New Mobility Solutions for a Changing Automotive Landscape: Development of a Shared Transportation Web Application

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New Mobility Solutions for a Changing Automotive Landscape: Development of a Shared Transportation Web Application

BY

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THESIS

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ABSTRACT

The American transportation landscape is changing. Americans, especially young people, are driving less for the first time in recorded history, and this trend is expected to continue in the foreseeable future (Davis and Baxandall 2013). This shift has been accompanied by a corresponding increase in popularity of alternative transportation models such as carsharing and ridesharing (Shaheen 2013). Presently, these models only focus on dense urban areas, and current research (Martin and Shaheen 2011) suggests that carsharing and ridesharing programs work best when paired with existing public transportation infrastructure. However, large suburban master planned communities (MPCs) are also increasing in popularity in the United States (Spivak 2012), and the majority of these communities have limited transit options (Mercedes-Benz R&D North America). We explored opportunities for new transportation solutions in these large communities by evaluating existing solutions, interviewing potential users, and analyzing interview and survey data from residents in a specific community. We found that there is an unmet need for a shared transportation solution in a large MPC and designed and implemented a mobile application to demonstrate such a solution. Our application has comparable performance, functionality, and ease of use to other transportation applications and, once implemented, will help residents save time, money, and the environment.

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INTRODUCTION

The automotive industry is enjoying unprecedented amounts of global success, selling over 82 million vehicles worldwide in 2013 (LeBeau 2014). China is now the world's largest car market by volume with over 22 million new car sales in 2013. However, the American car market, the world's second largest and perhaps the most influential, is stagnating and is poised to decline (Wards Auto 2014). The European car market is already in decline as well (EAMA 2014). In addition, the growth in auto sales in China is not sustainable in the long term, as China's main cities are already suffering from massive gridlock and pollution, and the Chinese government has implemented restrictions on car licensing to slow car sales (Green and Naughton 2014).

Traffic congestion and pollution problems are not unique to China. In 2011, Americans wasted 5.5 billion hours and lost $121 billion sitting in traffic (Schrank et al. 2012). Several states have passed recent legislation that aims to reduce greenhouse gas emissions, over 14% of which is caused by passenger vehicles (Environmental Protection Agency 2013). Technology has enabled people to connect with each other without being in the same location, and new transportation models such as carsharing and ridesharing offer new ways to get around. All of these effects are contributing to Americans driving less. Vehicle miles traveled per capita has been declining steadily since it peaked in 2005 (Federal Highway Administration 2014, US Census Bureau 2014). Some experts hypothesize that peak car travel has been reached and will continue to decline (Davis and Baxandall 2013).

As Americans decide to buy fewer cars and travel fewer miles, many are choosing to get to their destinations by means other than private automobiles. In particular, carsharing services such as Zipcar and ridesharing services such as Lyft have become increasingly popular. Carsharing and ridesharing services are particularly attractive because they reduce ownership and maintenance costs for their users in addition to reducing overall emissions (Shaheen and

Cohen 2013). However, these services are currently only offered in dense urban areas. Suburban areas currently remain underserved by transportation options other than private automobiles.

Our project explores alternative transportation modes that augment or replace private vehicle ownership in the United States with a focus on solutions for suburban neighborhoods. We considered several factors: (1) residents' existing transportation needs and challenges, (2) existing alternative transportation services such as carsharing, ridesharing, and carpooling, (3) financial and environmental impacts of a potential service, and (4) technology that could be used to implement a potential service. We found that there is a potential market for a shared transportation service in a large suburban master planned community (MPC) where there are few transportation options besides private automobiles.

This paper discusses the studies we performed in order to evaluate the need for an alternative transportation service in a large suburban MPC and focuses on the technologies and methods used to build a prototype mobile web application of a community transportation platform. For privacy reasons, the name and location of the MPC under study will remain confidential.

LITERATURE REVIEW

The Peak Car Phenomenon

During the recent recession, new car sales plummeted from a peak of 17.4 million vehicles in 2005 to merely 10.6 million vehicles in 2009 as owners elected to keep their used cars instead of buying new ones (Wards Auto 2014). As the economy recovered, new car sales have gradually increased, and Edmunds predicts 16.4 million new car sales in 2014 (Edmunds 2013). However, Goldman Sachs predicts that the North American new car sales market will decline to 15 million vehicles in 2020 (Wards Auto 2011).

New car sales in the European Union are already on the decline (European Automobile Manufacturers Association 2014), leading some experts to hypothesize that peak car travel has been reached and will continue to fall (Davis and Baxandall 2013). Indeed, for the first time in recorded history, the number of vehicle miles traveled per capita in the United States is declining steadily (US Census Bureau 2014, Federal Highway Administration 2014). See Fig. 1.

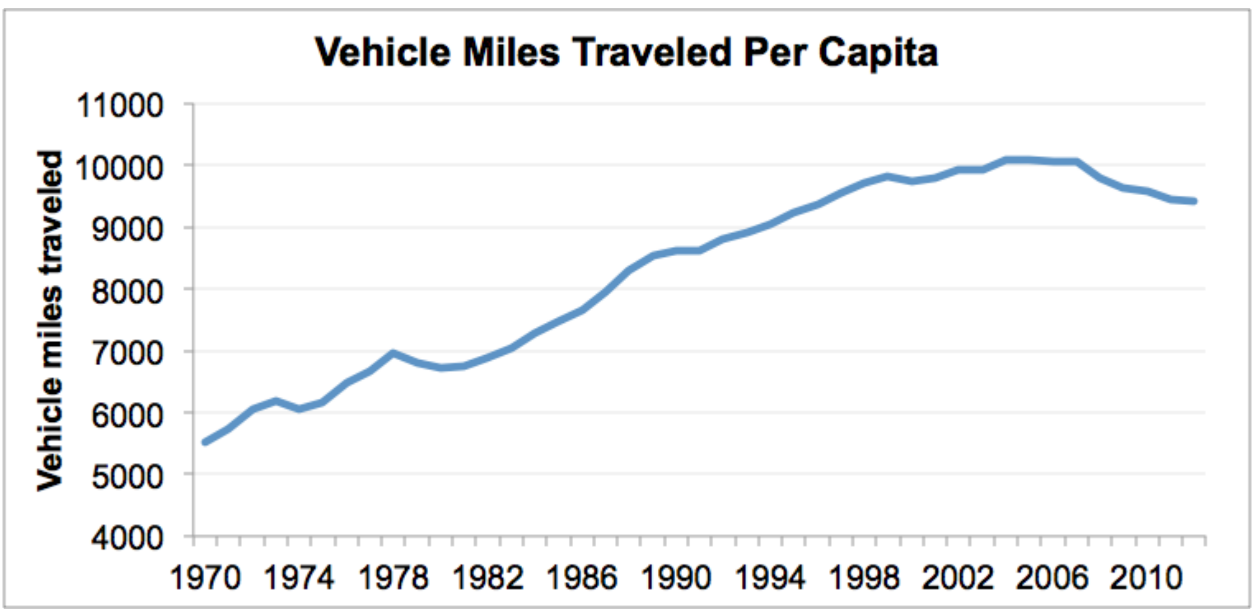

Figure 1. Vehicle miles traveled per capita in the United States, 1970-2012. The two dips in the 1970s are due to the 1973 and 1979 oil crises. (Federal Highway Administration 2014, US Census Bureau 2014)

Several factors are contributing to this peak car phenomenon. Technology improvements have made communication and transportation alternatives more convenient, and increased congestion, higher gas prices, and changes in licensing laws make driving less attractive. In particular, today's young people are driving much less than previous generations. The average number of miles traveled by 16 to 34 year olds decreased by 23% from 2001 to 2009 (Davis et al. 2012), and the percentage of licensed drivers for this age group has declined as well.

There are several political forces also influencing the changing automotive landscape. Public policies have shifted from promoting road building and suburban sprawl to emphasizing sustainability and environmental friendliness. Legislation such as California's Global Warming Solutions Act of 2006 and Sustainable Communities and Climate Protection Act of 2008 aim to reduce overall greenhouse gas emissions, 14% of which is caused by passenger vehicles (Environmental Protection Agency 2013).

As Americans look for ways to replace their private autos, new transportation options, including carsharing, have become popular. Carsharing, as the name implies, allows multiple users to share vehicles through a subscription service, gaining the benefits of private automobile use while avoiding some of the drawbacks such as high ownership costs.

New Transportation Models

The rise of carsharing has coincided with a decline in traditional ownership models in other industries and the rise of sharing, subscription, and pay-per-use models such as AirBnB, Netflix, and Rent the Runway. In 2002, there were 12,098 carsharing members in the United States. The following year, membership more than doubled to 25,640 members, and has grown steadily to nearly one million members in 2013 (Shaheen 2013), a 23.5% increase over 2012.

The carsharing market has experienced tremendous growth over the past decade and we anticipate that this growth will continue. Leading researchers (Shaheen and Cohen 2013) predict that revenue from North American carsharing programs could grow to $3.3 billion in 2016, up from $253 million in 2009. Shaheen and Cohen estimated a 10% growth potential for individuals over 21 in North America. Using second order polynomial regression on U.S. membership data, American carsharing membership is anticipated to grow over the next three years to 1.6 million members in 2016 (R^2 = 0.991). See Fig. 2.

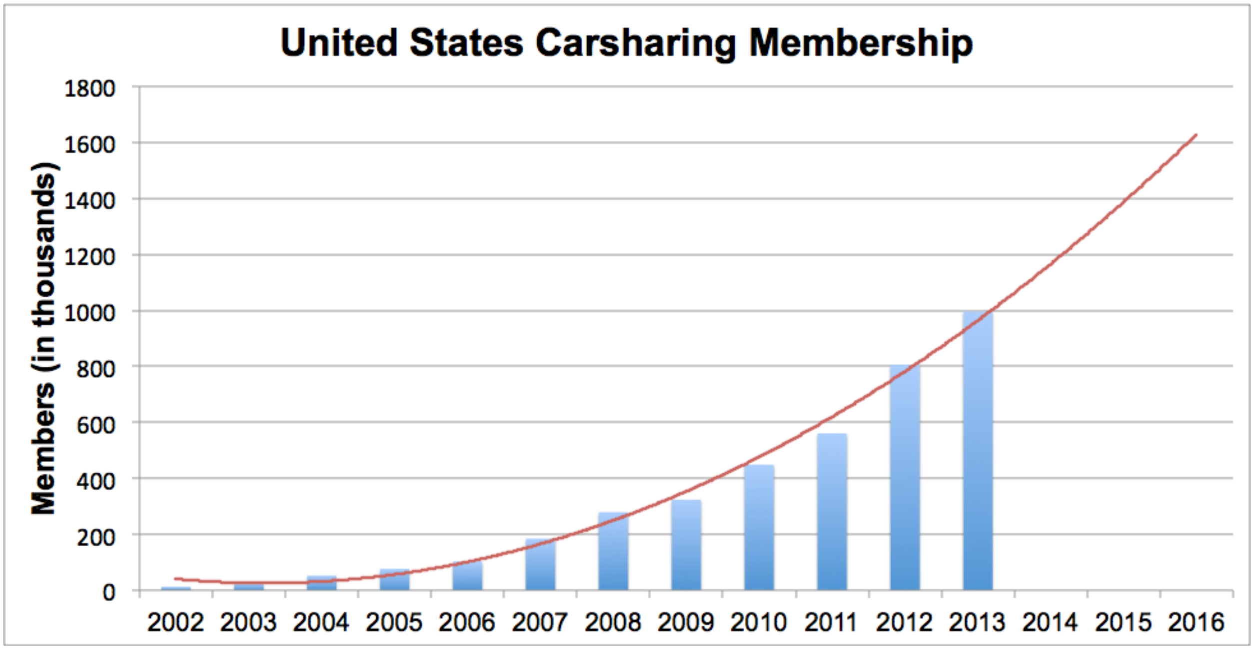

Figure 2. Carsharing membership in the United States with predicted membership trend. (Shaheen 2013)

Carsharing has numerous social and environmental benefits. It is estimated that an average North American carsharing user's carbon dioxide emissions are reduced by 27%, and up to 56% when avoided emissions, such as a forgone vehicle purchase, are considered (Shaheen and Cohen 2013). In addition, each shared vehicle reduces the need for 9 to 13 private vehicles (Martin et al. 2010). Studies also suggest that carsharing services reduce overall vehicle miles traveled as trips shift to walking, bicycling, and public transportation (Martin and Shaheen 2011). Clearly, carsharing services are more than just profit-making enterprises: they are also a step toward a more sustainable future.

Untapped Market Potential

Current carsharing services generate revenue by charging a recurring membership fee to users and a usage fee based on the time and/or distance that a vehicle is in use (Shaheen et al. 2005). This revenue model requires that a carsharing service acquire a minimum number of users in order to become profitable. As such, these services are rarely available outside of densely populated urban areas and university campuses (various carsharing service maps). Residents living in suburban areas can only choose between using their private automobiles or taking very sporadic public transportation. However, changing public policies are making transportation sharing services with other revenue models viable.

Information provided by Mercedes-Benz R&D North America indicates that real estate developers are compelled to pay upwards of $100 million per new development in order to compensate for the increased traffic originating from future residents. This traffic mitigation fee is based on estimates about the number of vehicle trips that residents will take. By implementing a shared transportation service for residents of the community, the developer can reduce the number of trips and save millions in avoided traffic mitigation fees (Mercedes-Benz R&D NA). In addition, the developer can provide the service exclusively for residents of the community and support running costs with a nominal increase in homeowners' association fees. Using this revenue model, suburban communities will not have to rely upon achieving a critical mass of users in order to remain financially viable.

METHODS AND MATERIALS

Our project consisted of three main phases: assessment of user transportation needs, analysis of competing services, and development of a prototype transportation service web application.

Needs Assessment

We interviewed twelve people in detail about their transportation usage. We selected participants who lived in affluent, suburban neighborhoods that have limited access to public transportation. The participants varied in age between 22 and 64, and all had completed some form of higher education. Each participant had one or more private vehicles in their household. We prepared a list of general questions to discover their feelings about alternative modes of transportation such as carsharing. We asked the subjects to perform part of their daily transportation routine and observed them as they drove their cars to various destinations during a contextual inquiry style interview (Beyer and Holtzblatt 1998). On average, each interview lasted approximately one hour.

Our industry sponsor, Mercedes-Benz R&D North America, provided us with a large amount of survey and focus group data from a representative suburban community. This community is home to approximately 20,000 residents living in more than 7,000 homes. We received survey data from 180 residents about their transportation destinations in and around the community. We also received recordings of one-hour focus group meetings for three age groups: teenagers, adults, and elderly residents. We organized the survey data into the most popular destinations and combined this data with needs identified from the focus groups to plan an optimal route for an exclusive community shuttle service.

Competitive Analysis

We evaluated existing transportation options such as private automobiles, public transportation, carpooling, carsharing, ridesharing, and taxis in order to determine where to position our service. In addition to using the majority of these services in order to gain a typical user's perspective, we evaluated several existing transportation applications, including NextBus, Lyft, and Google Maps using Nielsen's usability heuristics (Nielsen 1995) and other established user interface design principles (Hutchins et. al. 1985, Norman 1988). For each application, we identified examples of good user interface design and examples of major usability violations.

Application Development

Based on the results of our research and needs evaluation, we decided to develop a transportation service that integrated a private community shuttle with carsharing vehicles. The service must be accessible from a mobile device, but we decided against a native iOS or Android phone application because we did not have reliable data about smartphone proliferation in our target community and wanted to make the service available to as many residents as possible. Thus, we created a mobile web application using HTML, JavaScript, and CSS. This technology choice will allow any community member with a full-featured web browser and an internet connection to access the service.

After evaluating competing applications, it became clear that a critical feature for any transportation service was a map to help the user visualize their trips and destinations. Rather than develop a new mapping engine for our application, we chose to rely on a third party maps service and searched for one that had the following capabilities:

- Draw static shuttle routes on the map
- Draw markers to indicate shuttle stop, shuttle, carsharing, and user locations
- Display popup info windows when markers are clicked on
- Retrieve routing information and draw dynamic route paths on the map

- Support custom map styling and route waypoints
- Support porting to native iOS or Android apps if desired in the future

Once the mapping engine was selected, we focused on building the app using general software engineering best practices and established web development methods (refer to Appendix A for a brief discussion on how the application was implemented). Our heuristic evaluations of existing transportation apps informed our design choices. The application was designed to provide a device-agnostic user-friendly experience.

Application Testing

In order to ensure that our prototype application had acceptable performance, we measured the latency, load time, and frame rate achieved when performing basic tasks such as initializing the map, making a route request, changing the zoom level, and expanding the menu. We performed the tests on a Google/LG Nexus 5 smartphone running Android 4.4.2 and mobile Chrome 34.0.1847.114. The phone was connected to the San Francisco Bay Area AT&T LTE wireless network with WiFi turned off and the browser cache disabled. The performance metrics were captured using Chrome Developer Tools on a laptop attached to the phone with USB debugging enabled.

We measured the network latency, time to document ready event, and load time for two tasks: initializing the application and making a route request (updating the map). To gauge the responsiveness of the application, we measured the frame rate for the following tasks: manually zooming in and out of the map, moving the map, expanding and collapsing the menu, and submitting a route request, which draws paths on the map, creates markers, and causes the map to re-center and resize. Each test was repeated ten times and the results were averaged and compared to acceptable values for latency (Grigorik 2013) and frame rate. We also repeated these tasks using the official Google Maps web service (maps.google.com) and compared its performance to our application.

RESULTS AND DISCUSSION

Our research and user needs assessment revealed that there is opportunity for a shared transportation platform in suburban settings. Most suburban areas have limited travel options besides private vehicle ownership, which causes congestion and parking issues. In our experimental community, 93% of those surveyed said that they would use a private community shuttle if one were available. We built a prototype mobile app that demonstrates a new transportation service offering carsharing and shuttle services to the experimental community.

Needs Assessment

We interviewed twelve participants about their transportation habits. The participants lived in affluent neighborhoods with limited public transportation options. All of the participants indicated that they enjoyed the convenience and time saving benefits afforded by private vehicle ownership. Most indicated that they wanted to have at least one vehicle in their household for emergencies. Some participants did take public transportation when available, but most found it to be too time-consuming or inconvenient. However, when asked about parking and traffic difficulties, the participants expressed frustration with these aspects of car ownership. Interestingly, one participant brought up the idea of shared community transportation, commenting, “It would be great if our neighborhood had a shuttle that drops us off at BART in the morning.”

Every one of the twelve interview participants expressed reservations about lending their personal car to strangers. One participant refused to loan out his car at all, while the others preferred to only lend their vehicles to friends or family. In general, the participants were concerned about other drivers abusing or damaging their vehicles. However, the participants were open to the idea of a shared pool of vehicles for their community, but most expressed concerns about the costs associated with such a service.

The survey and focus group data revealed the need for other transportation options in the experimental community. The majority of focus group participants indicated that they would use a low cost shuttle circulator service, although the destinations and times of use varied slightly between the age groups. They also indicated that they would be more inclined to use a service that was exclusive to the community since they knew and trusted their neighbors. Out of 180 survey participants, 167 indicated that they would use a shuttle service to reach various destinations in and around the community. We identified convenience, timeliness, time saving, and safety as the user top needs from this data. These needs align closely with those expressed by our contextual interview subjects. We also reviewed the survey data and identified the top destinations in order to plan out a potential route for the shuttle service.

Competitive Analysis

We performed heuristic evaluations of three competing transportation mobile applications: NextBus, Lyft, and Google Maps. We used these evaluations to make design decisions about our prototype application.

The most glaring problem with the NextBus application was the lack of any useful location context. NextBus can detect a user's location and display the nearest bus stops, but if a user were unfamiliar with the surrounding area, he would have to use a separate mapping application to figure out how to get from his current location to the bus stop. When the user clicks on a bus route, a map displaying the route and the user's location is provided, but if the user does not know which bus route to select, he will have to use trial and error to find the route(s) that will get him to his destination. These problems are severe violations of the "visibility and system status" and "match between system and the real world" heuristics because they occur often, are persistent, and are difficult for users to overcome.

Lyft and Google Maps do a good job of bridging the gulfs of execution and evaluation (Hutchins et al. 1985) that exist in the NextBus app, and we found no major usability heuristic violations in either of these apps. The focus of these applications is a map interface that clearly displays the user’s current location and surrounding area. Lyft also displays the locations of the closest Lyft drivers and the amount of time until the user will be picked up. The mobile Google Maps interface is nearly identical to the desktop interface, which allows users familiar with the desktop version to easily adapt to the mobile interface. We used these design techniques in our application by displaying user position, shuttle positions and travel times, and stop locations on the map. In addition, we used standard responsive web design techniques to ensure that the desktop and mobile interfaces were as similar as possible.

Application Prototype: Map Engine Selection

We designed and developed a prototype mobile application to demonstrate a transportation service that offers private shuttles and carsharing vehicles exclusively for community members. An important part of the application development was selecting an appropriate maps engine. The maps service we chose had to be capable of the following tasks:

- Drawing static shuttle routes on the map
- Drawing markers to indicate shuttle stop, shuttle, carsharing, and user locations
- Displaying popup info windows when markers are clicked on
- Retrieving routing information and drawing dynamic route paths on the map
- Allowing custom map styling and route waypoints
- Allowing porting to native iOS or Android apps if desired in the future

We surveyed a number of maps engines, including Google Maps, Bing Maps, and Here Maps, which provide their own routing service with their maps, and OpenStreetMap, which must be paired with a separate routing service (see Table 1). Out of the available services, only Google Maps and MapQuest had all of the necessary features while requiring minimal setup. We elected to use Google Maps due to its familiarity to users, its thorough developer documentation and support, and its ability to provide a real time traffic layer and travel time estimates based on live traffic data. Our prototype does not use these traffic features, but it is feasible that they could be incorporated in the future.

				OpenStreetMap			
	Google Maps	Bing Maps	Here Maps	YOURS	MapQuest	OSRM	GraphHopper
US coverage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Driving directions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walking directions	Yes	Yes	Yes	Yes	Yes	No	Yes
Waypoints	Up to 8	Yes	Yes	Yes	Yes	Yes	No
Route instructions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Custom map styles	Yes	No	No	Yes	Yes	Yes	Yes
Notes	25000 free API calls/day	Poor documentation	2500 free API calls/day	Requires server setup			

Table 1. Comparison of available map and routing engines.

Application Prototype: Development and Testing

We used several web development frameworks and tools, including Twitter Bootstrap, jQuery, and Yeoman, to build our application. We relied on the Google Maps API and Google Directions API to render a map of the example community, get directions from point to point, and draw paths on the map (see Fig. 3). Refer to Appendix A for additional screenshots.

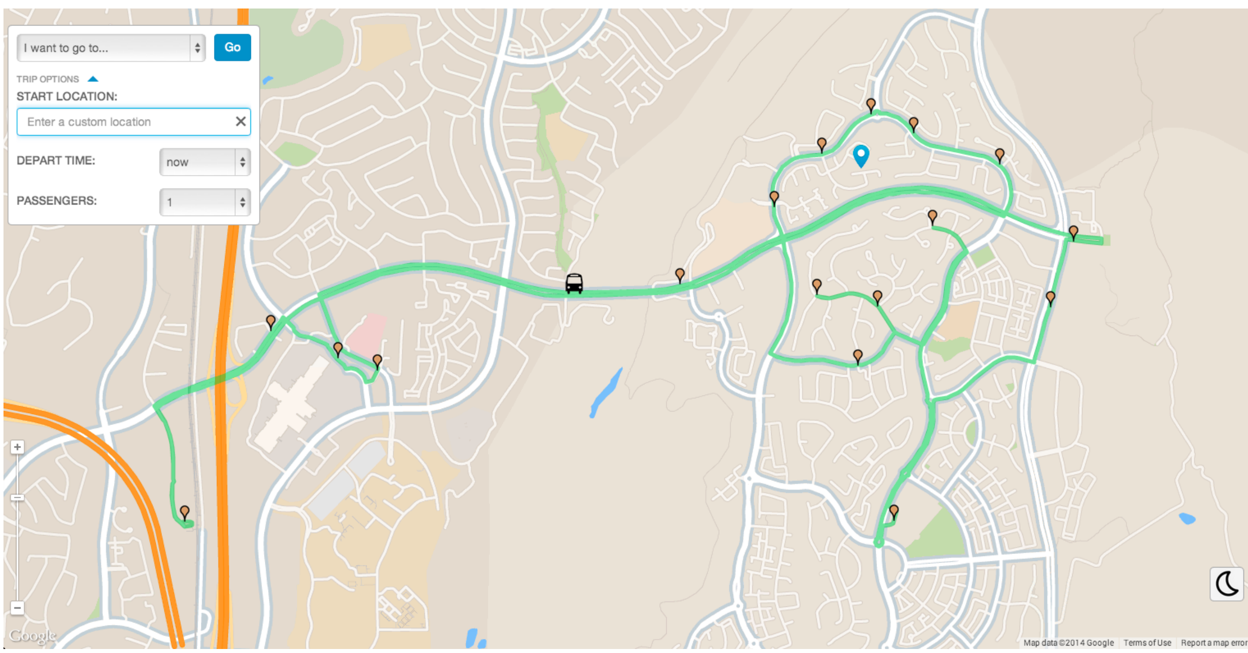

Figure 3. Desktop version of app prototype. Street labels have been removed for confidentiality.

Our application achieves performance comparable to the regular Google Maps mobile site (see Figs. 4-6). Google Maps benefits from lower network latency due to several resources being cached on the Android phone. On initial start-up, our application achieves a faster onLoad event, and users can see an interface with a blank map surface almost immediately (1.76 seconds). It does take slightly longer to load all of the map tiles through the API, however, but the delay is tolerable (6.388 seconds vs. 4.702 seconds for Google Maps).

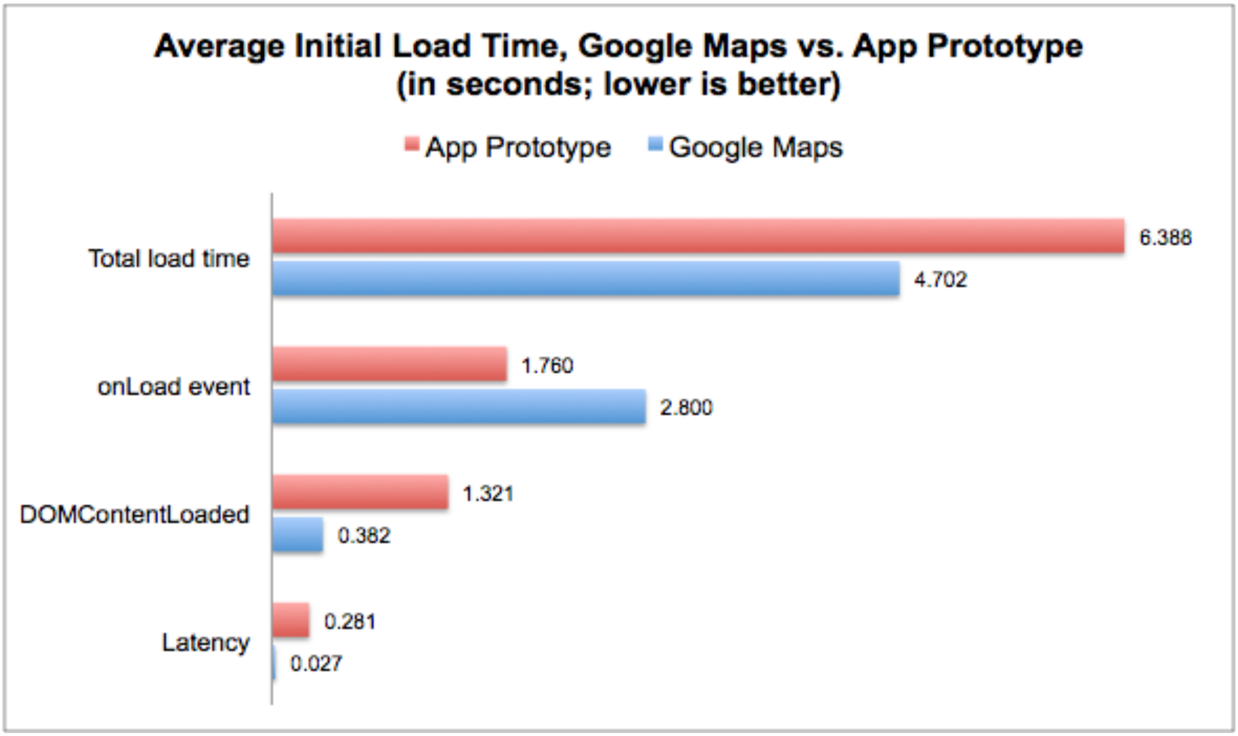

Figure 4. Comparison of average initial load time of app prototype to Google Maps.

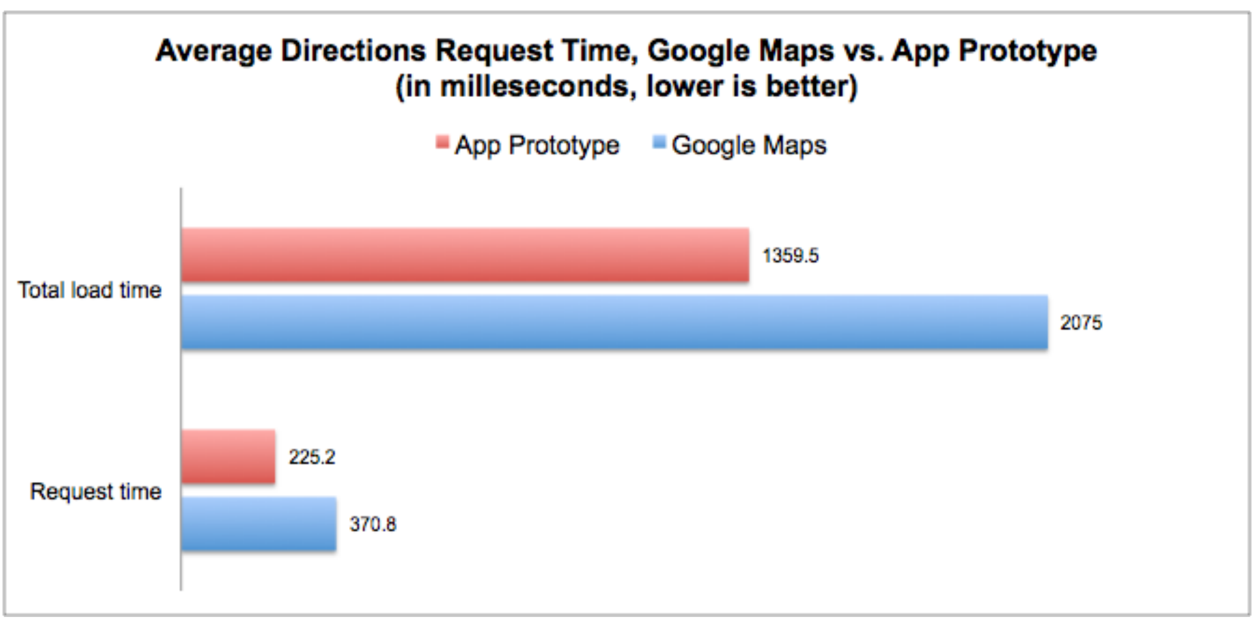

Figure 5. Comparison of average directions request time of app prototype to Google Maps.

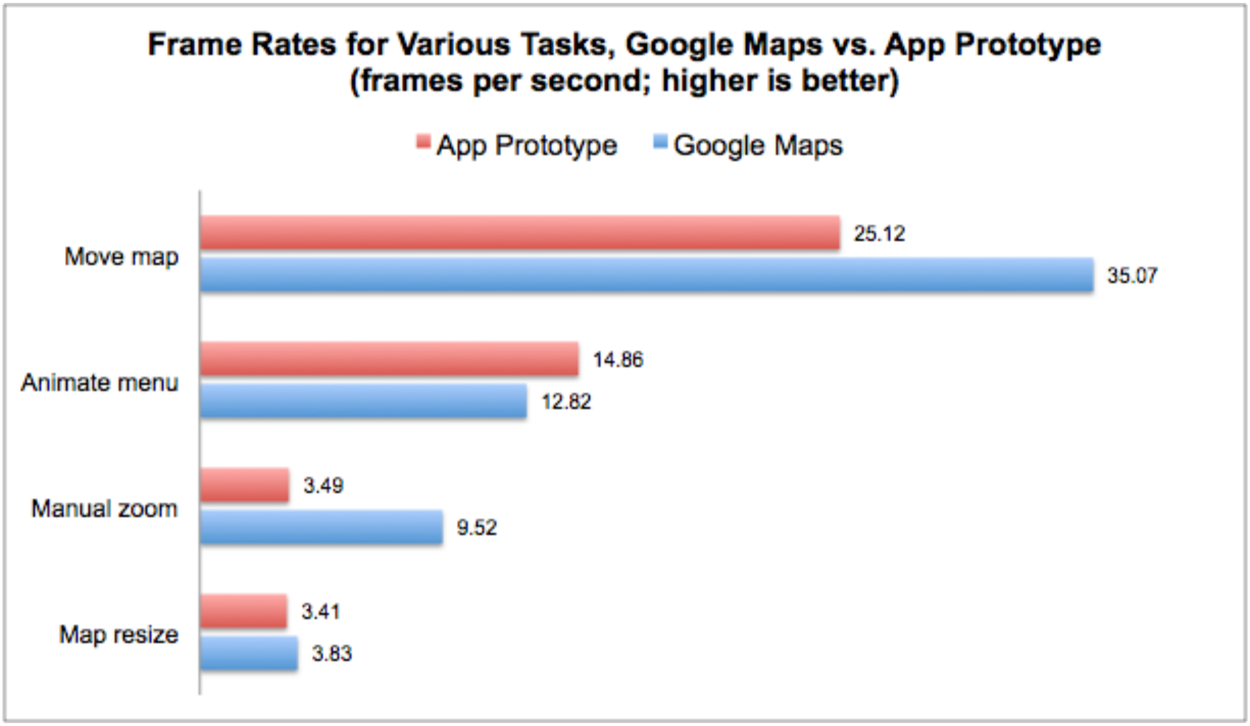

Figure 6. Comparison of frame rates for app prototype and Google Maps.

Surprisingly, directions requests are slightly faster in our application than in Google Maps. This could be due to the fact that our application only maps a small area, thus requiring fewer new map tiles to be retrieved when a request is made.

Frame rates for various tasks in our application are comparable to Google Maps. It would have been best to stay above approximately 24 frames per second (the rate used for NTSC television), but the 14 frames per second achieved during the menu animation still appears smooth to the human eye. We suspect that the low frame rates associated with zooming and resizing the map may be partially caused by the latency required to retrieve new map tile images over the network.

Overall, our prototype application provides a fast, consistent user experience across all devices, and will enable users to easily plan shuttle trips and reserve carsharing vehicles while on the go.

CONCLUSION

The once thriving American car culture is declining, and several factors are combining to make private vehicle ownership less attractive than it has been in the past. In particular, traffic, parking, and environmental concerns are driving change in urban areas as carsharing services continue to grow. We discovered that suburban communities are still reliant on private vehicles, and found that an example community could benefit from a shared transportation service that offers private shuttles and carsharing vehicles exclusively for community members. We also designed and developed a prototype mobile application to demonstrate how the service will operate.

The prototype application is meant to serve as a demonstration only and is not ready for real-world use. However, the app was designed to be as flexible as possible, and could be deployed for public consumption once it has been tested with users, the shuttle and carsharing logistics are finalized, and a number of technical hurdles are addressed.

Future Work: Performance Optimization

Currently, the application prototype uses a number of libraries to facilitate rapid development, including Twitter Bootstrap and jQuery. Once the application has been finalized, the unused portions of these libraries can be removed in order to reduce load time (see Appendix A for further discussion).

In order to draw shuttle routes, the application currently uses the Google Directions API to retrieve path objects representing the routes. Once the shuttle routes have been finalized, these path objects can be saved to disk in order to reduce the cost and latency associated with making numerous Directions API calls.

Future Work: Back-End Integration with Real Data

The prototype version of our application uses simulated data to demonstrate how the shuttle position and user location would be detected and updated in real time. Once the service is fully operational, we expect this simulated data to be replaced with actual data from real shuttles and users.

Future Work: Routing and Custom Destinations

The current prototype only serves a small portion of the target community, and has at most two shuttle routes active at any one time. In addition, the prototype does not currently allow a user to enter a destination other than one of the pre-set shuttle stops. As a result, finding the optimal multi-modal transportation route is a relatively simple task of calculating the walking path to the closest stop and then searching for the route from the origin stop to the destination stop. If the destination stop cannot be reached from the origin stop without a transfer, we instruct the user to transfer shuttles at a pre-determined transfer point.

This routing method is sufficient when used with a small number of stops and only two routes. However, as the shuttle service expands to serve the rest of the community, more sophisticated routing algorithms must be implemented in order to find the optimal route from one stop to another. In addition, users should be allowed to enter custom destinations other than pre-determined shuttle stops, and the application should direct the user to take the shuttle to the nearest stop and then walk to their destination. Determining the optimal route from one point to another using more than one form of transportation is a problem known as multi-modal transport with time windows, and several algorithms and heuristics exist for performing this task (Lozano and Storchi 2001, Ziliaskopoulos and Wardell 2000, Martin-Anderson 2011).

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Related works:

S. Nuru, “Identifying Opportunity Spaces in the Car/Ride Sharing Environment: Creating a Framework for a Suburban Community Circulator,” University of California Berkeley, 2014

W. Wu, “Residential Mobility Solution and Life-Cycle Assessment on Community Carsharing,” University of California Berkeley, 2014

R. Mehendiratta, “Residential Mobility Services with Mercedes-Benz,” University of California Berkeley, 2014

APPENDIX A: SOFTWARE DEVELOPMENT

Our application is built with HTML, JavaScript, and CSS, and uses the Google Maps JavaScript API V3 to draw a map with markers and routes, geocode user locations, and process routing requests. We used standard object-oriented programming techniques: a shuttle stop object has a name, location, and map marker object, while a route object has multiple stop objects, shuttle objects, a path object, times of operation, etc. For the prototype, we stored all of this data in memory, but we expect it to be retrieved from Mercedes' servers once the transportation service is fully operational. We used CSS media queries and other standard responsive web design techniques to ensure the interface worked on all devices.

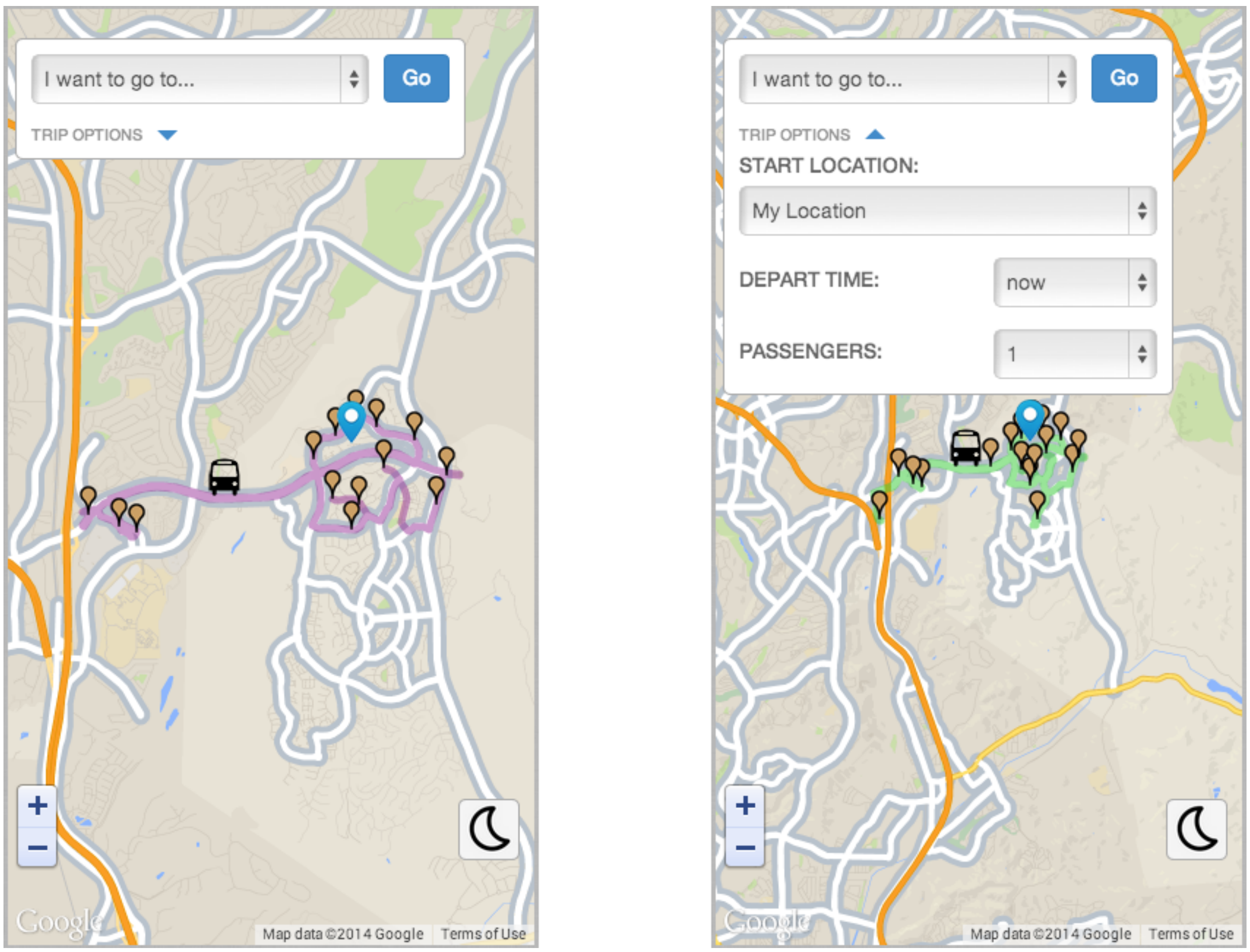

Figure A1. Prototype start-up screens for transportation app, as viewed on a Google Nexus 5.

On start-up, the user is presented with a map of the community with the currently active shuttle routes and stops shown on the map. The user's current location is obtained asynchronously using the Google Geolocation API and indicated by a blue marker. The user may then select their destination and start location options. If the start location is not a currently active shuttle stop, the user is directed to the closest stop and then takes the shuttle to the destination. The shuttle's route, the user's walking path, and their durations are all obtained asynchronously with the Google Directions API.

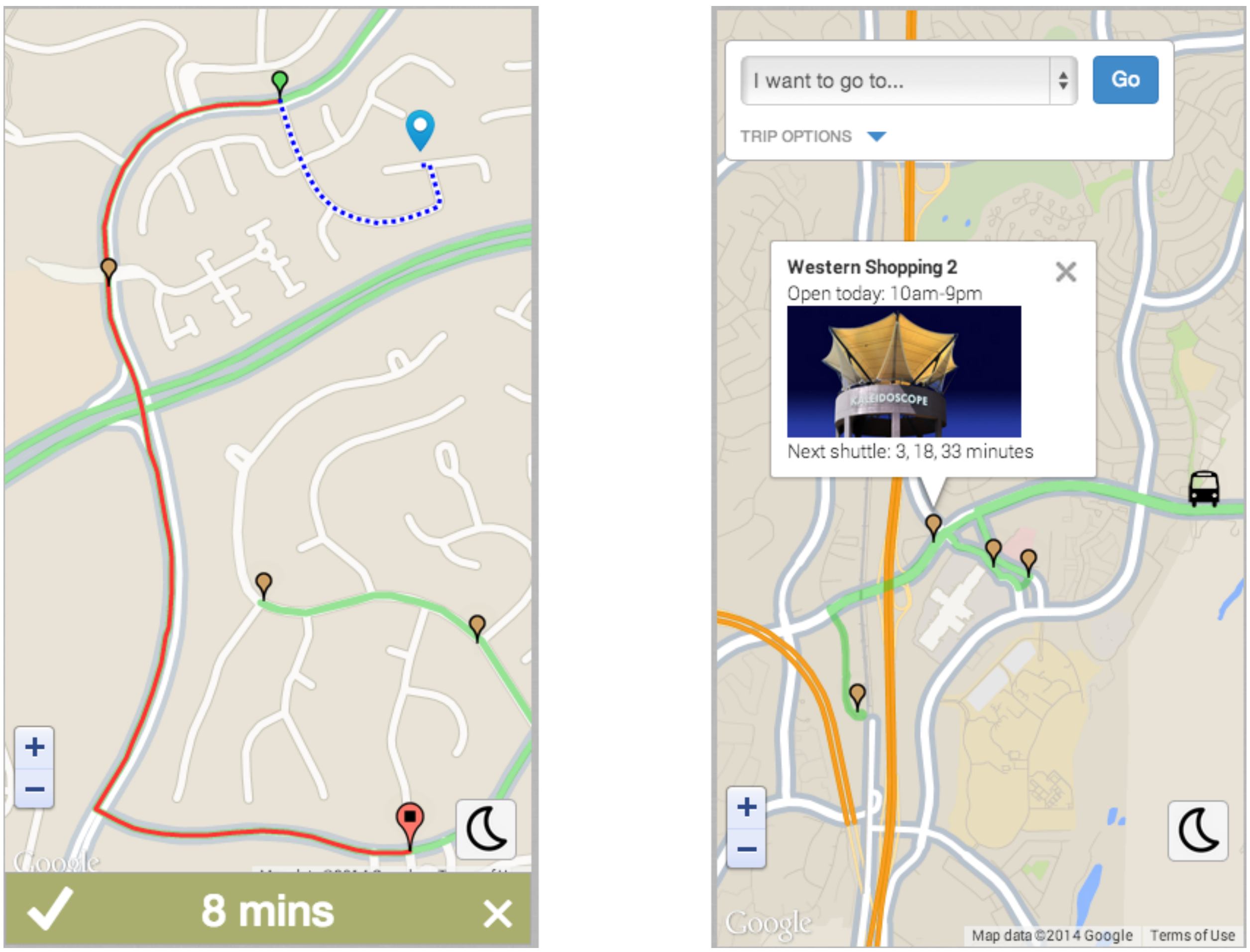

Figure A2. Users can view their trip and click on stops for more information.

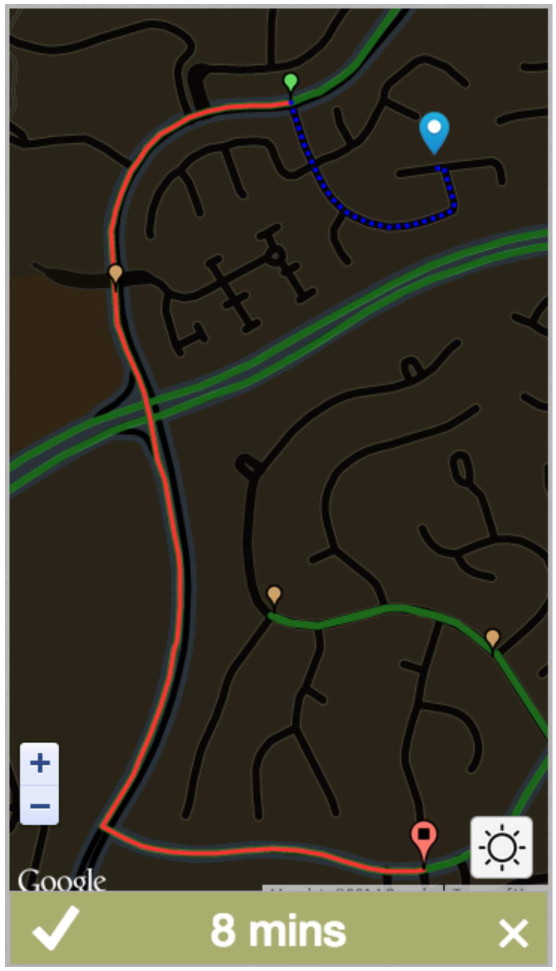

Figure A3. Users can select a night mode for better low-light viewing.

Using the Google Directions API

Paths on the map are known as polylines. A polyline is a series of connected line segments with starting and ending coordinates. These polylines are used to draw the shuttle route and the paths showing the user's current trip. We use the Google Maps Directions API to generate the necessary polylines. A directions request consists of a starting and ending location, up to eight waypoints, and a travel mode (walking or driving).

The Google Directions service will always return the shortest path from an origin to a destination, so in order to get a polyline that goes along a predetermined route, we add waypoints to our route request. These waypoints are determined manually and stored in the route objects. The response to a directions request consists of, among other things, a polyline representing the optimal path, the duration of the trip, and step-by-step directions.

Directions service requests are asynchronous, so we use jQuery deferred objects to chain multiple requests and process them once all of the responses have been obtained. This allows us to provide overall statistics for a trip, such as the total amount of time it takes to walk to a stop and then take the shuttle.

This method of drawing polylines has some limitations. First, Google charges a fee for each directions request beyond 25,000 per day. Second, the directions service limits the number of waypoints to at most 8, which prevents us from drawing complicated routes on our map. We can get around both of these limitations in the future by storing common trip information, such as polylines and duration from one stop to another, on our own servers. This would allow us to limit our use of the Google Directions service to only those trips that do not originate or terminate at a shuttle stop.

Performance Improvements for Deployment

Currently, the application prototype uses a number of libraries to facilitate rapid development, including Twitter Bootstrap and jQuery. Once the application has been finalized, the unused portions of these libraries can be removed with tools such as uncss (Osmani 2014) and by following performance best practices (Rocha 2014) to reduce load time. The jQuery library is used for its deferred object, which allows for asynchronous handling of multiple events (such as multiple sequential directions requests for walking and driving). This functionality has been incorporated into the native Javascript language, called promises. Once the promises interface is implemented in a majority of web browsers, switching to promises and removing jQuery from the application is a simple task, which will reduce the processing overhead from using jQuery instead of native Javascript.

The prototype version of our application uses simulated data to demonstrate how the shuttle position and user location would be detected and updated in real time. Once the service is fully operational, we expect this simulated data to be replaced with actual data from real shuttles and users. We have designed the prototype with this transition in mind by using JSON objects to hold the data. The reference to a local JSON object with simulated data can easily be replaced with an asynchronous call to a server that replies with real JSON data.