BUSINESS PLAN FOR A  
SUSTAINABLE MOBILITY INITIATIVE  

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This is the final report for an initiative formed by the Earth Institute in collaboration with Ericsson, Florida Power & Light, General Motors, Kitson & Partners, Verizon Wireless, and Volvo Group.  

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BACKGROUND

Automobile transportation has dramatically enhanced our personal mobility and helped us realize our aspirations for economic growth and prosperity. However, in our pursuit of personal mobility, we have damaged our environment, consumed our natural resources, wasted our time in traffic, harmed each other in collisions, and created disparities between the haves and the have-nots. In light of global trends in urbanization and global economic growth, the extrapolation of these side effects raises questions about the sustainability of today’s automobile transportation system.

Today, as a result of six converging technologies, a new mobility paradigm is within reach. These six technologies are the “Mobility Internet”¹, self-driving/driverless vehicles, shared vehicle systems, specific-purpose vehicle designs, advanced propulsion systems, and smart infrastructure. Together, they create the opportunity to provide better mobility services at radically reduced cost. This new paradigm cannot be fully realized, however, without harnessing market forces. Change on the scale required cannot be achieved by a single company or by government policy. Sustainable mobility will result from an integrated “system-of-systems” that excites consumers and creates profitable business models for suppliers. To reach significant scale and have a meaningful impact, the system must be capable of reaching a market “tipping point”, the point where the positive network externalities begin to snowball because consumers desire the new solution (value exceeds price) and companies want to supply the new solution (price exceeds cost). The convergence of these technologies will be transformational, enhancing consumers’ lives and creating significant business growth and shareholder value for the companies that get it right.

Because real change takes place in the real world, the Earth Institute has acted as a “catalyst” for accelerating the development of this new mobility paradigm. The Earth Institute’s Program on Sustainable Mobility has brought together companies that constitute the future commercial eco-system of sustainable mobility and worked with them to develop a business plan for a sustainable mobility initiative. The six companies collaborating with the Earth Institute in this initiative are Ericsson, Florida Power & Light, General Motors, Kitson & Partners, Verizon Wireless, and Volvo Group.

This report is the result of six months of effort from January to June 2012, during which time collaborating companies met regularly to discuss and develop a business plan for providing new mobility systems and services. The business plan was structured to meet the rigorous standards of venture investors, including a focus on building the business through multiple milestones, financed one at a time, with these milestones designed to be logical, achievable, and to strip away risks. The business plan includes information on the big idea, a clear explanation of the proposed business, technical rationale, milestones, risks, resources needed to achieve the milestones, and additional business opportunities to pursue along the way.

¹ The term “Mobility Internet” was first coined in William J. Mitchell, Christopher Borroni-Bird, and Lawrence D. Burns, “Reinventing the Automobile: Personal Urban Mobility for the 21st Century.” The MIT Press, 2010.
INTRODUCTION

Today, nearly a billion cars and trucks move people and goods along the world’s roads. Consumers spend trillions of dollars each year on personally owned vehicles, including the costs of fuel, depreciation, insurance, taxes, parking, and time, to experience the resulting mobility benefits. In addition, vast amounts are spent on public transportation and movement of freight.

Global automotive transportation has evolved to an enormous scale over the past century since the first motorized vehicle was invented. This has occurred with virtually no disruptive change to the fundamental system conceived of by Karl Benz and popularized by Henry Ford. While this mobility system provides considerable personal freedom for those who can afford it and enables substantial economic activity, it is associated with serious side effects in terms of safety, energy use and supplies, the environment, land use, traffic congestion, time use and equality of access.

In this context, a wide range of technology and business enablers are emerging that, when combined in innovative ways, promise to transform the way that people and goods move around and interact economically and socially. Road transportation is now as ripe for transformation as the telecommunications, photography, computer, media, television and pharmaceutical industries were over the past two decades.

The Opportunity

It is now possible to supply better mobility experiences at radically lower cost to consumers and society. This opportunity results from combining the following six emerging technology and business enablers in innovative ways:

- The “Mobility Internet” does for the movement of people and goods what the Internet has done for the movement of information by coordinating large amounts of real-time spatial and temporal connectivity and infrastructure data.
- Self-driving/driverless vehicles operate without human control enabling passengers to use their time as they please (e.g., texting, talking on the phone, eating, or watching a movie) without endangering themselves or others (see Appendix A).
- Shared vehicles are used by multiple people throughout the day rather than being used exclusively by single individuals (and parked 90 percent of the time).
- Specific-purpose vehicle designs are tailored to the type of mobility they supply and the number of passengers, making them more energy-, space-, and cost-efficient compared to general-purpose vehicles.
- Advanced propulsion systems move cars and trucks using alternative energy sources and power systems in addition to oil and combustion engines; they typically entail electric drive, electric motors and electronic and digital controls.
- Smart infrastructure uses sensors and communications technology to make more efficient use of resources and provide better, less costly services.

Individually, each of these building blocks promises incremental improvements over today’s road transportation services. When combined in innovative ways to enhance the mobility experiences of consumers, the improvements are radical and the changes are transformational.
To illustrate the opportunity, consider the following:

**Scenario #1:**

Joe, a typical car owner living in a U.S. city such as Ann Arbor, Michigan, spends about $16 per day to own his mid-size sedan, and an additional $5 per day to operate it, for a total of $21 per day. These costs include depreciation, insurance, gasoline, maintenance, license fees, finance charges and taxes. He also spends money on parking and must use 60 to 90 minutes of his time each day focused on driving his car to and from work, as well as to access shopping, school, recreational and community activities. He has a busy schedule and his time is valuable.

**Scenario #2:**

Bob and his wife live in Babcock Ranch, a new eco-city in Southwest Florida. Before moving to Babcock Ranch, they were a two-car household, spending about $16 per day to own each vehicle, with additional operating costs depending on how many miles they drove each day. Now that they have moved to Babcock Ranch, many of their daily activities (work, grocery store, health club, golf course) will be located within the town. They are wondering if it makes sense to continue to own two cars.

**Scenario #3:**

Anne lives in Manhattan with her husband and two children. Anne’s family sold their car when they moved to Manhattan due to the cost and hassle of parking. Instead they use the wide range of public and shared transportation options available. They use the subway or buses daily on their way to school and work, and use yellow taxis when they need to get somewhere faster or are unable to use public transportation. All in all, each adult spends an average of $200 per month for transportation via bus, subway, and yellow taxi. Although Manhattan has an excellent public transportation system, there are limitations. During rush hour, buses and trains are uncomfortably crowded. During non-rush hours, wait times for buses can be long. Traveling north south is easy, but going cross-town is either time-consuming (2 to 3 buses and subways) or expensive (yellow taxi). Anne and her family currently organize their schedule around the constraints of the public transportation system.

**New Mobility Service**

Now consider a new mobility service that can improve the experiences of Joe, Bob, and Anne. This new mobility service combines recent developments in driverless vehicle technologies with the emerging “Mobility Internet” that can coordinate the movements of these vehicles through space and time.

In Ann Arbor, Joe is able to spontaneously request a ride using an “app” on his smart phone. An autonomous vehicle arrives at his door within minutes and transports him directly to his destination. During the trip, Joe uses his time as he pleases. Upon arrival, he doesn’t need to park the vehicle, which continues on to a nearby location to pick up another rider.
At Babcock Ranch, Bob and his wife have spent the day golfing. They used the new mobility service to get to and from the golf course, without having to use their personally owned cars. At the weekend, when they want to visit friends who live outside Babcock Ranch, they can still use their personally owned car.

In Manhattan, Anne needs to get across town to a doctor’s appointment or a business meeting. Instead of trying to figure out whether she has time to take the bus or is willing to spend money on a yellow taxi, she requests a ride using an “app” on her smart phone. An autonomous vehicle arrives at her door and transports her directly to her destination.

**How much might this service cost to supply?**

Remarkably, initial estimates indicate that the cost to supply this service to Ann Arbor customers like Joe could be as little as $2 per day. This cost reduction is a result of:

- **Better capital utilization:** Far fewer shared, driverless vehicles are needed to provide the same level of service as personally owned vehicles.
- **Better capacity utilization:** During peak travel times, the shared vehicles are occupied more than 75 percent of the time, compared to Joe’s car which is in use less than 5 percent of the time; and
- **More efficient energy use:** When Joe travels alone or with one other person, the 1-to-2 passenger, purpose-designed vehicle that they ride in weighs 75 percent less than a conventional car, thereby using significantly less energy.

In addition to radically lower cost, Joe’s mobility experience is significantly better in terms of safety, convenience, time use and peace of mind. In fact, this new mobility experience is so good and meets his needs so well that Joe no longer owns a car.

Similarly, at Babcock Ranch, initial estimates indicate that the new mobility system can be provided for $3 per day per customer or about $1 per trip. Bob and his wife enjoy the convenience of this mobility service so much that they have sold their second car.

Finally, in Manhattan, the new mobility system could operate as an alternative mode of transportation, competing with both yellow taxicabs and public transportation. Yellow taxicab fares are about $5 per mile. Initial estimates indicate that a fleet of shared, driverless vehicles would cost about $0.40 per mile to operate. This therefore presents an appealing option in the current portfolio of mobility services. Compared to the bus or subway, shared, driverless vehicles would give Anne and her family superior comfort, convenience, and route flexibility. Compared to yellow taxicabs, they would be more convenient and less expensive as a result of purpose-built vehicle design, energy efficiency, and reduced labor costs.

**The Big Idea**

The big idea here is to create a company (NewCo) that develops and sells a *portfolio of mobility systems and services* based on the six converging enablers listed above, in particular, the emerging “Mobility Internet” and driverless vehicle technologies. NewCo will supply *better mobility experiences* than those available today from the existing mix of personally-owned
vehicles, publicly-owned transportation systems, and shared vehicle options. In addition, NewCo will provide these services at *radically lower cost.*

This is an extraordinary opportunity to realize superior margins, especially for first movers. In cities like Ann Arbor, for example, NewCo could price its personal mobility service at $7 per day (providing customers with a service comparable to car ownership with better utilization of their time) and still earn $5 per day off each subscriber. In Ann Arbor alone, 100,000 residents (1/3 of Ann Arbor’s population) using the service could result in a profit of $500,000 a day. Today, 240 million Americans own a car as a means of realizing personal mobility benefits. If NewCo realizes just a 1 percent market share (2.4 million customers) in the United States alone, its annual profit could be on the order of $4 billion.

NewCo’s Business Plan explains how this idea can be realized quickly, efficiently and with effective risk management.
NewCo is a **commercial venture** established for the purpose of developing and selling a portfolio of innovative mobility systems and services. These new products will be based on the integration of six technology and business enablers: the “Mobility Internet,” self-driving/driverless vehicles, shared vehicles, specific-purpose vehicle designs, advanced propulsion, and smart infrastructure.

NewCo is a **systems integrator**. It combines the capabilities of world-class suppliers and partners to deliver better mobility experiences to customers than those available from personally owning an automobile and from existing forms of public transportation. It supplies personal mobility services at a cost that is radically lower than the amount people pay today to own and operate an automobile; and it provides greater convenience and spontaneity than public transportation systems, at a competitive cost. These capabilities position NewCo to be a highly profitable first mover in transforming mobility.

**Business Approach**

NewCo will focus on **three** sequentially financed **milestones** from 2012 to 2016:

- Proof of Concept
- Prototype System Validation
- First Generation Commercial Product

NewCo will focus on:

- **Full Mobility System** development and integration and
- **Interim Applications** that use sub-systems or building blocks of the full mobility system.

In addition to Ann Arbor, Babcock Ranch, and Manhattan, suitable locations for the new mobility systems and services include: European cities (Stockholm, Lyons, Principality of Monaco); Asian cities (Bali, Singapore, Beijing); other US cities; and closed commercial or residential areas (Talis Park, Philadelphia Navy Yard, college campuses).

The opportunity to provide **better mobility experiences at radically lower cost** results from combining six emerging technology and business enablers in innovative ways. The purpose of this business plan is to describe a company (NewCo) that will develop and sell a portfolio of mobility systems and services based on these six enablers, with a focus on shared, driverless vehicle fleets. Results from transportation and financial modeling indicate that such a business would be highly profitable.
TECHNICAL RATIONALE

ANN ARBOR CASE STUDY: COST COMPARISON TO PERSONAL VEHICLE OWNERSHIP

To compare the potential benefits of a shared, driverless vehicle fleet with personally owned vehicles, a case study was done for Ann Arbor, Michigan. Travel patterns and the cost of personal vehicle ownership were analyzed to determine whether such a system could provide residents with a less expensive and more convenient way of getting around.

Ann Arbor has a population of 285,000 and covers an area of 130 square miles. Ann Arbor was selected for the case study because it is representative of other small to medium-sized cities in the United States, based on data from the 2009 National Household Travel Survey. The other cities used in the comparison were: Austin, Texas; Orlando, Florida; Rochester, New York; Sacramento, California; and Salt Lake City, Utah. Although the population of Ann Arbor is smaller than that of the other cities (which range from 650,000 to 1.5 million), the travel data are very similar, including: average trip time, average trip length, average trips per vehicle, average vehicles per person, average vehicle occupancy, and average vehicle usage. When the data were compared, vehicle usage patterns were found to be remarkably consistent between all six cities. The absolute size of a shared, driverless vehicle fleet would vary depending on the population and area of each city. However, because the travel data for the cities is so similar, the costs per consumer per day would be nearly the same as for Ann Arbor. The estimated cost savings per consumer per day would therefore hold for these cities as well.

Ann Arbor, Michigan

- 285,000 people
- 130 square miles
- 200,000 personally owned vehicles
- 740,000 trips per day
  - 528,000 internal trips (<70 miles)
- Average trip
  - 8.3 miles
  - 16.8 min
  - 30 mph
  - 1.6 people
- Vehicles used an average of 67 minutes/day (5%)

Source: 2009 National Household Travel Survey data for Detroit-Ann Arbor-Flint area
Methodology

To evaluate whether there is consumer value to be gained by operating a shared, driverless vehicle fleet in Ann Arbor, the following methodology was used:

• Obtained travel data for Ann Arbor, including number of trips per day, average trip time, average trip distance, average trip speed, and average number of passengers.
• Used queuing, network, and simulation models to estimate how a system of shared, driverless vehicles would perform in meeting the demand for daily trips within Ann Arbor.
• Determined the number of shared, driverless vehicles needed to ensure adequate coverage and acceptable wait times during peak periods.
• Once the fleet size was known, available cost estimates for owning and operating mid-sized vehicles were used to estimate the cost of providing mobility services.
• Finally, the estimated cost of providing mobility services was compared to the cost of personal car ownership.

Trip Data for Ann Arbor

In 2009, Ann Arbor residents owned a total of 200,000 passenger vehicles. According to the National Household Travel Survey\(^2\) these vehicles were driven for 740,000 trips per day, for an average of 3.7 trips per vehicle per day. Each trip averaged 8.3 miles and took 16.8 minutes at an average speed of 30 mph. The average number of occupants per trip was 1.6 and vehicles were in use a total of 67 minutes per day on average (about 5 percent of the time).

A shared driverless fleet would most likely compete for trips taken within the Ann Arbor urban area. The analysis therefore focused on the 120,000 vehicles that were driven less than 70 miles per day. These vehicles were responsible for 528,000 trips per day, for an average of 4.4 trips per vehicle per day. These internal trips averaged 5.8 miles in distance with 1.4 occupants.

Determining Shared, Driverless Fleet Size

To determine the size of the shared, driverless fleet that would be needed to serve the internal trips taken by the Ann Arbor community, queuing, network, and simulation models were used to estimate system performance. Results indicate that the same number of internal trips could be provided by a drastically reduced fleet size. The size of the shared, driverless fleet would vary depending on the acceptable wait time for consumers. For example, with a fleet size of 18,000 vehicles, consumers would expect to wait less than one minute for a vehicle to arrive, and the vehicle fleet would be utilized 75 percent of the time on average.

Results also indicate that economies of scale are reached quickly. The analysis looked at what the vehicle fleet size and wait time would be if the geographical area remained the same, while the number of participating consumers decreased. Economies of scale are reached at about 1,000 consumers. The benefits of shared, driverless fleets can therefore also be achieved for consumer groups with niche interests.

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\(^2\) U.S. Department of Transportation. 2009 National Household Travel Survey. Data for Detroit-Ann Arbor-Flint area.
Potential Cost Savings from Shared, Driverless Fleet

Cost Savings from Reduced Vehicle Ownership Costs

AAA\(^3\) has estimated that in 2012, the ownership costs for a medium-sized sedan were $16 per day.\(^4\) If this sedan were retrofitted with driverless technology, ownership costs could increase by about 20 percent, for a total of $19 per day. A shared, driverless fleet, however, would serve the needs of 120,000 consumers with 18,000 vehicles instead of 120,000. Even when the cost of the driverless technology is factored in, vehicle ownership costs are reduced to about 15 percent of the cost of the personally owned fleet, or under $3 per day per consumer.

Cost Savings from Reduced Operating Expenses

Additional cost savings can be achieved in both energy consumption and vehicle ownership if, instead of a fleet of general-purpose vehicles, the fleet consists of multiple vehicle designs that are purpose-built for the types of trips taken. For the vehicles driven within the urban area of Ann Arbor, approximately 90 percent of trips taken involve 1 to 2 occupants, with the remaining 10 percent involving 3 to 6 occupants. If a shared, driverless fleet included vehicles purpose-built to carry 1 to 2 occupants, energy consumption and vehicle cost could be significantly reduced.

To estimate these cost savings, assume that general-purpose vehicles (such as the mid-sized sedan described above) weigh approximately 3,000 to 4,000 pounds and that vehicles purpose-built for 1 to 2 occupants weigh 800 to 1,000 pounds. Vehicles that are one-fourth the mass can be estimated to cost approximately one-fourth to purchase. The reduced mass combined with improved energy efficiency from electric drive results in one-tenth the energy consumed.\(^5\) AAA has estimated that in 2012, the operating costs of a mid-size sedan are $0.20 per mile.\(^6\) The Ann Arbor data indicate that vehicles traveling within the urban area average 26 miles per day. The operating cost per day for these general-purpose vehicles is therefore approximately $5 per day. By using purpose-built vehicles, we can reduce the operating cost to under $1 per day and the ownership cost to under $1 per day.

Cost Savings from Parking Fees

The cost of parking a personally owned vehicle in Ann Arbor averages $5 per day (costs vary depending on location). Parking costs would be saved with the use of a shared, driverless fleet. Such a fleet would be in use approximately 75 percent of the time, as opposed to personally owned vehicles that are in use 5 percent of the time on average and are parked the remaining 95 percent of the time.

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\(^3\) AAA, 2012 “Your Driving Costs: How Much Are You Really Paying to Drive?”

\(^4\) Ownership costs including full-coverage insurance, license, registration, taxes, depreciation (15,000 miles annually) and finance charges were estimated to be $5,771 per year or $15.81 per day.

\(^5\) Multiply one-fourth the vehicle mass with an electric drive that uses two-fifths of the energy of current engines to achieve energy consumption of one-tenth of the general-purpose vehicle.

\(^6\) Operating costs including gas, maintenance, and tires were estimated to be $0.2006 per mile.
Cost Savings from Value of Time

In addition to the reduced costs of ownership, operation and parking, driverless vehicles will free up the travel time that is currently focused on driving and parking the vehicle. Consumers will be able to spend that time more productively on work or leisure activities. If consumers spend one hour less each weekday on driving and parking, and if the value of consumer time is estimated at $25 to $50 per hour, then the annual value of time saved ranges from $6,250 to $12,500 per year per consumer.\(^7\)

![Graph showing cost savings](image)

Figure 1. Potential savings in ownership and operating costs per consumer per day for travel within the Ann Arbor urban area when compared to cost of personal vehicle ownership.

Conclusions

A shared, driverless vehicle fleet would provide better mobility experiences at radically lower cost when compared to personally owned vehicles. Consumers would benefit from increased spontaneity, door-to-door convenience, more productive and relaxing travel time, more predictable and shorter travel times, and improved safety. The cost of operating and owning a mid-sized car is estimated to be $21 per day for 2012. Analysis indicates that these costs can be

\(^7\) The median annual income in the USA is $50,000, which translates into approximately $25 per hour. The typical new car buyer has an annual income of $80,000 to $100,000 per year, which translates into $40 to $50 per hour. If a consumer saves 1 hour per day for 250 days out of the year and their time is worth $25 per hour, then the annual value of time saved will be $6,250. If their time is worth $50 per hour, then the annual value of time saved will be $12,500.
reduced to under $2 per day (see Figure 1), representing a significant business opportunity. If parking expenses and the value of time spent driving are included, the total cost of today’s mobility system comes to about $50 per day, making the savings from a shared, driverless fleet even more dramatic.

BABCOCK RANCH CASE STUDY: COST COMPARISON TO PERSONAL VEHICLE OWNERSHIP

The Ann Arbor case study indicates that a shared, driverless fleet could provide better mobility experiences at radically lower cost when compared to personally owned vehicles and that these results can be extended to other medium-sized U.S. cities. But what about smaller urban or suburban areas? Could the cost savings and increased convenience of the new mobility service be provided for these communities as well? To find out, a case study was done for the planned eco-city of Babcock Ranch in southwest Florida.

The city of Babcock Ranch is being built on a former cattle ranch. In 2006, developers Kitson & Partners purchased the 91,000-acre ranch, selling 73,000 acres back to the state of Florida to create a nature preserve, and retaining 17,000 acres on which to build an eco-city. When completed (around the year 2030), Babcock Ranch will have a population of 50,000 residents, as well as retail, commercial, and office space.

Babcock Ranch, Florida

• 50,000 people at buildout
  – 20,000 by 2022
• 20 square miles total area, of which 10 square miles developed
• 115,000 internal trips per day
  – 2.3 trips per person
• Average trip
  – 3.5 miles
  – 25 mph
• 9,800 internal trips during peak hour

Source: Analysis done for Babcock Ranch by David Plummer & Associates, 2011

Babcock Ranch is envisioned as a “living laboratory,” combining a philosophy of sustainability with cutting-edge technology to create a highly attractive living environment. Over half of the 17,000 acres will be permanently protected as greenways and open space, and residents will have access to the adjacent 73,000-acre Babcock Ranch preserve. All commercial buildings and
homes will be certified as energy-efficient and constructed according to Florida Green Building Council standards. Babcock Ranch plans to be a platform for sustainable clean energy technology, as well as a proving ground for emerging “smart city” products and services. To that end, Florida Power & Light has committed to building the nation’s largest solar power facility (75 MW) at Babcock Ranch. In addition, an integrated “smart grid” will provide greater efficiencies and allow residents and businesses to monitor and control their energy consumption.

Methodology

To evaluate whether there is consumer value to be gained by operating a shared, driverless vehicle fleet in Babcock Ranch, the following methodology was used:

- Obtained travel data for Babcock Ranch, including number of trips per day, average trip time, average trip distance, average trip speed, and average number of passengers.
- Used queuing, network, and simulation models to estimate how a system of shared, driverless vehicles would perform in meeting the demand for daily trips within Babcock Ranch.
- Determined the number of shared, driverless vehicles needed to ensure adequate coverage and acceptable wait times during peak periods.
- Once the fleet size was known, available cost estimates of owning and operating mid-sized vehicles were used to estimate the cost of providing mobility services.
- Finally, the estimated cost of providing mobility services was compared to the cost of personal car ownership.

Trip Data for Babcock Ranch

When fully built out in 2030, the population of Babcock Ranch will be 50,000. The city will cover a total area of 20 square miles (17,000 acres), with 10 square miles retained in the form of parks and green spaces. The area within which vehicles will travel is therefore the remaining 10 square miles of developed property.

The analysis assumed that Babcock Ranch residents would use the shared, driverless fleet for trips taken within Babcock Ranch, and that they might continue to own one car for trips beginning and ending outside Babcock Ranch. Projected travel data was obtained from an analysis done by David Plummer & Associates for Babcock Ranch in 2011. This study estimated a total of 115,000 internal trips per day at build out, or an average of 2.3 trips per day per person. The average trip length was estimated to be 3.5 miles with an average vehicle speed of 25 mph.

Determining Shared, Driverless Fleet Size

By using the Babcock Ranch trip data combined with modeling of a shared, driverless fleet, the number of vehicles needed to cover the expected demand can be estimated. Model assumptions include random origins and destinations within Babcock Ranch, and a circuity factor of 1.5 applied to the straight-line distance when computing trip lengths. Peak hour trips

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were considered when determining the fleet size, as well as customer wait time and total vehicle utilization.

Results indicate that a fleet of 3,000 to 4,000 shared, driverless vehicles would be needed to serve a fully developed Babcock Ranch during the peak daily period. With a fleet this size, the average wait time for travelers would be well under one minute. A customer would always be close to an empty vehicle. For example, if there were 3,500 vehicles in the fleet, an average of 1,000 vehicles (100 per square mile) would be available at any time. Empty travel distances would also be very low. Estimates indicate that a shared fleet of 3,500 vehicles would be utilized 70 percent during peak periods, and would average only slightly less throughout the day.

As with Ann Arbor, scale economies are reached quickly in terms of the number of vehicles needed and the cost of owning and operating them. Costs are relatively constant once the number of customers rises above 5,000, and increase very little as the customer base changes from 5,000 to 1,000. In an area the size of Babcock Ranch, a relatively small population could therefore be efficiently served by a shared fleet.

**Cost Estimate for Shared, Driverless Mobility Service**

For the Ann Arbor analysis, the number of vehicles used for internal trips was known, making it possible to compare the cost of internal trips using personally owned vehicles with the cost of providing the same service using a shared, driverless fleet. For Babcock Ranch, the number of personally owned vehicles that would be used to travel internally is not known, making it impossible to estimate cost savings. However, it is possible to estimate the cost of providing the mobility service.

As noted above, AAA has estimated 2012 ownership costs for a medium-sized sedan to be $16 per day. For Babcock Ranch, we make the conservative assumption that the smaller, specific-purpose vehicles with driverless technology also have ownership costs of $16 per day.\(^9\) If the 50,000 residents of Babcock Ranch were served by a shared, driverless fleet of 3,500 vehicles, the ownership costs for this fleet would be about $1 per day per resident.

Similarly, we can estimate the operating costs using the 2012 AAA estimate of $0.20 per mile. Residents are expected to travel internally an average of 8 miles per day, resulting in operating costs of about $1.50 per day per resident. The mobility service could therefore be provided to consumers for a total cost of under $3 per day per person, or just over $1 per trip on average.

**Conclusions**

As with Ann Arbor, the Babcock Ranch analysis concludes that a shared, driverless fleet could provide improved mobility experiences at a very low cost. A shared, driverless vehicle fleet would provide increased spontaneity, door-to-door convenience, more productive and relaxing travel time, more predictable and shorter travel times, and improved safety. The shared, driverless fleet could complement the use of personally owned vehicles, with Babcock Ranch

\(^9\) In reality, ownership costs will most likely be lower because the 20 percent increase in costs due to the driverless technology will be more than offset by the decrease in costs of the smaller vehicle.
residents using the new mobility service when convenient. The cost of providing these services would be about $3 per day per person, or $1 per trip on average.

Because it is designated as an independent special district by the State of Florida, Babcock Ranch will have complete control over all the elements of the new city, including: residential and commercial buildings, energy, transportation, and communications. Babcock Ranch would therefore be an excellent demonstration site for driverless vehicle technologies, accelerating the rate of acceptance of this technology in other towns and cities.

MANHATTAN CASE STUDY: COST COMPARISON TO YELLOW TAXICABS

The island of Manhattan is home to a population of 1.6 million people living in an area of 23 square miles. Manhattan is one of the five boroughs in New York City, along with Brooklyn, Queens, the Bronx, and Staten Island. Because parking a car is difficult and expensive, only about 25 percent of Manhattan residents own a car. Manhattan has one of the world’s most well developed systems of public and private transportation. The Metropolitan Transit Authority (MTA) runs bus and subway services throughout Manhattan and the other boroughs. In addition, there are several types of for-hire car services available, including yellow taxicabs, dispatch cars, “black car” services, and limousine services. Finally, residents have access to hourly rental cars (ZipCar, Hertz on Demand) and traditional rental cars.

Manhattan, New York

- 1.6 million people
- 23 square miles
- 410,000 trips per day
  - 0.3 trips per adult
  - 88% of all taxicab trips internal to Manhattan
- Average Trip
  - 2 miles
  - 11 minutes
  - 11 mph
  - 1.4 passengers
- Taxicab Fleet
  - 13,000+ vehicles

Sources: 2009 National Household Travel Survey data; 2010 US Census; NYC taxi data; Schaller Consulting, The NYC Taxicab Fact Book (2006)
We believe that a shared, driverless vehicle fleet would compete strongly with the mobility services provided by yellow taxicabs and, to varying degrees, by buses, the subway, other for-hire car services, hourly rental cars and personally owned cars. For simplicity, this analysis focuses on comparing the cost of using a shared, driverless vehicle fleet to the cost of using yellow taxicabs within Manhattan. Because yellow taxicabs are now required to have GPS on board, excellent information on taxi trips is available.

**Manhattan’s Yellow Taxicabs**

There are multiple types of car services for hire in Manhattan. The best-known are the taxicabs, characterized by their yellow exteriors, their metered fares, and the fact that they can only be hailed by passengers from the street (i.e., you can’t call a yellow taxicab to come and pick you up). They are the only type of car service legally permitted to pick up passengers without prearrangement. In order to operate a yellow taxicab, an owner must purchase a license from the city. Only a limited number of these licenses are available (13,237 in 2011). They are often called “medallions” because of the metal medallion attached to the hood of a taxicab, indicating that the car is licensed.

In addition to the yellow taxicabs, dispatch, “black car”, and limousine services exist. For dispatch car service, a customer can call a central dispatch office and request that a car pick them up and take them to a specified location. Dispatch offices are in contact with available cars via radio. These car services range widely in terms of quality of service, price, and types of vehicles used. Customers using dispatch car services include passengers traveling to and from the airports, and residents of neighborhoods where yellow taxicabs are hard to find. “Black car” services are generally fleets of higher quality vehicles that contract with companies to transport employees occasionally or daily to and from work and the airport. Limousine services are often used for special events. All in all, there are over 40,000 for-hire vehicles operating in the five boroughs of New York City, in addition to the 13,000+ yellow taxicabs.

**Methodology**

To evaluate whether there is consumer value to be gained by operating a shared, driverless vehicle fleet in Manhattan, we used the following methodology:

- Obtained taxicab trip data for Manhattan, including number of trips per day, average trip time, average trip distance, average trip speed, and average number of passengers.
- Used queuing, network, and simulation models to estimate how a system of shared, driverless vehicles would perform in meeting Manhattan’s daily taxicab trip demand.
- Determined the number of shared, driverless vehicles needed to ensure adequate coverage and acceptable wait times during peak periods.
- Once the fleet size was known, available cost estimates of owning and operating mid-sized vehicles are used to estimate the per mile cost of providing mobility services.

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10 The Taxi & Limousine Commission (TLC) voted in April 2012 to allow livery cabs to be licensed to make street pick-ups in the outer boroughs and northern Manhattan where yellow taxicab service is low, a rule scheduled to take effect in the summer of 2012.


Finally, the estimated cost of providing mobility services were compared to existing fares charged by taxicabs.

**Trip Data for Manhattan**

Manhattan residents use taxicabs to get to a number of different destinations each day, including work, school, home, shopping, entertainment, and restaurants. All in all, taxicabs account for 470,000 trips per day in the five boroughs, with 88 percent of these trips internal to Manhattan (approximately 410,000 trips per day). Analysis of data obtained from FareShareNYC and the Taxi and Limousine Commission (TLC) was used to determine that during the weekday peak, over 300 taxicab trips are initiated per minute, with the average trip taking about 11 minutes to cover a distance of 2 miles. The average speed driven is between 10 and 11 mph depending on time of day, and the average number of passengers per trip is 1.4.

**Determining Shared, Driverless Fleet Size**

By using the taxicab trip data combined with modeling of a shared, driverless fleet, the number of shared, driverless vehicles needed to cover the demand currently met by yellow taxicabs can be estimated. Assumptions include random origins and destinations within Manhattan, and a circuity factor of 1.4 applied to the straight-line distance when computing trip lengths. Peak hour trips were considered when determining the fleet size, as well as customer wait time and total vehicle utilization.

Results indicate that a fleet of 9,000 shared, driverless vehicles could meet the demand with much shorter wait times and significantly improved vehicle utilization. Currently, the average wait time for a passenger hailing a yellow taxicab is 5 minutes. A fleet of 9,000 shared, driverless vehicles that were centrally coordinated to respond to passengers “hailing” them via their smartphones, could reduce the wait time to under 1 minute, while increasing the vehicle utilization.

**Potential Cost Savings from Shared, Driverless Fleet**

Passengers pay on average $5 per trip-mile when riding in a yellow taxicab. This revenue covers the labor cost of the driver, vehicle ownership and operating costs, and owner income. If we assume owner profit to be 15 percent, the cost of providing the yellow taxicab service is approximately $4 per trip-mile. In contrast, the cost of providing a similar service via a shared, driverless vehicle fleet is estimated to be $0.40 per mile. These cost savings are the result of fewer taxis, less empty miles and reduced labor costs of the driver.

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13 Ibid.
14 Data originally accessed at [http://faresharenyc.com/data-analysis/](http://faresharenyc.com/data-analysis/), with additional information provided by Jeff Novich, Charles Komanoff, and Aaron Glazer of FareShareNYC. Additional data subsequently obtained from the Taxi & Limousine Commission (TLC).
15 The average fare is $8 plus a 15 percent tip ($1.20) for a total of $9.20 for a 1.9-mile trip. The average cost per mile of the trip is therefore about $5.
16 $9.20 minus 15 percent is $7.80 per trip, divided by 1.9 miles per trip for a per trip-mile cost of $4.11.
17 AAA estimates the 2012 cost of owning a mid-sized sedan to be $16 per day. We make the conservative assumption that a smaller, specific-purpose vehicle with driverless technology will also cost $16 per day to own. Daily ownership
Cost Savings from Central Coordination

Significant cost savings are possible through improved coordination. Currently, yellow taxicabs aren’t allowed to provide scheduled or pre-arranged service (dispatch and “black car” services do this), so all trips are “hailed” from the street. This lack of central coordination results in a high level of empty miles for taxicabs, in addition to a higher wait time for customers (5 minutes on average). A fleet of 9,000 shared, driverless vehicles could reduce the wait time to under a minute and increase vehicle utilization to 70 percent during peak periods.

Cost Savings from Reduced Ownership and Operating Expenses

A fleet of 9,000 shared, driverless vehicles could meet the demand currently supplied by 13,000+ yellow taxicabs. This reduced fleet size results in savings from vehicle ownership costs. In addition, a more efficiently operated fleet would result in fewer empty miles, thereby reducing the total operating costs per loaded mile.

Conclusions

Manhattan’s yellow taxicabs are rated poorly for quality of service, with passengers giving them low ratings, compared to other modes of transportation, for ability to get a cab when you want one, value for money, safety from accidents, driver understanding of directions, and driver courtesy.18 A shared, driverless fleet could provide better mobility experiences at radically lower cost. Significantly reduced wait times can be achieved using central coordination from a dispatch system accessed via the Mobility Internet. The current per-mile fare for a yellow taxicab is $5, compared with an estimated $0.40 per-mile cost of operating a shared, driverless vehicle fleet.

Although the current analysis has focused on yellow taxicabs, these represent only 8 percent of trips taken by Manhattan residents each day. A convenient and affordable mobility service would most likely draw passengers from other modes of transportation as well, including buses, the subway, other for-hire car services, and hourly rental cars.

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BUSINESS CASE

In the previous section, case studies of Ann Arbor, Babcock Ranch, and Manhattan used transportation modeling to determine the size of the shared, driverless vehicle fleet needed to replace personally owned vehicles, second vehicles, or yellow taxicabs. Cost estimates were then used to determine whether it would be possible to provide the equivalent, or better, mobility service at a lower cost. These analyses indicated that in all three cases, it was possible to provide these services at a substantially lower cost on a per unit basis (per trip, per mile, or per day).

In this section, financial models are developed to estimate whether a business operating a shared, driverless vehicle fleet could be profitable over a 10-year period (2012 to 2022), when the costs of running such a business are taken into account. Financial models were created in Excel for all three locations: Ann Arbor, Babcock Ranch, and Manhattan. These financial models are a tool for studying sensitivity to various parameters (e.g., vehicle cost) and for estimating the required equity investment and potential net profit. Conservative assumptions were made when possible for both expenses and revenue.

For the sake of simplicity, the financial models assume that the technology has been fully developed and demonstrated and that the mobility systems have been commercially launched. They also assume that NewCo is established in each location as a separate business. In reality, there could be cost savings if multiple locations shared one headquarters.

Ann Arbor NewCo

In Ann Arbor, NewCo would most likely compete for the 528,000 trips taken via personally owned vehicles within the urban area each day. For the purposes of the financial model, we assumed that these trips were evenly distributed among the 285,000 residents, with each person therefore taking 1.9 internal trips per day on average.

Overhead Costs

The financial model assumed that Ann Arbor NewCo would be established in 2013, and that operations would commence two years later in 2015. During that time, Ann Arbor NewCo would pay rent on its office space of approximately $200,000 per year, as well as paying $400,000 per year in office technology costs, and $3,000 per month in utilities. The model assumes that Ann Arbor NewCo will need $1 million per year in advertising.

Upfront Capital Costs

We assumed that Ann Arbor NewCo would purchase the driverless vehicles for $20,000 each, with the driverless technology (retrofitted or built-in) accounting for about 25 percent of that cost. In addition, we assumed that the communications technology (smartphone app, vehicle communications hardware, network operations center) would be an initial, one-time cost of $5 million.
Recharging Costs

We assumed that each vehicle would need one extra battery for exchanging once a day at a cost of $2000 per battery, and that one recharging station would be required for each 48 vehicles (30 minutes per vehicle battery recharge). Recharging stations were estimated to cost $100,000 each and to depreciate over a 10-year period. In addition, we assumed that the vehicles would need to be parked and recharged at night. Pads for overnight parking/recharging were assumed to cost $2,000 each. Because the majority of employees will be involved with vehicle cleaning and maintenance, we tied the growth in number of employees to growth in the number of vehicles and recharging stations.

Operating Costs and Depreciation

We assumed vehicle operating costs of $0.0325 per mile for electricity, $0.05 per mile for maintenance, $2,100 per year for annual insurance, registration, license, and taxes, and $30 per month per vehicle for wireless communication costs. We also assumed that vehicles and overnight recharging pads would have to be replaced every 4 years.

Market Penetration

Transportation modeling indicates that 18,000 shared, driverless vehicles would be needed to meet peak hour demand for internal trips in the Ann Arbor urban area, which translates into about 6.3 vehicles per 100 customers. Because public transportation is limited, we assume that personal car ownership will remain popular in Ann Arbor. We therefore assume that Ann Arbor NewCo will have a relatively conservative market penetration of 5 percent when business commences in 2015, and that this will grow to 30 percent by 2022.

Revenue

Trip data indicated that Ann Arbor residents would travel 11 miles per day internally, and cost estimates indicated that the ownership and operating costs to provide the service would range from $2 per day (if specific-purpose vehicles are used) to $8 per day (for a mid-sized sedan). If Ann Arbor NewCo charged $1.00 per mile, then users would pay about $11 per day. This is competitive with using a personally owned vehicle at $16 per day plus operating costs. In 2015, at a market penetration of 5 percent of internal trips, the annual revenue would be $57 million, reaching $339 million in 2022 with a market penetration of 30 percent.

Sensitivity Analyses for Ann Arbor

Sensitivity analyses indicate that the financial model is relatively sensitive to trips per day and per mile revenue. It is relatively insensitive to vehicle cost and the number of vehicles needed per user.

\[\text{19} \quad \text{“Reinventing the Automobile” estimates 0.25 kWh per mile and U.S. average cost of electricity in October 2011 was $0.13/kWh for $0.0325 kWh per mile.}\]
\[\text{20} \quad \text{AAA 2012, “Your Driving Costs.” Maintenance costs per mile are estimated to be $0.0447.}\]
\[\text{21} \quad \text{Ibid.}\]
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Conclusions

With the current set of assumptions, the financial model indicates that Ann Arbor NewCo would be a very good investment. It predicts that an initial equity investment of $35 million would be required with net cash inflow occurring in the first year of operation (2015) and dividends distributed the following year (2016). The net present value (NPV) is estimated at $189 million and the internal rate of return (IRR) at 75 percent. Ann Arbor NewCo would be highly profitable, with an estimated net income of $22 million in 2015 increasing to $159 million by 2022.

Babcock Ranch NewCo

At Babcock Ranch, we assume that shared, driverless vehicles would complement the use of personally owned vehicles. Some households might use NewCo instead of owning a second car.
Babcock Ranch could decide to purchase its own shared, driverless fleet and provide mobility services as part of resident fees. Alternatively, the city could contract with an outside vendor to operate the service. That vendor could charge either a monthly fee for subscribers or a fee per mile traveled.

Overhead Costs

The financial model assumed that Babcock Ranch NewCo would be established in 2013, and that operations would commence two years later in 2015. During that time, Babcock Ranch NewCo would pay rent on its office space of approximately $200,000 per year, as well as paying $400,000 per year in office technology costs, and $3,000 per month in utilities. The model assumes that Babcock Ranch NewCo will need $1 million per year in advertising.

Upfront Capital Costs

We assumed that Babcock Ranch NewCo would purchase the driverless vehicles for $20,000 each, with the driverless technology (retrofitted or built-in) accounting for about 25 percent of that cost. In addition, we assumed that the communications technology (smartphone app, vehicle communications hardware, network operations center) would be an initial, one-time cost of $5 million.

Recharging Costs

We assumed that each vehicle would need one extra battery for exchanging once a day at a cost of $2000 per battery, and that one recharging station would be required for each 48 vehicles (30 minutes per vehicle battery recharge). Recharging stations were estimated to cost $100,000 each and to depreciate over a 10-year period. In addition, we assumed that the vehicles would need to be parked and recharged at night. Pads for overnight parking/recharging were assumed to cost $2,000 each. Because the majority of employees will be involved with vehicle cleaning and maintenance, we tied the growth in number of employees to growth in the number of vehicles and recharging stations.

Operating Costs and Depreciation

As with Ann Arbor, we assumed vehicle operating costs of $0.0325 per mile for electricity, $0.05 per mile for maintenance, $2,100 per year for annual insurance, registration, license, and taxes, and $30 per month per vehicle for wireless communications. We also assumed that vehicles and overnight recharging pads would need replacement every 4 years.

Market Penetration

When the business commences in 2015, the population of Babcock Ranch is projected to be about 1,100 residents. This number is expected to increase to 18,500 residents by 2022 before reaching a maximum of 50,000 in 2030. We assume Babcock Ranch NewCo’s mobility services will provide residents with transportation within the boundaries of the city, and that households will continue to own a personal vehicle for trips outside the city. Transportation modeling indicates that 3,500 vehicles would be needed to meet peak hour demand at build out, which
translates into about 7.5 vehicles per 100 customers. Because Babcock Ranch NewCo’s mobility system will be an important mode of transportation within the city, we assumed an initial market penetration of 50 percent in 2015, increasing to 80 percent by 2022. Babcock Ranch would therefore start off with 40 vehicles serving 550 customers in 2015, and grow to 1100 vehicles serving 14,500 customers by 2022.

Revenue

Trip data indicated that Babcock Ranch residents would travel 8 miles per day internally, and cost estimates indicated that the ownership and operating costs to provide the service would be about $3 per day. If Babcock Ranch NewCo charged $1.50 per mile, then users would pay about $12 per day. This is competitive with using a personally owned vehicle at $16 per day plus operating costs. In 2015, at a market penetration of 50 percent, the annual revenue would be $2.4 million. This would reach $65 million in 2022 with a market penetration of 80 percent and a population of 18,500.

Sensitivity Analyses for Babcock Ranch

Sensitivity analyses indicate that the financial model is relatively sensitive to vehicle cost, trips per day, and per mile revenue. It is relatively insensitive to the number of vehicles needed per user.

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**Conclusions**

With the current set of assumptions, the financial model indicates that Babcock Ranch NewCo would be a good investment. It predicts that an initial equity investment of $17 million would be required, with net cash inflow occurring six years after business commencement (2018) and dividends distributed the following year (2019). The net present value (NPV) is estimated at $7.9 million and the internal rate of return (IRR) at 36 percent. Babcock Ranch NewCo would be profitable, with an estimated net income of $2 million in 2017 increasing to $28 million by 2022.

**Manhattan NewCo**

In Manhattan, we assume that NewCo would provide an alternative mode of transportation to residents currently using buses, the subway, yellow taxicabs and other for-hire vehicles. Although NewCo will most likely draw passengers from other modes of public transportation, we simplify by assuming that it will only draw passengers from yellow taxicabs.

**Overhead Costs**

The financial model assumed that Manhattan NewCo would be established in 2013, and that operations would commence two years later in 2015. During that time, NY NewCo would pay rent on its office space of approximately $1.2 million per year, as well as paying $1 million per year in office technology costs, and $10,000 per month in utilities. These rates are higher than the figures used for Ann Arbor and Babcock Ranch because of the high cost of real estate in Manhattan. Advertising is also expensive in Manhattan, and to compete with existing transportation services, we estimated that NY NewCo would need to spend $10 million per year in advertising.

**Upfront Capital Costs**

We assumed that Manhattan NewCo would purchase the driverless vehicles for $20,000 each, with the driverless technology (retrofitted or built-in) accounting for about 25 percent of that cost. In addition, we assumed that the communications technology (smartphone app, vehicle communications hardware, network operations center) would be an initial, one-time cost of $7 million.

**Recharging Costs**

We assumed that each vehicle would need one extra battery for exchanging once a day at a cost of $2000 per battery, and that one recharging station would be required for each 48 vehicles (30 minutes to recharge a battery). In Manhattan, recharging stations were estimated to cost
$300,000 each and to depreciate over 10 years. In addition, we assumed that the vehicles would need to be parked and recharged at night. Pads for overnight parking/recharging were assumed to cost $10,000 each in Manhattan, with an additional rental cost for the parking space of $150 per vehicle per month. Because the majority of employees will be involved with vehicle cleaning maintenance, we tied the growth in number of employees to growth in the number of vehicles and recharging stations.

Operating Costs and Depreciation

We assumed vehicle operating costs of $0.0325 per mile for electricity, $0.05 per mile for maintenance, $2,100 per year for annual insurance, registration, license, and taxes, and $30 per month per vehicle for wireless communication costs. We also assumed that vehicles and overnight recharging pads would need replacement every 4 years.

Market Penetration

Transportation modeling indicates that a fleet of 9,000 shared, driverless vehicles would be needed to replace the 410,000 yellow taxicab trips per day that are internal to Manhattan. This translates into approximately 5.5 vehicles per 1000 customers. We assumed that Manhattan NewCo would replace 10 percent of yellow taxicab trips in its first year of operation (2015) and that this would increase to 50 percent by the end of the ten-year business period (2022). In reality, Manhattan NewCo would also draw passengers from other modes of transportation, such as buses, the subway, and other for-hire car services. Trips taken via yellow taxicab account for only 8 percent of all trips taken by individuals in New York City each day. Our market penetration assumptions therefore estimate that, at its maximum, the new mobility system will successfully compete for 4 percent of all trips taken each day.

Revenue

New York taxicabs charge an initial fee of $2.50 per trip, plus $0.40 per one-fifth of a mile ($2.00 per mile) thereafter or per minute when the taxi is moving slowly (less than 6 miles per hour). In addition, there are surcharges for nighttime ($0.50 between 8pm and 6am) and rush hour ($1.00 between 4pm and 8pm Monday through Friday). All in all, taxicab fares average about $5 per mile. The financial model assumes that Manhattan NewCo would charge $1.50 per mile. In 2015, at a market penetration rate of 10 percent of yellow taxicab rides, the annual revenue would be $54 million, reaching $291 million when market penetration of 50 percent of yellow taxicab rides is reached.

Sensitivity Analyses for Manhattan

Sensitivity analyses indicate that the financial model is relatively sensitive to trips per day and per mile revenue. It is relatively insensitive to vehicle cost and the number of vehicles needed per user.
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<th>IRR</th>
<th>Project NPV</th>
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</tr>
<tr>
<td>$50,000</td>
<td>29%</td>
<td>$6 million</td>
<td>$120 million</td>
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<table>
<thead>
<tr>
<th>Trips Per Day</th>
<th>IRR</th>
<th>Project NPV</th>
<th>Investment</th>
</tr>
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<tbody>
<tr>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.2</td>
<td>27%</td>
<td>($10 million)</td>
<td>$80 million</td>
</tr>
<tr>
<td>0.3</td>
<td>44%</td>
<td>$135 million</td>
<td>$80 million</td>
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<tr>
<td>0.4</td>
<td>56%</td>
<td>$279 million</td>
<td>$80 million</td>
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<tr>
<td>0.5</td>
<td>66%</td>
<td>$423 million</td>
<td>$80 million</td>
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<table>
<thead>
<tr>
<th>Vehicle/User</th>
<th>IRR</th>
<th>Project NPV</th>
<th>Investment</th>
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<tr>
<td>0.45%</td>
<td>48%</td>
<td>$164 million</td>
<td>$80 million</td>
</tr>
<tr>
<td>0.55%</td>
<td>44%</td>
<td>$135 million</td>
<td>$80 million</td>
</tr>
<tr>
<td>0.65%</td>
<td>40%</td>
<td>$105 million</td>
<td>$80 million</td>
</tr>
<tr>
<td>0.75%</td>
<td>34%</td>
<td>$55 million</td>
<td>$100 million</td>
</tr>
<tr>
<td>0.85%</td>
<td>31%</td>
<td>$21 million</td>
<td>$105 million</td>
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<table>
<thead>
<tr>
<th>Per Mile Rev</th>
<th>IRR</th>
<th>Project NPV</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.00</td>
<td>25%</td>
<td>($29 million)</td>
<td>$90 million</td>
</tr>
<tr>
<td>$1.25</td>
<td>36%</td>
<td>$58 million</td>
<td>$80 million</td>
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<tr>
<td>$1.50</td>
<td>44%</td>
<td>$135 million</td>
<td>$80 million</td>
</tr>
<tr>
<td>$1.75</td>
<td>51%</td>
<td>$211 million</td>
<td>$80 million</td>
</tr>
<tr>
<td>$2.00</td>
<td>59%</td>
<td>$298 million</td>
<td>$70 million</td>
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Conclusions

With the current set of assumptions, the financial model indicates that Manhattan NewCo would be a very good investment. It predicts that an initial equity investment of $80 million would be required, with net cash inflow occurring and dividends distributed one year after business commencement (2016). The net present value (NPV) is estimated at $134.5 million and the internal rate of return (IRR) at 44 percent. Manhattan NewCo would be highly profitable, with an estimated net income of $13 million in 2015, increasing to $117 million by 2022.
MILESTONES

Venture capital business plans include milestones designed to strip away the risks of seeking the ultimate “prize” and to entice new investors to join at each stage along the path. NewCo’s portfolio of new mobility systems and services will result from a five-year development and commercialization plan (2012 to 2016) leading to the launch of the full mobility system (shared, driverless vehicle fleet). Interim applications may be developed along the way. This plan consists of three milestones: proof of concept, prototype system validation, and first generation commercial product (see Figure 2). These three milestones represent logical, achievable steps that strip away risk.

Figure 2. Milestones with Timeline

Milestone 1: Proof of Concept

Consumer and market research will focus on identifying and deeply understanding potential customers and specifying their mobility experiences. Modeling work will simulate the mobility system at Babcock Ranch and other potential demonstration sites. Pricing and revenue models and project cost assessments will be used to estimate profitability. Risks will be identified as well as steps to reduce them. A “Go/No Go” decision will be made on whether or not to proceed to the next milestone.
Milestone 2: Prototype System Validation

The second milestone will include the design and engineering of vehicles, device hardware, communications and control systems, and infrastructure for the prototype system. Once this prototype system is specified and built, work will begin on validating the system in terms of safety, performance, cost, and consumer acceptance. The system will also be vetted with regards to regulatory agencies, legal considerations, and insurance issues. After this milestone is achieved, the “Go/No Go” decision will be based not only on technical and regulatory feasibility, but also on potential for profitability and whether or not identified risks have been successfully mitigated.

Milestone 3: First Generation Commercial Product

The third milestone will require decisions about whether the components for the mobility system (vehicles, device hardware, communications and control systems, infrastructure) will be produced by NewCo or purchased from other sources. The selected location(s) will be prepared for product launch. The brand will be defined, and marketing, sales, and service capabilities will be created. Any necessary regulatory approvals will be obtained.
RISKS

As with the development of any new technology or business, there are a number of inherent risks for NewCo, including risks associated with the technology, execution of the project, consumer acceptance, regulation, competition, and the market.

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Description</th>
</tr>
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</table>
| Technology        | • Need for reliable wireless connection between vehicles and infrastructure  
                    • Need to deliver fail proof/fail safe self-driving/driverless vehicles  
                    • Need for robust vehicle recognition mechanisms  
                    • Need to collect and analyze enormous amounts of spatial and temporal data |
| Execution         | • On-time execution of driverless vehicle technology  
                    • Successful construction of City of Babcock Ranch                                                                                   |
| Consumer Acceptance| • Sense of safety and control in a driverless vehicle  
                    • Attitudes toward shared vehicle schemes  
                    • Data privacy concerns                                                                                                               |
| Regulation        | • Unclear regulatory environment for driverless vehicles                                                                                   |
| Competition       | • Potential competition from other domestic and international automakers and tech companies                                             |
| Market            | • Market growth limitations for demonstration sites  
                    • Spin-off application market considerations                                                                                        |

The venture capital approach to developing a business plan is focused on stripping away risk. For NewCo, risks will be mitigated in several ways, including: (1) the use of individually financed milestones; (2) the use of demonstration sites for the full mobility system; and (3) the concurrent development of interim applications for the communications systems and vehicle systems (e.g., Taxi-Net and Talis-Ride).

In addition, a number of global trends are likely to increase the demand for the product, thereby mitigating market risks. For example, accelerated climate change will intensify the demand for low- to zero-emission mobility solutions. The volatility of the world oil supply will increase demand for mobility solutions based on alternatives to oil. In the context of these global trends, younger consumer cohorts may abandon traditional notions of personal vehicle ownership.

Demonstration Sites

Risks are mitigated by focusing on multiple demonstration sites for the commercial launch of the mobility system. NewCo will initially deploy the full mobility system at selected demonstration sites, including Babcock Ranch, an innovative new city in Florida. Babcock Ranch allows for a controlled setting (low speed, limited mixed traffic), thereby mitigating driverless
technology risks. Integrated infrastructure can be designed and built without retrofitting existing infrastructure. In addition, Babcock Ranch residents will consist demographically of individuals who are self-selecting to live in a city with advanced technology, not only in its mobility systems, but also in its communication, energy, healthcare, and educational systems. This mitigates consumer acceptance risks. Finally, a commercial launch in a controlled setting allows the technology to be successfully demonstrated, thereby facilitating the adoption of the technology in other locations.

Development of Interim Applications

The markets for the full mobility systems and services should prove sufficient to generate an attractive return. In the process of developing and validating a shared, driverless fleet, a number of technology applications must be developed. These technology applications can be developed concurrently and independently of the ultimate “prize,” and can mitigate financial risks by generating revenue earlier than the full mobility system. In addition, these applications can mitigate technology and consumer acceptance risks by testing components, or combinations of components, by exposing new markets to aspects of the business model, and by accelerating consumer acceptance and adoption.

Talis-Ride

Earlier demonstrations of self-driving vehicle technologies could be done at smaller sites than Babcock Ranch. Potential sites include Talis Park, a gated, luxury residential community in Naples, Florida, owned by Kitson & Partners. Talis Park covers an area of 450 acres and will grow from about 200 residents in 2013 to about 1100 in 2018. Talis-Ride is envisioned as a mobility service consisting of small, driverless, shared, electric vehicles that will operate within Talis Park, with residents benefitting from a convenient mobility system. In addition, the Philadelphia Navy Yard is interested in using driverless vehicles to transport employees within the Navy Yard and between the Navy Yard and connection points to public transportation.

Talis-Ride would demonstrate the use of driverless technologies in a small, closed setting, thereby accelerating the development of the technology as well as consumer acceptance. Because Kitson & Partners owns Talis Park, and because this is a closed community, regulatory approval risks are mitigated.

Taxi-Net

Taxi-Net is envisioned as a smartphone app or “cyber” dispatcher that would connect customers to a coordinated system of vehicles for hire (taxicabs or car services). Currently, yellow taxicabs are the only vehicles in Manhattan licensed to pick up passengers that “hail” them from the street. However, our analysis shows that they operate with a high level of empty miles and an average customer wait time of 5 minutes. Coordinating passenger pickup would improve service to customers by reducing the length and uncertainty of wait times. It would also improve profitability for taxicabs by reducing empty miles per shift. The system would be of interest to other types of car hire services as well. Currently, customers call one company, whose dispatcher radios to their cars. If multiple car service companies were connected by Taxi-Net, increased efficiency for both customers and drivers would result.
Taxi-Net could be created by integrating existing technologies. Components required would be: (1) a smartphone app allowing customers to request a ride and transmit information on their location and destination; (2) billing system; (3) communications hardware for vehicles to transmit information about vehicle location and availability, and (4) an automated dispatch center to coordinate this information. The service could be personalized, with the smartphone app remembering the customer’s name and use history and transmitting this information to the driver. In addition, a version 2.0 could be developed that would include connectivity to home, tourist attractions, etc. This service could be expanded to any major cities where taxis and cars-for-hire are prevalent.
BUSINESS MODEL

A business model describes how a commercial system creates, delivers, and captures value. In creating NewCo, it will be important to choose a business model that meets the needs of all the collaborators, who may have different risk/return profiles, investment guidelines, and strategic directions. NewCo could be organized as a joint venture, where all collaborators would invest in the new company and share both the risks and the rewards. Alternatively, one collaborator could take the lead in establishing NewCo, while using the other collaborators as suppliers.

Joint Venture

In a joint venture, multiple companies invest in a new company. In the case of NewCo, complementary companies with synergistic technology and business interests would create a new company to design, develop, test, validate, demonstrate and commercialize a portfolio of mobility systems and services based on converging technologies. Collaborators would purchase shares either with capital or with in-kind resources. Once the right commercial eco-system emerges, other investors might also be included.

The attraction of a joint venture is that companies can share both the risks and the rewards. Complementary companies depend on each other to create, deliver, and capture value. The upside reward is realized together through a co-dependent eco-system. The downside risk is hedged by having everyone invest. Each company will have a seat on the board, and the board will be responsible for governance. A lean leadership team will be hired to run NewCo. This team will be accountable for meeting the objectives set by the Board and will be rewarded based on performance relative to these objectives.

The NewCo joint venture would have a “start-up” culture, expectations, and practices. The purpose of the venture will be to create superior shareholder value. The culture will be entrepreneurial. The expectations will include business plan performance in terms of cash flow, revenue growth, profit and timing. The practices will include deep customer understanding, outstanding customer experience, rapid and efficient prototyping.

Proven practices from venture capital companies should be used, including disciplined funding stages used to manage risk. The management team can consider government funding if it believes this will help meet objectives. However, the business potential of NewCo must not hinge on ongoing government subsidies.

Sole Ownership and Suppliers

Another potential business model involves one company creating NewCo as a sole owner, and using the other collaborators as suppliers. In this case, the one company acts as an integrator of the complementary technologies, and delivers the mobility systems and services to customers.

Other Business Models

Other structures might include a consortium, public/private partnerships, or some form of integration with public transportation.
WORLD CLASS TEAM

To take advantage of the transformation in mobility made possible by converging technology enablers, several different industries must come together to integrate their complementary areas of expertise. The current collaboration brings together world-class representatives from all the required industries. These companies, and the synergy between them, will enable a commercial “system-of-systems” for integrating and capitalizing on these technologies.

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Expertise</th>
</tr>
</thead>
</table>
| Columbia University  | • World renowned research and educational institution  
• Earth Institute blends scientific research, education, and practical solutions to guide planet towards sustainability  
• Facilitator                                                                                       |
| Ericsson             | • Advanced sensor and cellular communication systems that provide more and better real-time information  
• Mobile-network solutions                                                                          |
| Florida Power & Light| • Innovative company with 20 years work in alternative energy  
• Expertise in energy infrastructure  
• Working with Kitson & Partners to develop a solar array at Babcock Ranch                     |
| General Motors       | • World leader in designing and manufacturing of lightweight and commercial vehicles  
• Extensive experience in driver-assist technologies, connected vehicles, driverless vehicles, and electric propulsion systems  
• Developers of the EN-V                                                                              |
| Kitson & Partners    | • Forward-thinking real estate development company that aims to create transformational communities  
• Owners of Babcock Ranch                                                                        |
| Verizon Wireless     | • Leader in providing wireless solutions  
• Developers of breakthrough non-traditional devices, services, and applications that take full advantage of 3G and 4G LTE networks                  |
| Volvo Group          | • Second largest manufacturer of commercial vehicles in the world  
• Extensive experience in development of driverless vehicles, telematics, alternative fuels  
• Expertise in transportation services                                                             |
CONCLUSIONS

By combining six trends in business and technology, including the “Mobility Internet,” self-driving/driverless vehicles, shared vehicle systems, specific-purpose vehicle designs, advanced propulsion systems, and smart infrastructure, NewCo can provide better mobility experiences at radically lower cost to consumers in a variety of settings. Shared, driverless vehicle fleets can successfully compete with other modes of public and private transportation in Ann Arbor, Babcock Ranch, and Manhattan, by providing mobility services that are more convenient, more energy and resource efficient, safer, and cheaper.

The Earth Institute’s Program on Sustainable Mobility used transportation modeling, financial modeling, and cost analyses to arrive at the following conclusions:

• **Shared, driverless vehicle fleets result in greater efficiencies.** In Ann Arbor and Babcock Ranch, far fewer cars are needed to cover the same number of trips as personally owned vehicles. In Manhattan, central coordination of the shared vehicles would result in much greater efficiencies compared to the current system of “hailing” yellow taxis from the street.

• **Greater efficiencies result in cost savings for the customer.** These cost savings are a result of reduced capital investment (fewer vehicles) and reduced operating expenses (fewer empty miles). In addition, cost savings can be expected from reduced parking expenses and increased time productivity (no need to focus on driving).

• **Economies of scale are reached quickly with a shared, driverless vehicle fleet.** Cost savings per trip/mile/day occur even for small fleets of shared vehicles. In Ann Arbor, the benefits of shared fleets can be reached with as few as 1,000 customers. At Babcock Ranch, costs are relatively constant above 5,000 customers and rise only slightly as the customer base changes from 5,000 to 1,000.

• **Consumers experience greater convenience with a shared, driverless vehicle fleet.** In Ann Arbor, a fleet size of 18,000 would result in average customer wait times of less than 1 minute. In Babcock Ranch, a fleet of 3,000 to 4,000 vehicles would result in average wait times of well under a minute. Similarly, in Manhattan, a fleet of 9,000 vehicles would result in average wait times of less than a minute.

• **Results are consistent for a wide range of residential areas.** Ann Arbor is representative of the traffic patterns of other medium-sized US cities, including Austin, TX, Orlando, FL, Rochester, NY, Sacramento, CA, and Salt Lake City, UT. Babcock Ranch is representative not only of new developments, but also of smaller suburban and urban areas. Finally, Manhattan represents a densely populated urban center with roughly 70,000 people per square mile.

• **A business providing mobility services with shared, driverless vehicles could be run profitably.** Financial modeling took into account upfront capital expenditure, overhead costs, and operating costs to estimate the initial equity investment required, the
internal rate of return, net project value, and projected net profits. Evaluations of all three locations indicated that businesses would be profitable.

• **Sustainability benefits are substantial with fleets of shared, driverless vehicles.** Such a mobility system would improve transportation safety, improve roadway capacity, reduce congestion, increase energy efficiency, and improve land use (less land needed for parking). Advanced propulsion systems and specific-purpose vehicle designs would enable use of renewable energy sources and further increase energy efficiency.