will be challenged due to more fuel being used. In the ideal situation, our shuttle would have 10 passengers per trip. That means that any one passenger's fuel usage per commute is drastically reduced compared to their regular commute. To put that into a life cycle perspective, the largest phase in any vehicle's life cycle energy or CO2 analysis is the use phase as shown in Figure 8 and Figure 9. We know that 27% of the average American's driving due to their commute (3). As shown in Figure 16 , the a passenger in our 10 passenger shuttle uses 22% of the fuel that the baseline Ford Fusion driver would use. Based on these values a shuttle passenger would use 50.4GJ less energy and 3.6 fewer tons of CO2 over the life of their vehicle due to reduction in commuting energy. The customer's hydrocarbon, particulate, SOx, etc emissions would be reduced at the same rate.

If a customer always takes the shuttle during his or her commute, the customer's personal vehicle would last longer, so the customer could potentially extend the life of their vehicle. Perhaps a two car family could become a one car family if the product really took off and one household commuter could count on the shuttle service every day. This would eliminate some raw material usage as well as energy and emissions associated with the manufacture of the second household car. The additional shuttles would have to be accounted for in the material production phase, but the net number of vehicles on the road would be lower, so it would be a net environmental improvement.

If the product catches on and more people take shuttles than drive themselves, congestion could be reduced, saving additional energy and reducing emissions further. Roads would also last longer with fewer vehicles travelling on them, improving the road material usable life.

Considering social sustainability, we have survey feedback that shows a commuter will be happy not dealing with the stress of the daily commute and the ability to shorten their overall work day by multitasking on the road. Socially, this service will likely make customers happier and less stressed, improving their health. However, a single shuttle service must accommodate groups of people from different backgrounds and work schedules. Thus, it will be challenging to deal with each passenger's personal needs such as working hours, time to report to and return from work, and flexible hours. The company may need to develop several different shuttle schedules and running hours and keep them as flexible as possible in order to meet each customer's needs. Thus, inconvenient situations lead to social unsustainability and eventually impact economic and financial sustainability within this initiative. If vehicles are mostly empty, the company will not meet financial and environmental targets.

It is worth noting that successful "corporate" or "private" shuttle services, similar to the product that we are developing, have impacted public transportation offered by the local government or city. According to AllThingsD's report, employee shuttle services offered by tech companies such as Google, Yahoo, and Apple in San Francisco Bay Area have generated significant complaints from residents such as "*forcing Muni buses to disgorge passengers in the middle of streets, blocking crosswalks, backing up traffic, traveling on restricted streets and interfering with bicycles using bike lanes.*" (41) The San Francisco Municipal Transportation Agency corporate board has discussed a plan for an 18-month trial of a policy that would bring the essentially unregulated private bus systems into line based on complaints from public bus drivers and passengers (42). This is possibly a concern for our shuttle, so we may have to deal with the public relations aspect if our shuttle gains popularity.

Economically, our shuttle business is challenged. It is able to make a monthly profit if the distance between commuters is short and if the buses are full. We need to consider other means of income in order to make this truly sustainable in a robust way. If we can find another means of income or keep our shuttles full and distances short, our company is properly positioned to succeed, since no equivalent service is currently offered in the metro Detroit area. Also, we truly believe shuttle service can provide the benefit of reducing fuel consumption emissions. However, the product will be unsustainable and unsuccessful if the majority of daily commuters still choose to drive individually due to the inconvenience, and not to cooperate with a daily commuting schedule.

Design Critique

Our goal for the project is aiming to reduce fuel consumption for daily commuters and reduce the CO_2 emissions for the global environment. Among the team members, we have been engaging in lengthy project discussions, brainstorming the bright ideas, researching the current markets for ultimate solutions, carefully selecting the baseline and persona, conducting a comprehensive survey process, and finally choosing to use a shuttle service as the final product of our research. The design process has also gone through several alterations to fine tune the final product design with an extensive ethnography analysis and information of LCA. We have established solid business plan towards the sustainability design of the final product. We believe that most of the feedback from the alpha design survey was positive and encouraging, leading to stronger specifications of the final product.

Despite the team's efforts of trying to create a great product design, the team feels like there are still some area of improvements to pursue, such as: the validity of the travel-route algorithm (since it has not been verified with an actual shuttle service), defined pickup/drop-off areas, the possibility of business costs being too high, and finally, the possibility that the recoupment time for costs will be too long. Several of these weaknesses will be addressed in the future project validation plans.

Future Recommendations

System-level recommendations for improvement include:

- Focus our attention to suburban commuters in metro Detroit earlier in the design process
    - Spent too much time with too wide of a scope

- Spend more time understanding the design process early on before trying to come up with solutions
- Use LCA software for more detailed analysis of the use phase, material production and assembly phases of the shuttle vs. baseline. Explore other design tools like the LIDS wheel.
- Optimize the vehicle – Sensitivity analysis to different and more efficient shuttle vehicles: Optimize vehicle--what size vehicle is best? What powertrain?
    - Which configuration makes the most sense in terms of cost? Environmental impact? Customer needs?
- Talk to existing shuttle services to gain valuable information about customer needs and how to be successful in this business
- Analyze other cities and regions in terms of market potential
- Get employers involved in our business – talk to them about benefits for them such as a tax credit
- Find other ways of generating revenue (tax write-off, grants, company subsidies, government subsidy, and advertising, charging for services (meals, for example. or first class vs. coach or executive shuttle))

Detailed-level recommendations for improvement include:

- Design for function and sustainability: best seats, best seat location in a van, and work with a auto company/interior design company like Prefix to integrate it and ensure safety.
- Routing Algorithm – The routing algorithm was not explained in detail, the details of how this algorithm might work needs to be further refined.
- More research on Wi-Fi internet service providers. Work with Wi-Fi/internet provider to enhance the features of internet services, such as 4G mobile Wi-Fi hot spot on the shuttle.
- Work with a company and create a prototype of the shuttle bus
- Further grading and refinement of shuttle concept with metro Detroit commuters
- Shop around for insurance
- Investigate purchasing a warranty for shuttle vs. paying for repairs
- Further investigate and break-down overhead costs for the business

Acknowledgements

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Appendix I: Ethnographic Data Collected

Interview - Suburban/Rural/Carpooler Commuter

Profile: Married, No Kids, Age 28, Long Commute (45 minutes, 45 miles), Suburban/Rural, Occasional Car-pooler, Middle-Class but frugal

Q: Describe your commute to work…for example walk me through your commute to work and back home today.

A: Got in my car this morning at around 6:45 AM. I stopped to get some coffee. I live in Grand Blanc and first drove on local streets for 10 minutes (city driving/back roads) and then about 35 minutes of expressway driving. The city driving is not too busy at the time I leave. There are about 1 or 2 lights, a couple of stop signs. The expressway driving consists of I-69 for 5 minutes, then I-475 for 10 minutes, and then I-75 for 20 minutes. My work is not far off of I-75 in Saginaw. I usually get to work right around 7:30 AM. After work I usually take the same way home. However about once a week I go to a co-workers house that lives in Saginaw and leave to come home around 8 PM or so. At that time I avoid I-475 and I-69 because I don't feel comfortable at night (a lot of crime). So I take I-75 to US-23. Traffic is not really an issue on my commute. When it is the summer time and everyone is going up north I am going the opposite way from the traffic.

Q: What do you like about your commute?

A: I like that I can zone out for a nice 40-45 minute ride before work. I like listening to the radio. Also like that I have plenty of time to make phone calls.

Q: What is frustrating about your commute?

A: The snow in winter makes the drive stressful. I have to be extra cautious and it slows down the drive. I have lost traction a couple times in the past and started skidding. It is a little nerve racking. There is a stretch of the drive that is never plowed north of Frankenmuth (between Birch Run and Bridgeport where there are no exits off I-75).

Q: Tell me what comes to your mind when you think about commuting to work…

A: I wish the drive was shorter. I often compare my current commute to my previous 10 minute commute. I sometimes dread my commute especially when the weather is bad.

Q: Have you ever compared alternatives to your current method of getting to work? Ex. Mass Transit, Telecommuting, car-pooling, moving?

A: No, I've never talked to my employer about telecommuting. I overheard somebody else saying that they tried talking to management about that and it didn't work out. Anyways it probably wouldn't work out since I work at a plant and have to often physically work with machines. I also have to travel to suppliers quite a bit. Sometimes I have to go to Macomb County or down to Detroit. When that is the case then I don't do the commute to work and just go straight there instead.

Q: What did you like about carpooling?

A: I especially liked that it saved gas. I alternated driving with one other person. We car-pooled from Flint area which is about 15 minutes into my drive. I also liked that there was flexibility to have them drive if I was super tired.

Q: What did you dislike about carpooling?

A: There were times when our schedules didn't match or I had to go to suppliers and we would cancel the carpool. It was frustrating to have to follow the carpooler schedule. For example if I wanted to leave early I would have to suck it up and stay unless they could manage to get a ride

from someone else. There was a big reliance on each other's schedule. We no longer carpool because he has to take his daughter to school and it would be too far out of his way.
Q: How could your commute improve?
A: The commute might improve if I carpooled with more people. The problem with that is even more difficult scheduling. Additionally, the roads could be cleared a lot better in winter. I cannot afford to get into an accident.
Q: What do you see in the future of transportation?
A: I see vehicles continuing to get better miles per gallon. Gas prices will continue to go up. I will probably try to carpool even more in the future.
Q: What concerns you about the future of transportation?
A: Definitely the price of gas concerns me. When I worked in Ann Arbor there was tons of traffic. I do not commute in an area with a lot of traffic, but I can definitely imagine a concern for people living in congested areas is that traffic will only get worse with increasing population.
Q: Have you personally made any changes to save time, energy or money in respect to your commute to work?
A: Just carpooling. I have stuck with purchasing small cars for my commute.
Thanks for the interview, any closing thoughts or questions for me?
A: No

Interview – Urban/Mass Transit/Walk Commuter

Profile: Age: 22, Marital Status: single, Own/Rent home? Rent, do you own a vehicle? No, Location: Hong Kong (US student study abroad)
Q: Please describe your commute to work. Do you drive or take public transportation?
A: Public transportation or walk. 20 min walk to campus, 5min bus ride. Two types of buses, either city bus or private bus. Private bus is faster, but more expensive and not consistent.
Q: Walk me through your commute to work and back home today.
A: Usually there are a lot of buses going by when she wants to go to class. If she has time, she takes the cheaper city bus, which takes longer. If late for class, then takes private bus, which costs more, but is much faster. City bus is consistent and stops at designated times. Private buses are unpredictable. For mornings with later class start time, there are fewer buses and she has missed the bus and had to walk and was late for class. On the way home in the afternoon, stand at bus stop and take the bus back to the dorm. Usually prefer private bus because fewer people in line and sometimes city bus is full, but it does cost more. City bus makes a lot of stops, so can take forever to get back.
Q: What do you like about your commute?
A: Don't have to drive in the crazy traffic. Let someone else drive. Don't have to own a car here. Q: What is frustrating about your commute?
A: Missing a bus or having to stand in the rain waiting for a bus. Slow city bus with many stops takes too long sometimes.
Q: Tell me what comes to your mind when you think about commuting to work…
A: Hope I don't miss the bus.
Q: Have you ever compared alternatives to your current method of getting to work? Ex. Mass Transit, Telecommuting, car-pooling, moving? Did you try alternate methods? Why/why not?

A: She has to go to class, but telecommuting would be nice. She is taking mass transit and sometimes walks if the weather is nice and time permitting. Bike wouldn't be possible with no bike lanes, crazy traffic, and really steep mountainside. Driving a car would be too difficult.
Q: If you did, what did you like/dislike about the alternative?
A: Described above
Q: How could your commute improve?
Q: Faster city bus or cheaper private bus. Would be great if all buses stopped right in front of dorm at very consistent times or if they'd alert her when they were approaching. Mass transit is sometimes inconvenient and really sucks to miss a bus.
Q: What do you see in the future of transportation?
A: More mass transit, smaller cars
Q: What concerns you about the future of transportation?
A: Congestion and pollution
Q: Have you personally made any changes to save time, energy or money in respect to your commute to work?
A: If it is nice out, she likes to walk, but it takes a lot longer.
Thanks for the interview! Any closing thoughts or questions for me?
A: Wishes public transportation was as convenient in the U.S. as it is in Hong Kong. Probably could only happen in dense cities, though. Likes not having to drive and fight traffic, but doesn't like missing a bus and doesn't like how time consuming it can be.

Interview – Rural Commuter

Profile: Age: 28, Marital Status: married with infant, Own/Rent home? Rent, do you own a vehicle? Yes. Used Chevy Malibu, Location: Rural Colorado
Q: Describe your commute to work…
A: 15min commute. Commute is mostly on 55mph county roads
Q: Walk me through your commute to work and back home today.
A: She leaves at 7:50 and drives 70mph on county roads and makes it there at 8:01. Always waits until the last minute. Leaves at the end of the day and drives just over the speed limit to make it home in 15min.
Q: What do you like about your commute?
A: It is short
Q: What is frustrating about your commute?
A: She likes to speed (always late) and traffic is slow.
Q: Tell me what comes to your mind when you think about commuting to work…
A: I'm late, got to hurry up.
Q: Have you ever compared alternatives to your current method of getting to work? Ex. Mass Transit, Telecommuting, car-pooling, moving?
A: There are no other options. Not many people around, so no mass transportation. Car-pooling not an option because nobody lives close by. The only option is to drive herself. Would be nice to have faster way to get there.
Q: How could your commute improve?
A: Some way to speed it up so she could wake up & leave later. Another lane to make it easier to pass the slow cars.
Q: What do you see in the future of transportation?

A: Better fuel economy.
Q: What concerns you about the future of transportation?
A: Cars are expensive and gas is expensive.
Q: Have you personally made any changes to save time, energy or money in respect to your commute to work?
A: Just drive faster to save time. Has a fairly good mpg, but could always do better with a newer car.
Q: Thanks for the interview, any closing thoughts or questions for me?
A: Wants flying car or to be beamed places instantly.

Interview – Car Salesman

Q: Do people come into the dealer and ask for a commuter car? If so, what are they looking for? What specifics?
A: Commuter car? You mean regular sedan? If yes, and then we sell 80% of regular sedan, and most of them are lease. At dealership we like to maintain the customer loyalty thru the leasing program because we know the customers always come back to renew their leases after two or 3 years. This is a good way to generate the car sell. On the other side, we also like to feed our used cars sell department with good supply. You know. Kind of like a win-win situation.
Q: Are there attributes that customers have a bad reaction to/that turn away customers?
A: Not sure what you mean, can you be more specific? I think own a car is a privilege, even though you do not need it for daily commute. Unless the government provides the comprehension public transportation to allow people go from point A to point B with any hassle, (laugh!) You and I both know those days won't come any time soon, People will continue buying car for going to work, taking family to vacation, or even just buy a sport car and put it in the garage just like buying an art work.
Q: What usually sells a car, in your experience? What attributes? What is the biggest driver?
A: In my 15 year car sell experience, the big driving force for customers to eventually put the money down and take the vehicle is a good deal that consists of good vehicle price, great vehicle features, great vehicle fuel economy, the repetition of dealership services, plus the reliability of vehicle itself.
Q: What do you think about fuel saving technologies? (Like, CVTs, 8speed transmissions, start-stop, etc.?) About hybrids? (Like the Chevy Volt, e-Assist)
A: I would say the smaller cars, the better fuel technology. Personality I did not like hybrid vehicles, it is way to complicate, cost more money to build and services. GM new Ecotec engines are doing great, providing bigger power but burning less fuel. I heard the next Ecotec engines will be even better. I feel good about the future of GM powertrain.
The start/stop system is a good feature to save the fuel while vehicle is stop for traffic light, or simply stuck in the traffic jam. I recall I read some paper that vehicle idling is accounting 30-45% of fuel consumptions. That is one of reasons that we seems the hybrid vehicles have good fuel economy. But we all know Hybrid mechanism cost more money. GM e-Assist is a mild hybrid. We see a good fuel economy on Malibu with e-Assist. Customers like it.
Q: What do you think about the car sharing trend? Do you fear it will take away business or do you see dealers becoming a part of that business?
A: You mean like MichVan, or Zip car like in California? (Can you say something both what you think about them?) OK, Yeah, MichVan is a good way to gather people with the same route to work. But then you lose the flexibility of your work hours since you have a bus to catch. Unlike the public transportation, if you miss the bus, you have to figure out the way home yourself. And next ZIP car.

I do like the idea, and I think it is very attracted to the people in the big city such as New York, or Chicago because they provide you a means to maneuver around those big cities without worrying the parking. I kind of assume those Zip cars have a way to find the designated parking using the internet technology.

Q: What do you think about infotainment systems? Do they help sell the car? Do people want to see their real time fuel economy and track their mpg?

A: I believe a nice infotainment system will attract good deal of customers to the show room. But one thing to remember they are only added-on features, they won't improve the vehicle performance and sometime just bring the negative sell to the vehicles if not reliable. Ford's my Ford Touch is a great example.

For fuel economy gage on the dashboard, it is a good way to indicate how good or how bad that drivers operate the vehicle. I have many customers like it and use it to improve their driving habits and save the fuel usage. Also, some vehicles are equipped with different drive modes from sport to Eco to regulate the fuel usage while driving in order to provide different driving experience and purpose. I think those are great ideas and they should be on every vehicle, I think.

Q: Do people ask for mobile apps to do the same features as infotainment systems? What are people's opinions about mobile apps that interface with the vehicle (Volt remote start thru app):

A: Mobile App, Like ON-Star. I like it a lot, personally. I felt I have totally control to my vehicles by just using a small device on my palm. I can check all the status of my vehicle's conditions. I can lock/unlock the door start the engine from remote location. I can even locate my vehicle if I am on a big parking lot like Ford Field, or Palace of Auburn Hill. This technology is wonderful. GM should put more efforts to make it even better with more features

Survey – General Commuting Q&A

29 responses

Briefly describe the field you do work in and your job. Are your hours flexible?

Automotive engineering Nanny. Do not have flexible hours. medical field, I work for Grifols Plasma care (a plasma donation center) screening donors to make sure they fit the requirements for donating. My hours are flexible. Client SME Support Desktop - yes they can be flexible if needed Automotive, tool & diemaker, yes hours are flexible. Engineering support work for an automotive development/durability lab. Starting time and ending time is somewhat flexible, but I must work 8 hours per day, 40 hours per week. Engineer, work at a desk most of the day. Hours are flexible I do application programming in support of GM's powertrain development laboratory. The hours are flexible as long as we are here during a set of core hours. Process improvement specialist/system integrator for automotive manufacturer. The title is Applications engineer. We use the available software/hardware tools to create test applications/schedules to test rotating equipment (electric motors, transmissions, engines, engine sub-components (water pumps, oil pumps, timing chains, etc.). Our hours are faily flexible unless there is a hot job. Automotive engineering, test bed programming. Hours somewhat flexible. work with computer, hours flexible Analysis - Business Support. Flexible Hours Engineer in hydrid system development for major OEM. Hours are somewhat flexible (+/- 1 hour start and end) Information Security/Director of Network and Information Security Hours are fixed 8am to 5pm I am a teacher. My hours are not all that flexible. I start at 730 am and have to be there until 315 pm. Automotive/Electrical hybrid application with somewhat flexible hours. Engineering at GM in the Electrification organization. Hours are flexible. Laboratory Engineer at Automotive company. Yes flexible hours with core hours 10am - 2pm. Industrial engineer for a tier one exhaust manufacturer. Hours are standard 7-4 but flexible when needed. Software Application Engineering Education. Set hours I work in retail and I am a sales associate and cashier. I help customers find items in the store. My hours are flexible I am an attorney. The time I go into work is consistent, but the time I leave work varies. Hybrid vehicle controls. My hours are somewhat flexible. Manufacturing Engineer- In charge of purchasing machines for my company. Hours are NOT flexible. I am an automotive engineer working in the field of vehicle propulsion electrification and energy management. Yes, my hours are flexible. automotive engineer. yes, somewhat flexible. I work as an automotive test engineer. My hours are somewhat flexible, but my management would prefer that I'm in the office between 9:00 and 5:00.

How many hours a day do you work on average?

8.5 7 30 9 8 10 9.5 7.5

How far is your daily commute to work?

35 40 22 2 30 32 5 4 31 9 17 18 16 14 12 20 10 12.7 3.5 52 50

How long is your daily commute to work?

35 40 25 7 30 17 15 20 10 110 45 50

What percent of your current commute is city driving?

33 40 25 7 5 20 100 90 10 85 66 70 60 50

What gas mileage do you typically get on your commute?

35 40 22 23 24 25 26 27 28 30 32 19 17 18 15 16 21 20 22 999 50

What are your favorite and least favorite parts of your commute?

Scenery fav. Least fav. Bad weather roads favorite: listening to audio books and NPR least favorite: traffic backups Most Favorite: Nothing Least FAvorite: Traffic Stress Least favorite: traffic. Favorite: scenery, listening to NPR Favorite parts: listening to the radio Least favorite part: other drivers Favorite mostly expressway driving. Least Favorite: Back ups due to accidents or excessive traffic during commute time. I like my commute is so short. It is so short not many complaints... Stop lights? favorite: a lot shorter than I used to travel least: traffic light and constructions Favorite: listening to the radio Least Favorite: leaving my home I love that I live so close and can keep miles off my vehicle, saving over $200 in gas and 1.5 hours per day compared to my last commute. I hate that traffic is still terrible, on certain days when I leave work it takes over 30 minutes to go 2 miles. Least favorite part of the commute is how long it takes. There are 32 traffic lights standing in the way. My favorite is listening to music in the morning and talk radio on the way home. My favourite part is drinking a coffee on the drive. Otherwise I really dislike the entire commute process. The shorter the better. Commutes take up my personal time, take away from my productivity, rack up miles on my car which depreciate it faster and ultimately end up costing me money....and also fuel, of course, costs me money. City driving is the least favorite because it take most of my time. Highway is my favorite for the exact opposite reason. my least favorite would be traffic, my favorite is I have a lot of time to think. Favorite: calling family members and listening to interesting stories on NPR Least favorite: waste of time, the stress of terrible drivers Favorite: Get to listen to news and music of choice. the traffic behind me consistent. short. not very scenic. Favorite is listening to the radio and being able to make phone calls if needed. Least favorite is all the lights and how long it takes. My favorite part is how close it is and listening to the radio. My least favorite part is the traffic Favorite: sometimes radio talk shows are entertaining Least favorite: bad drivers, slow traffic, having to pay attention favorite : commute in : time to gather thoughts, develop focus and targets. favorite : commute home : public radio broadcasts - thoughtful programming. Favorite: Easy Driving Least Favorite: Length of Commute least favorite is city traffic favorite is expressway travel Least - traffic congestion and too many stop lights. Favorite - Higher highwasy speeds. Favorite-living close to work Least favorite-working Time to think and unwind from the long noisy day. Least favorite is having to drive on a two lane highway. Favorite - Drinking coffee, listen to radio, comfortable seat Least favorite - That it takes so long to go such a short distance, have to leave at odd hours to avoid traffic, nuisance, too many traffic lights, traffic bottleneck, other drivers, construction, bad weather, no direct route or expressway available There's nothing that great about the commute. Dislike dealing with winter conditions - extra de-ice and heating times.

Do you multitask on your commute and if so what do you do?

no No I only take calls because of the blue tooth connection in my vehicle. I might eat a quick breakfast sandwich. I occasionally eat breakfast on my commute. Usually have conversations and updates from my employees not really. sometimes phone calls, breakfast not usually. I listen to music and take calls if needed. occationally taking phone call with bluetooth Sometimes listen to teachings. No No I do not I sometimes take conference calls or eat breakfast during the drive Phone calls to friends and family occasional phone call using headset, thats it. Catch up on world events Yes, if needed make phone calls. Sometimes I make/take phone calls for business. I do try to do all my personal phone calling while driving. Bluetooth is a must in my vehicle. Text messaging, phone calls for work and personal, snacking, learn a foreign language (CDs) Not usually, sometimes I make phonecalls on the way home Conference calls, Yes, on occasion. Conf calls. Listen to TED talks/audio books.

Do you commute alone? Do you prefer to drive yourself or have others drive you? Why?

Commute by self prefer to have down time alone I commute alone. I would not mind commuting if others were going the same way at the same times. alone Yes I commute alone. I'd rather be driven to avoid having to pay attention, as long as the driver can be trusted. I'd rather be doing other, more productive things. I commute alone, but only due to the flexibility which allows me to come and go when and where I please. Yes - I need the flexibility of driving alone. Yes, commute alone. I don't mind driving, but do like the idea of others driving to make my commute more productive. I currently commute alone. I prefer to drive myself in good weather, but would prefer to carpool on bad weather. yes. have done both. alone for short, with others for longer commutes. I commute alone. I prefer to drive myself. I like the freedom of being able to stop off to run errands, work which ever hours I want...and also not feel the awkward silence. I am not much of a talker most mornings. Commute alone. yes. I prefer to drive alone. Alone. I need to go home at lunch everyday so I need a car else I wouldn't mind carpooling I commute alone because I prefer to be by myself in the morning. I have to see my co-workers all day at work. Yes prefer to Alone. Not really worth the hassle to coordinate for such a short commute. I commute alone. I prefer to drive myself. My job often requires me to travel to other company locations. Alone. I sometimes prefer to drive myself, but for a repetitive commute would be happy to have someone else drive. I commute alone even though my roommate goes to the same place and we work similar hours. I prefer to drive by myself so that I don't have to wait on anyone else and can be flexible in my schedule. I also like to drive, I always feel weird being a passenger. Yes Yes. Drive myself because I do not like the way all people drive and do not want to rely on someone else. No. Others drive me. More relaxing, less stressful. I commute alone. I prefer to drive with others because it allows for company I commute alone. I would prefer to have others drive me. I don't like driving. Yes I commute alone but would perfer my own driver. Alone. I would prefer to ride share. It lowers the cost and the effort it takes. I prefer to drive by myself. Gives total flexibility on timing of start/leave, radio station/audio book, no coordination hassles I did car pool but then it was no longer feasible. I prefer now to travel alone. Yes. I like to drive myself. I trust my driving!!

If you knew more people that had the same commute as you, would you consider carpooling? Why or why not?

Sure - but it is hard to find on a short drive. Yeah I would to keep company and time to socialize Yes, depending on if it would benefit both of us. Prob not. Like flexibility and personal time Yes - cost savings. I would prefer to carpool to save on the cost and have some company. No., may need to leave but couldn't of commuted with others I would be open to carpooling if there was a good fit. It would cut down on fuel costs, would allow more time not having to pay attention, and could have interesting conversations with passengers. probably not. the benefit in terms of fuel cost saved and less wear and tear on car do not outweigh the cost in terms of coordination hassle and lost timing freedom. I would consider carpooling, at least a few days a week. Yes, because I do not have to drive as much no. short distance. not worth schedule synchronization. I would not unless we had a set work schedule. I commuted to school when I had a set schedule, but my work schedule changes too much and it's always nice to be able to go out to lunch wherever I want. Yes, for the reasons above. I carpooled with 3 other people many years ago for about 5 years. It was beneficial to all of us. Not really. 1. I like going out for lunch. 2. It seems like a lot of coordinating has to take place on a daily basis. 3. It limits my freedom. I would consider it on days when the weather is bad and it would be easier for us to ride together. Otherwise, I would hate to have a committed time when I needed to leave the office at night, which would be necessary if I was carpooling. Yes, it would help save on gas. pro: more rest, can chat more con: not flexible, especially now need to pick up grocery on way home Probably not. I don't like the fact that with carpooling you have to rely on other's schedule. If you want to leave but they have to stay then you are SOL. Also you have to really know someone to carpool with them daily. No, as stated above, my job often requires me to travel to other company locations. I would resist commuting for the reasons mentioned above. depends on the people Yes No, To difficult to manage Doubt it. Not really worth the hassle to coordinate for such a short commute. However, I would consider biking or walking with a group. Yes. Save $$. yes, it would save on gas. I'd consider it, but we'd have to have the same schedule. My schedule is never consistent, so that would likely be a problem. I'd hate to feel obligated to either leave earlier or later because of someone else's schedule.

Would you consider riding a shuttle or van service to work if it was offered in your area? Why or why not?

No,as stated above, my job often requires me to travel to other company locations. Yes, because I do not have to drive as much. Yes, If it was reliable and reasonably priced Probably not because I like the freedom of being able to come and go as I want and not be tied down to a shuttle services time schedule. I wouldn't mind riding a shuttle but I wouldn't prefer it. It would be nice to save money but kind of uncomfortable yes. No. I have more freedom to come and go from work driving myself. No. I would prefer to know the individuals I am communiting with and the driver. Yes. Assuming I could be flexible with start/end times. I would consider it if it was only people at work that rode and maybe if I had a further commute. The shuttle would have to run at least every 10-15 minutes. Warren has a bus system, but I wouldn't want to ride with other people on it. yes. Then I could do work, still enjoy some private time hopefully, and not have to drive. no, I need my vehicle due to if I have to leave work early or for an emergency I would consider a shuttle if the hassle was minimized. I would consider the shuttle before shared commuting because the shuttle is less personal, IMHO. However it would still be hard to give up the freedom of having a car. Also, if business required me to travel during the day, then I would need to deal with pool vehicles, which is another inconvenience. no, if something happened I would have no way to get back until the shuttle/van was ready. Maybe, depends on price. I am very cheap and my commute is quite short compared to many others. It also depends on convenience. Yes as long as it did not add to the commute time i.e. having to stop many times to pick up or drop off others.It would reduce my costs.and allow more time for other activities on the commute. definitely yes Carpooling is a better option for me since you know the people better. Might use if no other alternative No. Too many stops and it probably won't save time. No. Ride is fine Yes - it may be cheaper. Yes, if it was convenient and efficient. I would like to have someone else drive so I could multi task and also avoid the stress of driving. Yes. Save $$. Yes, this way there is a time schedule and I would not have to drive myself. Probably not because I would be tied to their schedule. It depends on the flexibility. Do I need to committ to 5 days at specific times? I would definitely consider it. Yes, to save on fuel costs and to be able to do more productive things during the commute time. Downsides would be having to be certain place at certain time and it would likely take more time overall. No, same reason

Survey - Kano Needs Analysis Questions

Cost

If the product in question reduces the cost of your daily commute, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

If the product increases the cost of your daily commute, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate the cost of your current commute? *

	1	2	3	4	5	6	7	
Totally unsatisfactory	○	○	○	○	○	○	○	Excellent

Safety

If the product reduces your likelihood of getting in an accident during the commute, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product slightly increases your likelihood of getting in an accident during the commute, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate the safety of your current commute? *

	1	2	3	4	5	6	7	
Totally unsatisfactory	○	○	○	○	○	○	○	Excellent

Comfort

If the product is more comfortable than the vehicle you commute in, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product is less comfortable than the vehicle you commute in, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate your comfort level during your current commute?

	1	2	3	4	5	6	7	
Totally unsatisfactory	○	○	○	○	○	○	○	Excellent

Stress Level

If the product makes your commute less stressful, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product makes your commute more stressful, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate your stress level from your current commute? *

	1	2	3	4	5	6	7	
Totally unsatisfactory	○	○	○	○	○	○	○	Excellent

Reliability

If the product provides a reliable commute how do you feel? *
Examples: always able to get to work, never breaks down

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product does not provide a reliable commute how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate the reliability of your current commute? *

1 2 3 4 5 6 7

Totally unsatisfactory ○ ○ ○ ○ ○ ○ ○ Excellent

Consistency

If the product provides a consistent commuting time, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product does not provide a consistent commuting time, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate the consistency of your commute time from day to day? *

1 2 3 4 5 6 7

Totally unsatisfactory ○ ○ ○ ○ ○ ○ ○ Excellent

Entertainment

If the product provides a means of entertainment, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product does not provide entertainment or discourages entertainment, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

How would you rate the entertainment features of your current commute? *

	1	2	3	4	5	6	7	
Totally unsatisfactory	○	○	○	○	○	○	○	Excellent

Time

If the product maintains or improves work/home time balance, how do you feel? *
Examples: ability to work during commute, able to sleep during commute

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product decreases your work/home time balance, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Departure Flexibility

If the product provides flexibility in departure time, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Would you be willing to pay for this attribute or more of this attribute? *

If the product is not flexible in departure time how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Multi-Use

If the product allows for stops along the way, how do you feel? *
Example: stop to go grocery shopping

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

If the product does not allow for stops along the way, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Environmental Considerations

If the product is fuel efficient or reduces environmentally harmful emissions, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

If the product is not fuel efficient or increases environmentally harmful emissions, how do you feel? *

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

Survey – Alpha Design Feedback & Results

Alpha design survey and survey results are shown below. The survey can also be found at: https://docs.google.com/forms/d/1i-2bq8NUDVJnzVJX2YEOJbfgFsZiuUzoxvcM9Y0CB7I/viewformhttps://docs.google.com/forms/d/1i-2bq8NUDVJnzVJX2YEOJbfgFsZiuUzoxvcM9Y0CB7I/viewform

29 responses

Survey Numerical Response Summary

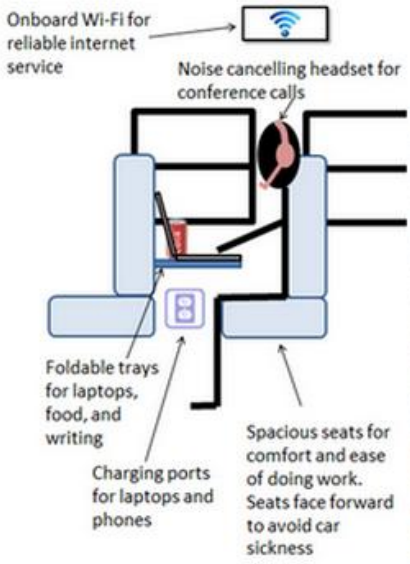
	How many hours a day do you work on average? (hours)	How far is your daily commute to work? (miles)	How long is your daily commute to work? (min)	What percent of your current commute is city driving? (%)	What gas mileage do you typically get on your commute? (mpg)	How many times a week do you think you would use the service?* (days)	Approximately how much per month would you be willing to pay for your shuttle?* ($)	If the shuttle increased your commuting time, how much additional time would you tolerate?* (min)
Average	8.4	20.2	34.3	51.0	25.7	4	108.2	21.8
Maximum	10	52	110	100	50	5	250	60
Minimum	6	2	7	5	15	2	30	5
Std Dev	0.7	14.2	23.2	37.7	9.0	1.2	49.6	8.7

* Survey takers who responded that they would ride the shuttle 0 times/week or pay <$10/month for the service were thrown out

Project Description

Your company sponsors a shuttle service that picks you up and drops you off at work in the morning and then reverses the process in the evening. The shuttle would have 8-12 passengers when full and would make several stops along the way, lengthening the commute time for any one passenger. However, free wifi is available for working on the road as well as noise cancelling headsets for conference calls. Each seat has a fold down table for working and outlets for accessory power. Your company agrees to count any time spent working on the road toward your regular work hours so you need not work 8 hours in your office. Optionally the shuttle would provide snacks, beverages and breakfast at a reasonable cost.

Please answer the following question as they relate to the above concept.



How many times a week do you think you would use the service?

3 2 0 5 4

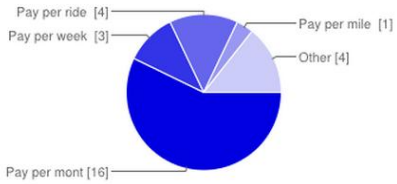
Approximately how much per month would you be willing to pay for your shuttle?

150 40 200 0 30 5 160 20 100 90 10 50.00 80 60 250 50

If the shuttle increased your commuting time, how much additional time would you tolerate?

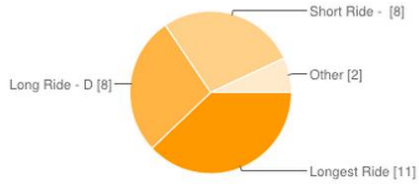
0 30 5 15 20 10 60

Which would you prefer?



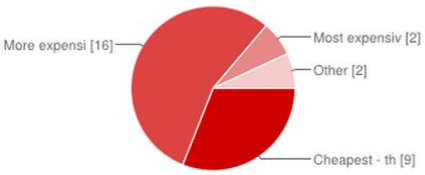
Pay per month service	16	57%
Pay per week service	3	11%
Pay per ride service	4	14%
Pay per mile service	1	4%
Other	4	14%

Which would you prefer?



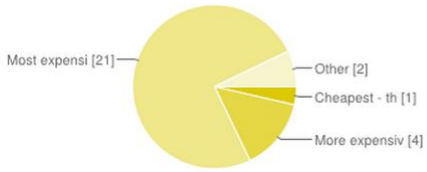
Longest Ride - Schedule to be picked up from your house	11	38%
Long Ride - Designated shuttle stop in or near your neighborhood	8	28%
Short Ride - Shuttle leaves from the nearest park and ride	8	28%
Other	2	7%

Which would you prefer?



Cheapest - the shuttle service offers one pickup time (each way)	9	31%
More expensive - the shuttle service offers 3 pickup times separated by an hour (each way)	16	55%
Most expensive - schedule the shuttle yourself	2	7%
Other	2	7%

Which would you prefer if money was not a concern?

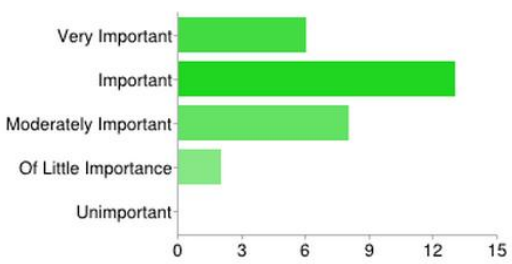


Cheapest - the shuttle service offers one pickup time (each way)	1	4%
More expensive - the shuttle service offers 3 pickup times separated by an hour (each way)	4	14%
Most expensive - schedule the shuttle yourself	21	75%
Other	2	7%

Would you purchase snacks, beverages or breakfast on the way to work? What would you expect as options and at what price? Would a monthly pricing option on breakfast interest you?

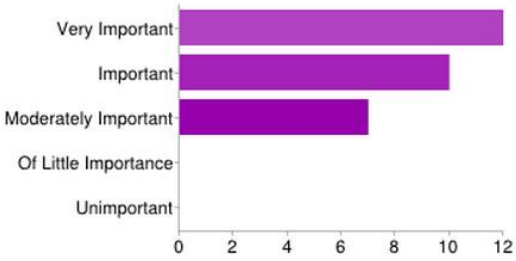
no No options. No breakfast. Just quick service. Yes, that way I could eat on the way and sleep in longer. Bagels, muffins, donuts, coffee, and lattes all under $2.50 each. Yes. would purchase snacks or breakfast, but not very often. Not every day, but probably regularly. Would probably rather have a pay as you go option. Maybe with a running tab to be paid monthly. N/A Coffee bar. Prob would bring own breakfast I would purchase snacks depending on the drive time. Quick things like granola bars, yogurt, juice, milk, muffins, etc. Price - <1.00-3.00 Granola bars, cereal, orange juice, and biscuits.$2, yes a monthly price option would work Would not purchase Yes, if they were good quality. I'd expect pastries, fruit, yogurt, granola bars, coffee, water, and juice for breakfast. Maybe an ala carte menu and also a $5 combination. I probably wouldn't pay the monthly price because I wouldn't always eat on the bus and would only consider it if there was a large variety that changed frequently. Perhaps if the price was competitive. I would pay for a monthly plan if it saved me money. Maybe like a microwavable breakfast sandwich or toasted bagel. no. No yes No i would probably just bring my own breakfast. No, purchasing food is not important for me. I would probably, at most, purchase a coffee. I pay $2 today for a Tim Hortons XL....so cheaper than $2 woudl be good, however...each day, I pay $6 for fuel, and $2 for coffee. So the shuttle would need to be significantly cheaper each day, if replacing the same services, to get me to consider. I usually keep snacks at my desk and have a coffee maker, so I probably wouldn't buy any food, maybe on days I forget to bring some breakfast. I would not purchase anything I'd love to eat breakfast on my ride to work. And considering the potential savings from fuel and vehicle miles, I could easily rationalize the higher cost of a purchased breakfast. I'm just not sure that the service would be likely to provide a breakfast that would be interesting enough. Not likely. I'm a health freak...and the ride had better not be THAT long!! Yes I would expect the pricing to be like that of an airplane, maybe a little bit cheaper because of the ease of getting the food on the shuttle as compared to getting it on a plane. No I would not purchase from the shuttle not much

Fastest wifi connection [Grade these attributes of the shuttle service as they relate to you]



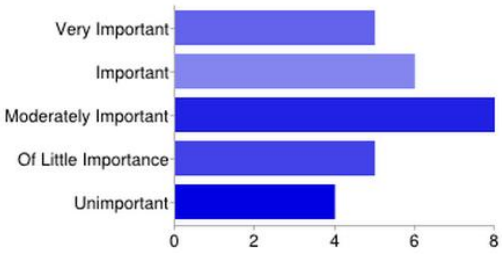
Very Important	6	21%
Important	13	45%
Moderately Important	8	28%
Of Little Importance	2	7%
Unimportant	0	0%

Quickest drive to work [Grade these attributes of the shuttle service as they relate to you]



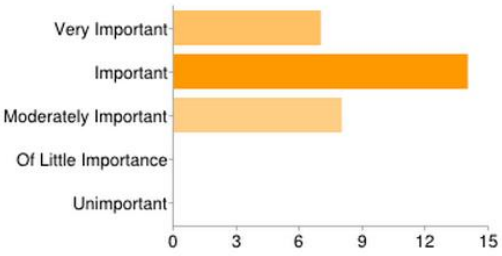
Very Important	**12**	41%
Important	**10**	34%
Moderately Important	**7**	24%
Of Little Importance	**0**	0%
Unimportant	**0**	0%

Ability to have conference calls undisturbed [Grade these attributes of the shuttle service as they relate to you]



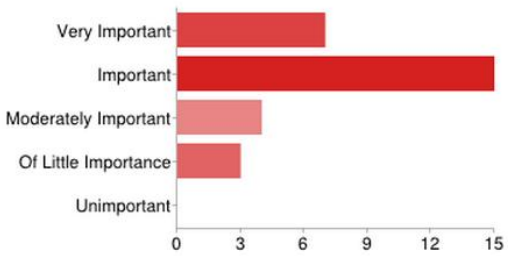
Very Important	**5**	18%
Important	**6**	21%
Moderately Important	**8**	29%
Of Little Importance	**5**	18%
Unimportant	**4**	14%

Comfortable seat [Grade these attributes of the shuttle service as they relate to you]



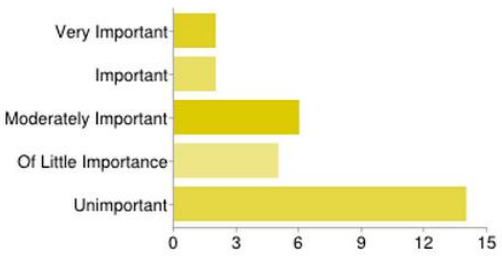
Very Important	**7**	24%
Important	**14**	48%
Moderately Important	**8**	28%
Of Little Importance	**0**	0%
Unimportant	**0**	0%

Enough space to comfortably work on computer [Grade these attributes of the shuttle service as they relate to you]



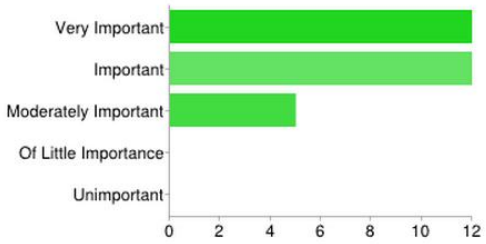
Very Important	**7**	24%
Important	**15**	52%
Moderately Important	**4**	14%
Of Little Importance	**3**	10%
Unimportant	**0**	0%

Cheap food availability [Grade these attributes of the shuttle service as they relate to you]



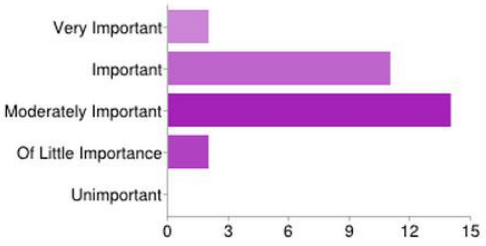
Very Important	**2**	7%
Important	**2**	7%
Moderately Important	**6**	21%
Of Little Importance	**5**	17%
Unimportant	**14**	48%

Known arrival time [Grade these attributes of the shuttle service as they relate to you]



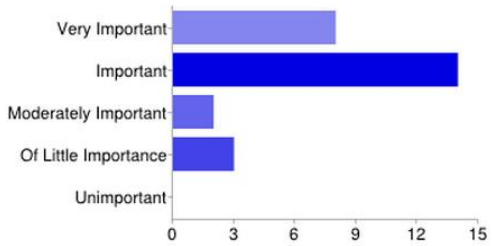
Very Important	12	41%
Important	12	41%
Moderately Important	5	17%
Of Little Importance	0	0%
Unimportant	0	0%

Quiet [Grade these attributes of the shuttle service as they relate to you]



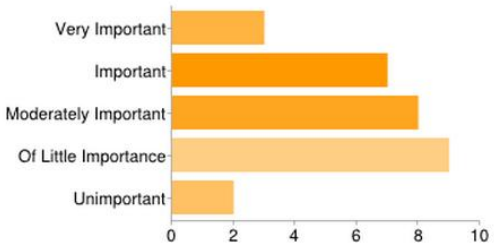
Very Important	2	7%
Important	11	38%
Moderately Important	14	48%
Of Little Importance	2	7%
Unimportant	0	0%

More options for pickup and drop-off times [Grade these attributes of the shuttle service as they relate to you]



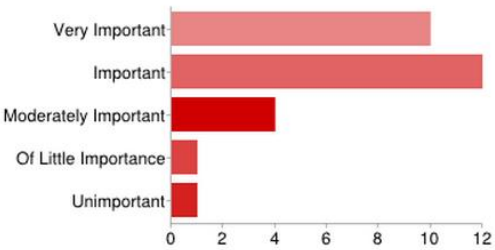
Very Important	8	30%
Important	14	52%
Moderately Important	2	7%
Of Little Importance	3	11%
Unimportant	0	0%

Individual air controls (A/C and heat) [Grade these attributes of the shuttle service as they relate to you]



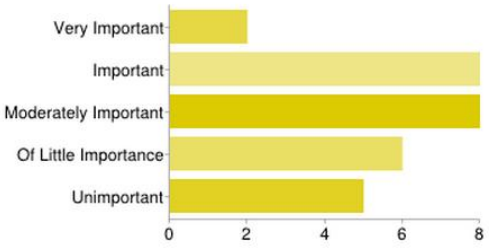
Very Important	3	10%
Important	7	24%
Moderately Important	8	28%
Of Little Importance	9	31%
Unimportant	2	7%

Cheapest ride to work [Grade these attributes of the shuttle service as they relate to you]



Very Important	10	36%
Important	12	43%
Moderately Important	4	14%
Of Little Importance	1	4%
Unimportant	1	4%

Seat preference (aisle or window) [Grade these attributes of the shuttle service as they relate to you]



Very Important	2	7%
Important	8	28%
Moderately Important	8	28%
Of Little Importance	6	21%
Unimportant	5	17%

Would you be a customer if this shuttle service was offered in your area? Why or why not?

Yes - it would save wear and tear on the my vehicle. Yes, because it give me the option to drive or ride. Very likely. I would not have to drive, it would be a cheaper alternative. It would lower my carbon foot print. Not likely, unless it was very cheap. Even then, it takes away alot of my work flexiblity. Perhaps if it was convenient to my work schedule No - I live to close to work. no. commute short. I would probably want to try it out a few times before committing to it. These are the most important to me + Cheap cost for ride + Could be picked up from home at a known time + Offers cheap and good breakfast + Enough space to do work yes I would if it was done well, reasonable price, high reliability I don't think I would because I like to be on my own schedule and sometimes have to drive places during work or after work without having to go home first. No not needed commute good Not in my current situation Sure, . Yes I would because it would be cheaper on gas and less mileage on my car Yes, this way I would not have to worry about relying on my own car and I could get things done or just relax on the way in. Yes, if I could have the flexibility to only ride & pay for it the days I want to. There will be other days when my car is more convenient. If it was supported by my management, I'd be foolish not to pay for the service: 1) cost savings. 2) time savings (breakfast and work time). 3) potential aggravation reduction (leave the driving to someone else). Probably I would try it, and decide once some data were available. I would definitely try it out. However, I would doubt that a shuttle service would work for someone that is as close as I am -- would likely need to consider a different operating pattern for closer employees (double my commute?) -- heck, I'm close enough that I could come home for lunch! No, already have short commute yes, it would save on money paid for gas. Yes Yes. I would try it out to see how it worked with my job requirements and personal needs. I would if it was quick enough, less expensive than my normal commute, and if I could work efficiently during the drive. I'd have to try it out to see if I liked it. If it was less convenient than my normal commute, I probably wouldn't continue riding. would depend on final details. boils down to added hassle being worth it for more productive time. Depends how long the shuttle would run and the cost. if the options were correct I would be a customer. It is a good alternative to driving.

What do you like and dislike about the shuttle service idea?

Like it counts towards work and wifi. Don't like possible uncertainty about pick up and drop off. It makes it more rigid/less freedom to come and go as you please. If you have to change your schedule for the day you may have to make provisions like notifying someone that you won't be riding. I would dislike it because it limits my work flexability The freedom to come and go when you can. If you have no car there is less chance for you to be able to leave the office if you need to. I like the timing and saving money. I dislike the extra time it would take and it wouldn't be at the exact time I have to work concerned the additional hassles of time and place coordination would not be worth dealing with. I feel like it is either going to be too expensive or increase the commute time to an unreasonable level. If those two factors are kept under control, I think the shuttle would be very popular. I would need a flexible shuttle service that gave me the flexibility for hours of pick up and departure. I like the fee wifi and space to work on while getting credit for time at work but feel that the scenario above is too pie in the sky and cost prohibitive. It's a great idea -- they actually exist from Ann Arbor to Dearborn -- don't know how the amenities compare. I feel like it might cramp my space. Also with my short drive I might spend most of my time just booting and shutting down my computer. I like that it allows for doing more interesting/productive things during commute time, reduces fuel consumption, is potentially cheaper, reduces congestion on roads if a lot of people take advantage of it. Saves $$. Economically and environmentally responsible. Not being on time or late arrival home I like the idea of commuting on company time. I would dislike losing the freedom of having a car at work. Not sure if I will adjust to being a productive passenger. I might have nausea issues. In addition, I usually like to de-compress from work on the way home. It would require some adjusting, and I'm not sure whether I will love it or hate it - depends on execution. In the end, I would love a shuttle service of some sort, just to save money. I like that I would get to rest on the commute and potentially save money over driving individually. I don't like that it would force me to be on a schedule, limiting my options to stop places on the way home from work or go out to lunch. I like that I have time to relax, make calls, someone else can get frustrated with driving. Dislike that I may not have as much control as I would like over the things that are most important to me. i like that I would save more money, I don't like that it would make additional stops Like: multitasking, not having to drive myself, cost if less than my current commute Dislike: increase commute time, possibly crowded (harder to multi-task), could get car sick I can ride and multitask instead of focused on driving If ride tough nice option The regimen it would put me on. I like all the ideas presented. i wouldn't like locked in times and loss of flexiblity - but it would be nice for someone else to drive.

Additional Comments/Suggestions

Sounds great when does it start? None Sounds like a good idea. I think that this would make it much easier for more people to look for jobs because they would not have to have a car. I believe most people would be interested in having this as an option. Computers built into seats so people can do work immediately and don't need to setup. n/a I think it would be great if people lived in a similar area and worked a set schedule, but carpooling also solves that issue. Maybe it would be good to have a system of people looking to carpool. There is a definite relationship between the cost savings and the time cost/savings and the appeal. I'd be willing to add 10min or 25% to my commute time (each direction) AND some reduction in comfort, for a 50% reduction in my commuting costs ($100/month savings) and driver responsibilities. My lunch schedule is more stable than my start/stop schedule. Maybe that is another offering for your customers? (and would make for much better utilization of your resources.) Wonder if you could also group by activity? e.g. running group or yoga group? Would be great for after a Happy Hour!! :) For many of my employees, a shuttle service would work and could result in better work performance.

Appendix II: Concept Generation

Below are all of the concepts generated by brainstorming and functional decomposition related to the persona's and other stakeholder needs.

Design Topics related to the persona's needs:	Challenges?	Reasons why it improves the current situation in terms of Economic, Environmental, Social improvements
Baseline...Commute is 25 miles (Troy to Detroit), Heavy traffic, 1 person in vehicle, Midsize car (Ford Fusion 22/30 MPG)		
Shuttle service with Wi-Fi capability, sound deadening headsets for calls, snack/breakfast options. Companies would count commute time as work time	commuter behavioral change, convincing companies to do it, car sickness	If enough companies do it, it reduces congestion and fuel (better fuel usage to people moved ratio). Commuter can multitask, shortening their overall work day. Would only have a chance if costs less than costs average car to drive the same number of miles. (Deal is employers provide cheaper transportation if employees work an extra half hour a day). Could reduce parking spaces needed at office http://www.google.com/green/efficiency/oncampus/ Social issue - http://io9.com/5976477/the-hidden-bus-routes-in-san-francisco-that-are-only-for-techno+elites Benefits for the employer - http://www.commute.com/employers/tax_savings
Telecommuting strict company policy (5 days per month)	getting companies to agree, reducing overall energy usage, Productivity and teamwork consideration	improves congestion on road (potential fuel savings), improves safety b/c fewer drivers, eliminates commute cost for drivers Employer can receive tax incentive if Telework program reduces commute trips by 6 percent - http://www.bestworkplaces.org/pdf/taxbenes_07.pdf
Van pool employer benefit plan	Cost considerations	Employees who participate in qualified vanpools can use Commuter Check Vouchers to pay their monthly fares by giving the Vouchers directly to their driver or affiliated Vanpool provider. By offering commuter benefits, you, the employer, can save up to 10% on average in payroll tax savings. Section 132 (f) of federal tax law allows employees to reduce their commuting costs by up to 40%, while helping employers save 10% or more on payroll taxes. http://www.commutercheck.com/Home.aspx

Company policy option of 4 day work weeks	10 working hours per day may not fit for everyone	Reduce the fuel consumption for one day per week Corporate reduces the energy usage of office May qualify for corporate tax break http://workawesome.com/office-life/the-four-day-workweek-pros-and-cons/
Phone app to find best route based on speeds, traffic, lights, and distance	safety concerns of looking at phone while driving, acquiring user data fast enough before customer base is built	This is a mobile phone application that uses Google maps traffic and map data, current user speed and location, and user speed and location history to predict the best route. The app will navigate the user to their destination and update the route real time if accidents occur. The user defines "best route" as shortest distance, best fuel economy, or fastest route. Benefits are reduced commute time and possibly reduced commute cost. This is similar to the Waze app, but predicts traffic light patterns, navigates, and updates the route as needed in real time.
Incentives to encourage employees to work earlier hours (like 4AM to 1PM) - for example offer locker, shower, drycleaning and free breakfast to those employees	Productivity, Cost to Employer	Will lead to offset in traffic - May qualify for corporate tax break http://www.nbcnews.com/id/39523298/ns/health-mens_health
Carpool incentive program offered by employer like additional vacation time for carpoolers		May qualify for corporate tax break
Replace stop lights/stop signs with pedestrian lights and/or traffic circles. or have more traffic lights with sensors	initial investment, convincing government. might need to change local policies	Reduces number of stop signs/lights needed, so traffic flow & therefore fuel consumption are improved. Sensors help light stay green longer, also improving flow & consumption. Safer because pedestrians have a blinking light to warn drivers they are there.
GM Super Cruise	Cost, Safety	
Phone app to let you know when to speed up or slow down for a traffic light based on when it will change	is there a market, how to get good traffic light data?	improve fuel economy by driving in the most fuel efficient way between traffic lights
Phone app to tell you traffic on your normal routes immediately after you enter your car	car needs bluetooth, is there a market?	avoid traffic by re-thinking your route after listening to traffic reports your phone tells you after you get into your car
phone app or software package to re-calibrate your PHEV system operation based on route and usual traffic patterns	safety issues with recalibration, have to work with automakers to develop app	phone app would allow your PHEV to optimize its battery usage based on the desired route that you would input into the app. More battery would be used for shorter routes and less for longer routes. The result is fuel economy improvement over the baseline calibration, especially for shorter routes with shorter distance/time between plug ins

Phone app to tell you your instantaneous fuel economy	might exist already, dangerous to look at phone while driving	There are devices that plug into the OBDII port that report signals available. Fuel economy can be calculated from this signal. Drivers can use this to monitor their driving habits in real time. Could make it a game and play vs their friends.
Launch Technology for PHEV - control strategy that regulates acceleration and deceleration to maximize efficiency	Safety	
Pulse and Glide cruise control	Annoyance Factor, Efficiency Improvement	
Remove side mirrors and replace with cameras	Cost	Currently (based on urban drive cycle) 4% of fuel energy is lost due to overcoming aerodynamic drag
Different hybrid architectures - such as 4 electric motors controlling wheels	Safety/Control, Cost	
Braking control for either conventional or PHEV. slows vehicle down as you approach stop sign/light at the optimal rate	Safety	Currently (based on urban drive cycle) 7% of fuel energy is lost due to braking
start stop systems in a conventional car - see ISG section of http://www.fueleconomy.gov/feg/tech_engine_more.shtml	Cost	Currently (based on urban drive cycle) 6% of fuel energy is lost due to standby
BMW Turbosteamer	Cost	Uses exhaust gas and reduces heat loss in an ICE
Pneumatic Hybrid technology	Cost	Forces highly compressed air into the engine, which they claim reduces fuel consumption by 30% - http://www.fastcompany.com/1218510/hybrid-compressed-air-cars-way
Aerodynamic body by using fluid dynamics in the design	Cost	http://en.wikipedia.org/wiki/Volkswagen_1-litre_carhttp://en.wikipedia.org/wiki/Volkswagen_1-litre_car
Remove wipers and replace front windshield with water-repellent glass	Cost, Safety	http://en.wikipedia.org/wiki/Water-repellant_glasshttp://en.wikipedia.org/wiki/Water-repellant_glass
Vehicle body from re-inforced foam	Safety	http://www.spira4u.com/http://www.spira4u.com/
PHEV with Solar Recharge on roof	Cost	

Speed governor based on GPS - use control technology and public road speed limit to limit maximum vehicle speed	Cost, Practicality, Annoyance Factor	
Autonomous vehicles (Be more specific)	initial investment	Optimizes route, so fuel savings and probably congestion reduction. improves safety because takes driver out of the equation, improves commute cost by optimizing route
Odd Hours/Shift Work Days		
Electric corporate car sharing program	Corporate cost justification	May qualify for corporate tax break
More satellite offices for large corporation	Corporate cost justification	May qualify for corporate tax break
Incentives to encourage employees to live closer to work		May qualify for corporate tax break
"Walkable Communities" or "Urbanist Neighborhoods" - Suburban communities with shopping, churches, schools, transit stops and businesses built within walking or biking distance	Major planning and new home construction	Less traffic on highways and expressways, reduce fuel cost for individuals
Policy encouraging urban living close to businesses	Who will buy into it? Schools are worse in urban areas, crime is worse in urban areas, crowded, etc.	Reduce vehicle fuel cost for individual, less miles traveled
H2 PEM Fuel Cell Vehicles		
PHEVs		
EVs		
Bi-fuel (CNG & Gasoline) Vehicles	Infrastructure for CNG vehicles not fully developed, Still a fossil fuel based solution, Complexity in efficient bi-fuel engine	CNG is cleaner than petroleum, Cheaper than petroleum
Lightweight Materials for Vehicles		
Increase fuel tax to pay for mass transportation	Public approval very low, chances are that road construction projects would take precedence	Provides a system to drastically reduce vehicle miles traveled

Accelerated retirement of vehicles		
Pay as you drive insurance		
VMT Tax		
Optimized E-85 Engine & Fuel		
ZIP Car		

Appendix III: Alpha Design Fuel Economy Calculations

The baseline commute from Troy to Detroit is assumed to be as shown in the google maps link below.
https://maps.google.com/maps?q=troy+michigan&ie=UTF-8&hq=&hnear=0x8824c40a318bcc13:0xb44b00c67e9177a7,Troy,+MI&gl=us&ei=xxSJUp_rI4my2wWlhYDIAQ&ved=0CJUBELYD

https://maps.google.com/maps?q=troy+michigan&ie=UTF-8&hq=&hnear=0x8824c40a318bcc13:0xb44b00c67e9177a7,Troy,+MI&gl=us&ei=xxSJUp_rI4my2wWlhYDIAQ&ved=0CJUBELYD

The baseline commute is 14% city driving and 86% highway driving and 24 miles total.

The methodology and calculations to compare fuel usage per passenger one -way on their commute in a Ford Fusion or as a passenger in a shuttle is shown below.

Method and Assumptions:

- Baseline: 2008 Ford Fusion (20mpg city/28mpg highway)
- Shuttle: 12 passenger 2014 Chevy Express (11mpg city/17mpg highway)
- Both vehicles get the EPA label city and highway fuel economy.
- Baseline commute is 24 miles, 14% is city driving and 86% is highway driving, which is based on the persona's commute.
- Each additional shuttle passenger adds 0.5 miles of city driving, which adjusts both the total miles driven and the average fuel economy of the shuttle.
- Average fuel economy is calculated by taking city mpg * city miles driven + highway mpg * highway miles driven
- Total fuel used = Total Miles Driven/Average fuel economy
- Fuel used per passenger=Total fuel used/number of passengers

Calculation results: One way commuter fuel usage for baseline commute in Ford Fusion vs Shuttle commute in Chevy Express

Vehicle	One way Commute miles	Number of Passengers	City MPG	Highway MPG	Average MPG	Total Fuel Used (gal)	Fuel Used Per Passenger (gal/passenger)
2008 Ford Fusion	24	1	20	28	26.88	0.89	0.89
2014 Chevy Express	24	1	11	17	16.16	1.49	1.49
2014 Chevy Express	24.5	2	11	17	16.05	1.53	0.76
2014 Chevy Express	25	3	11	17	15.95	1.57	0.52
2014 Chevy Express	25.5	4	11	17	15.86	1.61	0.40
2014 Chevy Express	26	5	11	17	15.76	1.65	0.33
2014 Chevy Express	26.5	6	11	17	15.67	1.69	0.28
2014 Chevy Express	27	7	11	17	15.59	1.73	0.25
2014 Chevy Express	27.5	8	11	17	15.50	1.77	0.22
2014 Chevy Express	28	9	11	17	15.42	1.82	0.20
2014 Chevy Express	28.5	10	11	17	15.35	1.86	0.19
2014 Chevy Express	29	11	11	17	15.27	1.90	0.17
2014 Chevy Express	29.5	12	11	17	15.20	1.94	0.16

Calculations for additional miles per commuter

additional miles per commuter 2

Vehicle	One way Commute miles	Number of Passengers	City MPG	Highway MPG	Average MPG	Total Fuel Used (gal)	Fuel Used Per Passenger (gal/passenger)	kg CO2	kg CO2/passenger
2008 Ford Fusion	24	1	20	28	26.88	0.89	0.89	7.96	7.96
2014 Chevy Express	24	1	11	17	16.16	1.49	1.49	13.25	13.25
2014 Chevy Express	26	2	11	17	15.76	1.65	0.82	14.71	7.36
2014 Chevy Express	28	3	11	17	15.42	1.82	0.61	16.19	5.40
2014 Chevy Express	30	4	11	17	15.13	1.98	0.50	17.69	4.42
2014 Chevy Express	32	5	11	17	14.87	2.15	0.43	19.19	3.84
2014 Chevy Express	34	6	11	17	14.64	2.32	0.39	20.71	3.45
2014 Chevy Express	36	7	11	17	14.44	2.49	0.36	22.24	3.18
2014 Chevy Express	38	8	11	17	14.26	2.66	0.33	23.77	2.97
2014 Chevy Express	40	9	11	17	14.10	2.84	0.32	25.31	2.81
2014 Chevy Express	42	10	11	17	13.95	3.01	0.30	26.85	2.69
2014 Chevy Express	44	11	11	17	13.81	3.19	0.29	28.41	2.58
2014 Chevy Express	46	12	11	17	13.69	3.36	0.28	29.96	2.50

additional miles per commuter 5

Vehicle	One way Commute miles	Number of Passengers	City MPG	Highway MPG	Average MPG	Total Fuel Used (gal)	Fuel Used Per Passenger (gal/passenger)	kg CO2	kg CO2/passenger
2008 Ford Fusion	24	1	20	28	26.88	0.89	0.89	7.96	7.96
2014 Chevy Express	24	1	11	17	16.16	1.49	1.49	13.25	13.25
2014 Chevy Express	29	2	11	17	15.27	1.90	0.95	16.94	8.47
2014 Chevy Express	34	3	11	17	14.64	2.32	0.77	20.71	6.90
2014 Chevy Express	39	4	11	17	14.18	2.75	0.69	24.54	6.13
2014 Chevy Express	44	5	11	17	13.81	3.19	0.64	28.41	5.68
2014 Chevy Express	49	6	11	17	13.53	3.62	0.60	32.31	5.38
2014 Chevy Express	54	7	11	17	13.29	4.06	0.58	36.23	5.18
2014 Chevy Express	59	8	11	17	13.10	4.50	0.56	40.17	5.02
2014 Chevy Express	64	9	11	17	12.94	4.95	0.55	44.13	4.90
2014 Chevy Express	69	10	11	17	12.79	5.39	0.54	48.10	4.81
2014 Chevy Express	74	11	11	17	12.67	5.84	0.53	52.08	4.73
2014 Chevy Express	79	12	11	17	12.57	6.29	0.52	56.06	4.67

Appendix IV Cost and Revenue

The following tables show cost and revenue estimates.

Calculation assumptions			
Number of passengers	10		
Number of shuttles in fleet	5		
Number of Trips	5		
Rider Fee (per month)	214		
(miles)	0.5		
Daily Travel Distance (miles)	285	distance and fuel calcs: 28.5 miles/leg*2legs*trips	
Price of Gas ($/gallon)	4		
Fuel Economy (mpg)	13		
Startup costs	**Cost ($)**	**Source**	**Notes**
Prototype Costs	16,445.00		
Company Registration Fee	25	http://www.michigan.gov/documents/dleg/BCS_CD_267_281959_7.pdf	
Shuttle Van	175,000.00	http://www.gmfleet.com/chevrolet/express-3500-passenger-van.html	This van has good fuel economy. 11city/17highway
WiFi Device	250	https://www.verizonwireless.com/b2c/store/controller?item=phoneFirst&action=viewPlanList&changePlan=true&cartIndexLocation=1&catId=4296	Verizon Jetpack® 4G LTE Mobile Hotspot MHS291L
Tray tables	2,000.00	http://www.cargoliner.com/viewproduct.php?ca=prod&catid=724&prodid=8932	Double the cost assuming higher quality tray tables
Add A/C and Power Outlets	750		estimate based on installing it ourselves ($15*shuttles*seats/shuttle)
Noise cancelling headsets	4,500.00	http://accessories.us.dell.com/sna/productdetail.aspx?c=us&l=en&s=bsd&cs=04&sku=A3695361&baynote_bnrank=0&baynote_irrank=0&~ck=baynoteSearch	($90*shuttles*seats/shuttle)
Website and App Design	20,000.00	http://www.bluecloudsolutions.com/blog/cost-develop-app/	mostly a guess, but based on the source
Route algorithm development	10,000.00	http://www.bluecloudsolutions.com/blog/cost-develop-app/	mostly a guess, but based on the source
Radio Advertising	20,000.00	http://www.strategicmediainc.com/radio-advertising-articles/radio_advertising_costs_how_much_should_i_budget.html	
Company Flyers and Brochures	1,500.00		
Smart Navigation System	1,000.00		This is a smart navigation device that receives input from our central computer system and routes drivers according to routing algorithm. Assume $200/vehicle
TOTAL FIRST YEAR FIXED COST	235,025.00		
Monthly costs	**Cost ($)**	**Source**	**Notes**
WiFi service	1,775.00	Verizon Jetpack® 4G LTE Mobile Hotspot MHS291L, 50GB/month	http://www.motorauthority.com/news/1078763_internet-on-the-go-mobile-wifi-hotspots-vs-oem-solutions (good review)
Driver Pay & benefits	16,800.00	http://www.triptac.org/Documents/RepositoryDocuments/Bus_Lifecycle_Guide.pdf	assumed hourly rate $20/hr. 8 hours driven per day (6:00-10:00am &3:00-7:00pm). Assumed 21 work days per month
Gas	9,207.69		(Distance/shuttle *number of shuttles*$/gallon*21days/month)/13mpg
Maintenance	8,977.50	http://www.triptac.org/Documents/RepositoryDocuments/Bus_Lifecycle_Guide.pdf	Assume 30cents/mile. Source says 60cents/mile, but we will do some maintenance ourselves
Insurance	1,400.00	http://www.lctmag.com/vehicles/article/40724/what-you-need-to-know-when-you-get-a-bus?page=3	
Our income	3,780.00		Assume $7.50/hr *8 hrs/day* 3 people * 21 days/month
Route Algorithm continued optimization	500		This is payment to the developer to ensure continued optimization
Website hosting	10	http://www.hostgator.com/shared	
Corporate Income Tax (CIT)	75.6	http://www.michigan.gov/documents/SBTBrochureExample_3251_7.pdf	Small business alternate tax (Profit+owners' income)*2%
Federal Income Tax	289.17	http://www.irs.gov/	FICA & Medicare
Monthly cost before overhead	42,814.96		
Overhead	2,140.75		Assume 5%
TOTAL MONTHLY COST	44,955.71		

TOTAL FIRST YEAR COST	774,493.53		
Revenue			
Rider fee	53,500.00	$8,544	
TOTAL YEARLY REVENUE	642,000.00		
month for rider	132.05		
even monthly cost	179.82		
Payback Time Calculation			
Fixed Cost	$235,025.00		
Monthly Cost	$44,955.71		
Monthly Revenue	$53,500.00		
Monthly Profit	$8,544.29		
Months to Payback	28		
Prototype Costs			
Shuttle	3500		
WiFi Device	50		
Tray tables	200		
Add A/C and Power Outlets	150		
Noise cancelling headsets	900		
Website and App Design	5,000.00		
Route algorithm development	5,000.00		
WiFi service	355		
Gas	1,000.00		
Insurance	280		
Website hosting	10		
Total	**16445**		

Cost sensitivity

STUDY NAME	Baseline (0.5miles/passenger)	2 miles/passenger	5 miles/passenger	10 vans	20 vans	$3/gal	$5/gal	8 passengers/van	5 passengers/van
Number of passengers	10	10	10	10	10	10	10	8	5
fleet	5	5	5	10	20	5	5	5	5
Number of Trips	5	5	5	5	5	5	5	5	5
Rider Fee (per month)	214	214	214	214	214	214	214	214	214
passenger (miles)	0.5	2	5	0.5	0.5	0.5	0.5	0.5	0.5
(miles)	285	420	690	285	285	285	285	275	260
Price of Gas ($/gallon)	4	4	4	4	4	3	5	4	4
Fuel Economy	15.35	13.95	12.79	15.35	15.35	15.35	15.35	15.5	15.76
		.	.						
Startup costs									
Line Item	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**
Fee	25	25	25	25	25	25	25	25	25
Shuttle Van	175,000.00	175,000.00	175,000.00	350,000.00	700,000.00	175,000.00	175,000.00	175,000.00	175,000.00
WiFi Device	250	250	250	500	1,000.00	250	250	250	250
Tray tables	2,000.00	2,000.00	2,000.00	4,000.00	8,000.00	2,000.00	2,000.00	1,600.00	1,000.00
Outlets	750	750	750	1,500.00	3,000.00	750	750	600	375
headsets	4,500.00	4,500.00	4,500.00	9,000.00	18,000.00	4,500.00	4,500.00	3,600.00	2,250.00
Website and App Design	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
development	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Radio Advertising	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Brochures	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00
System	1,000.00	1,000.00	1,000.00	2,000.00	4,000.00	1,000.00	1,000.00	1,000.00	1,000.00
SUBTOTAL	235,025.00	235,025.00	235,025.00	418,525.00	785,525.00	235,025.00	235,025.00	233,575.00	231,400.00
Monthly costs									
Line Item	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**
WiFi service	1,775.00	1,775.00	1,775.00	3,550.00	7,100.00	1,775.00	1,775.00	1,775.00	1,775.00
Driver Pay & benefits	16,800.00	16,800.00	16,800.00	33,600.00	67,200.00	16,800.00	16,800.00	16,800.00	16,800.00
Gas	7,798.05	12,645.16	22,658.33	15,596.09	31,192.18	5,848.53	9,747.56	7,451.61	6,928.93
Maintenance	8,977.50	13,230.00	21,735.00	17,955.00	35,910.00	8,977.50	8,977.50	8,662.50	8,190.00
Insurance	1,400.00	1,400.00	1,400.00	2,800.00	5,600.00	1,400.00	1,400.00	1,400.00	1,400.00
Our income	3,780.00	3,780.00	3,780.00	3,780.00	3,780.00	3,780.00	3,780.00	3,780.00	3,780.00
continued optimization	500	500	500	500	500	500	500	500	500
Website hosting	10	10	10	10	10	10	10	10	10
(CIT)	75.6	75.6	75.6	75.6	75.6	75.6	75.6	75.6	75.6
Federal Income Tax	289.17	289.17	289.17	289.17	289.17	289.17	289.17	289.17	289.17
overhead	41,405.32	50,504.93	69,023.10	78,155.86	151,656.95	39,455.80	43,354.83	40,743.88	39,748.70
Overhead	2,070.27	2,525.25	3,451.15	3,907.79	7,582.85	1,972.79	2,167.74	2,037.19	1,987.44
SUBTOTAL	43,475.58	53,030.18	72,474.25	82,063.65	159,239.80	41,428.59	45,522.57	42,781.08	41,736.14
COST	756,731.98	871,387.13	1,104,716.02	1,403,288.85	2,696,402.60	732,168.13	781,295.82	746,947.92	732,233.67
Revenue									
Rider fee	53,500.00	53,500.00	53,500.00	107,000.00	214,000.00	53,500.00	53,500.00	42,800.00	26,750.00
REVENUE	642,000.00	642,000.00	642,000.00	1,284,000.00	2,568,000.00	642,000.00	642,000.00	513,600.00	321,000.00
Calculated Average cost of fuel per month for rider	132.05	132.05	132.05	132.05	132.05	99.04	165.06	132.05	132.05
Calculated Rider fee needed to break even monthly cost	173.9	212.12	289.9	164.13	159.24	165.71	182.09	213.91	333.89
Cost difference from baseline	0	38.22	115.99	-9.78	-14.66	-8.19	8.19	40	159.99