CAIT-UTC-069

Develop and Pilot Test Smart Phone /Tablet App for Paratransit Demand-Response Passenger Pick-up Alerts to Assist Passengers with Disabilities and Reduce No-Shows and Dwell Times

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16. Abstract
This research produced an arrival notification system for paratransit passengers with disabilities. Almost all existing curb-to-curb paratransit services have significantly large pick-up time window ranging from 20 to 40 minutes from the scheduled time producing substantial passenger waiting times. The arrival notification system presented in this study delivers an automated voice call to a registered user once the paratransit vehicle is in the near proximity to the pick-up location. The system utilizes Google Traffic API for the vehicle arrival estimation. Unlike other vehicle arrival notification systems in the state-of-the-practice, the proposed system is compact and does not require additional equipment such as radio transmitting and positioning devices. Using consumer mobile devices with Android or iOS platform, the proposed system is designed to exploit commercial cellular network service (i.e., 3G and 4G-LTE). In addition to the passenger notification, the proposed system provides paratransit drivers with real-time route guidance information developed through Google Maps API. Field evaluation conducted in Essex County, New Jersey, reveals significant reduction in passenger waiting time. The passenger waiting time was reduced by 15 to 20 minutes. In addition, accuracy of the notification system was tested: during the test, in almost all cases, vehicle arrived 1 minute earlier from the proposed arrival time.

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DESCRIPTION OF THE PROBLEM

Unlike fixed-route transit, paratransit is a public transportation service that offers flexible routes to accommodate specific categories of users such as elderly or disabled population. The main characteristic of paratransit is that it usually provides door-to-door service for users who reserve a ride. Basic paratransit offers service between user-specified origin and destination that is within the paratransit operating area (1). Although there are some paratransit services open to the general public, most of the service have eligibility requirements, and can be restricted to individuals with disabilities or senior citizens. ADA paratransit service is accessible in the same service area and during the same hours as regular, fixed-route service (1). The Americans with Disabilities Act (ADA) of 1990 (2) that protects the rights of people with disabilities requires public transportation system to offer ADA paratransit service to individuals who are unable to use local bus service as a result of their disability. According to ADA, not everyone with disability is eligible to use ADA paratransit services. Individuals with disabilities who can access regular fixed-route public services do not qualify for this paratransit category. Specifically, a person qualifies for paratransit if it falls into one of three categories: 1) persons who cannot get on or off the regular public transit vehicle due to their disability (e.g., person with cognitive disabilities or a person with visual impairment; 2) persons who are capable of using regular public transit but accessible vehicles are not available or are down to maintenance; and 3) persons with disability that prevents them from approaching public transit stops (e.g., impairment conditions that prevent them from overcoming barriers such as curbs or steps). In most cases paratransit providers use small, lift-equipped vans or minibuses with flexible route deviations that are suitable for curb-to-curb service in residential areas. Although most paratransit agencies have the wide variety of vehicles ranging from small sedans or vans to minibuses, proper organization and fleet utilization represents a complex organizational challenge (3). Despite the drastic advancement of demand forecasting techniques for the past two decades, precisely predicting the demand of disabled people for paratransit service represents a complex problem, especially for moderate to large sized American cities where demand variation can be large.(4). Such organizational practices, as well as adverse traffic conditions can result in unpredictable waiting times on the customer side. Aforementioned facts are forcing paratransit agencies to develop policies that often require customers to accept long waiting times when scheduling a ride.

Existing Paratransit Practice

Paratransit demand increased as a result of ADA-supported expansion of paratransit services. Various “dial a ride” agencies are operating around the country with similar or even identical scheduling and dispatching practices. Access-a-Ride Service operated by Metropolitan Transportation Agency (MTA) in New York City is a curb-to-curb service that requires customers to schedule their ride in advance (5). According to the policies developed by MTA a vehicle can arrive at the pick-up location any time within the 30 minutes pick-up window (5). Similarly, San Francisco Paratransit rules and policies defined a 20 minutes “on-time” window where vehicle is allowed to arrive 5 minutes prior or 15 minutes after the scheduled time (6).

Chittenden County Transportation Authority (CCTA) paratransit for individuals with disabilities in Vermont and Specialized Community Area Transportation (SCAT) of North Carolina have a 30 minutes pick-up window that requires customers to be available 10 minutes before or 20 minutes after the scheduled time (7-8). Chicago Paratransit service known as Pace, defined a 20 minutes pick-up window (9). NJ Transit's Access Link has a 40 minutes time window policy, where vehicle can arrive 20 minutes before or 20 minutes after the scheduled time (10). Different agencies have different penalties for customers who do not show up at the pick-up locations and they vary from written warnings to suspension of services (5). Almost all the agencies commit to wait for maximum 5 minutes after vehicle arrival. Those policies are the main reason for customer complaints or even service cancelation. In situation where a customer is required to come to the curb to meet the vehicle within five minutes, customers tend to wait for the vehicle outdoors close to the pick-up location. The long waiting is often uncomfortable during inclement weather, especially for persons with different cognitive or psychological limitations or persons with significant health difficulties.

The main purpose of this study is to develop a smart arrival notification system for ADA passenger. The proposed system will send a text message or initiate an automated telephone call when paratransit vehicle is close to the pick-up location. Thus the proposed notification system will enable ADA passenger to spend less time outdoors and leave their house or waiting area when a transit vehicle is in the near proximity. In addition the proposed system also allows ADA passengers to customize an advance notification setup that will accommodate their personal needs, which significantly reduce the passenger waiting time.

The main structure of this paper is the following. In the next section, both state-of-the-art and practice efforts for transit arrival notification technologies will be reviewed. The overall system architecture of proposed smart arrival notification system developed by the research team will be presented along with details for core components in the next section. The section of field evaluations will discuss experimental design and data collection approach to evaluate the performance of the proposed system, followed by the evaluation results. Findings and future research will be addressed in the section of concluding remarks.

APPROACH

The Rutgers CAIT and NJIT research team developed a personalized notification system for ADA paratransit passenger that provides highly accurate arrival time estimation. The bus arrival time is calculated using real time traffic information through Google API (26). One of the main advantages of this solution is that it provides a personalized notification through a telephone call or SMS to each ADA passenger individually. Each passenger has option to setup the advance notification time to meet their own needs. The predicted arrival time is calculated using current vehicle location and the pick-up location of an ADA passenger along with an estimated time of arrival (ETA) obtained from the Google Traffic and Google Distance Matrix API (27). Google Traffic obtains prevailing traffic speed and travel time data through their crowd-sourcing environment, where data is obtained by analyzing the GPS-determined locations transmitted to Google by a large number of mobile phone users. Google processes the incoming raw data about mobile phone device locations, and then excludes anomalies such as traffic signals, postal vehicles or regular bus service, which make frequent stops. This makes Google traffic model one of the most accurate models currently in the market (28).

METHODOLOGY

System Architecture

Figure 1 depicts high-level overall system architecture for the arrival notification system that the research team developed. Integrating with commercial tools provided by Google and Twilio (29), the primary components of the system are consisted of 1) Mobile Application and 2) Service Manager. Twilio is a private company which provide automated programmable phone call and text message services. The Twilio's programmable voice and message services have been adopted by numerous private companies providing similar services, such as Uber, Home Depot, Box, etc.

Running on a mobile device (e.g., smartphone and tablet PC), the mobile application handles vehicle positioning, route guidance, and arrival time estimation. It also triggers automatic phone call and text message services to ADA passengers based on the estimated arrival time and passenger pick-up schedules obtained from the service manager. The service manager deals with ADA customer information, such as address, pick-up time, phone numbers, and passenger to pick-up location assignment. Details for both components are discussed in the next sections.

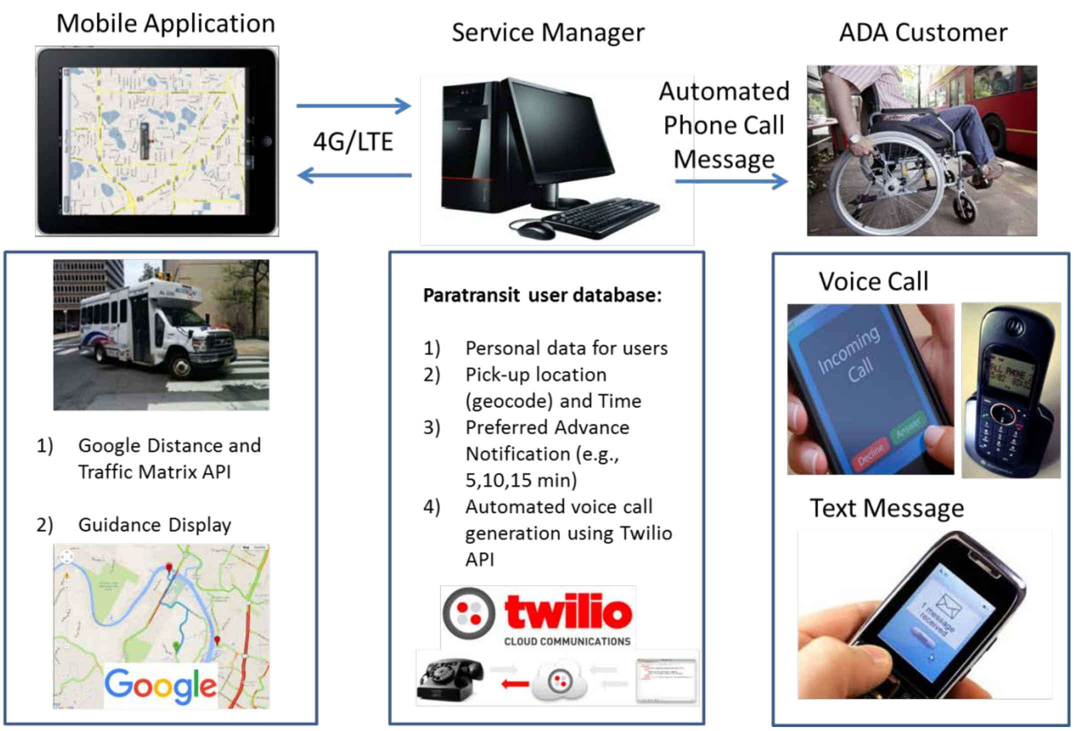

Figure 1. Passenger advanced notification- system architecture

Mobile Application

The research team developed the mobile application on both Android and iOS platforms. Figure 2 presents the actual deployment of the mobile application running on an Android Tablet for a case study that will be discussed in the next section. The application obtains instantaneous vehicle position information through a GPS receiver embedded in the mobile device to update the origin of the trip to the next pick-up location. The customer pick-up location is obtained from the service manager. Once the next destination is identified, the estimated arrival time is calculated through Google Traffic and Google Distance Matrix API. Combining the customer data from the service manager and real-time information from the mobile application (e.g., instantaneous position, estimated travel time, and route to the destination), the mobile application triggers a phone call request message to the service manager once the vehicle arrives to the desired proximity to the passenger.

Reflecting prevailing traffic congestion condition, the mobile application also provides the driver of paratransit vehicle with real-time route guidance information as shown on Figure 3. Customized for our notification system, the route guidance is handled by standard Google Maps navigation panel (30) by displaying a recommended route on the display of the mobile device. The customer pick-up location and the current vehicle position are also visible on the mobile application display for driver's convenience as shown on Figure 3. Once a notification phone-call to the next ADA passenger has been initiated, the driver is notified over the display with a simple message, "Calling".

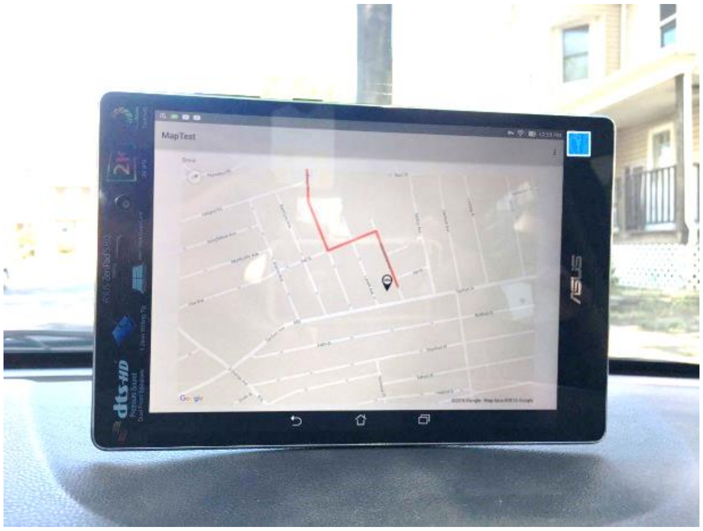

Figure 2 Deployment of the Mobile Application

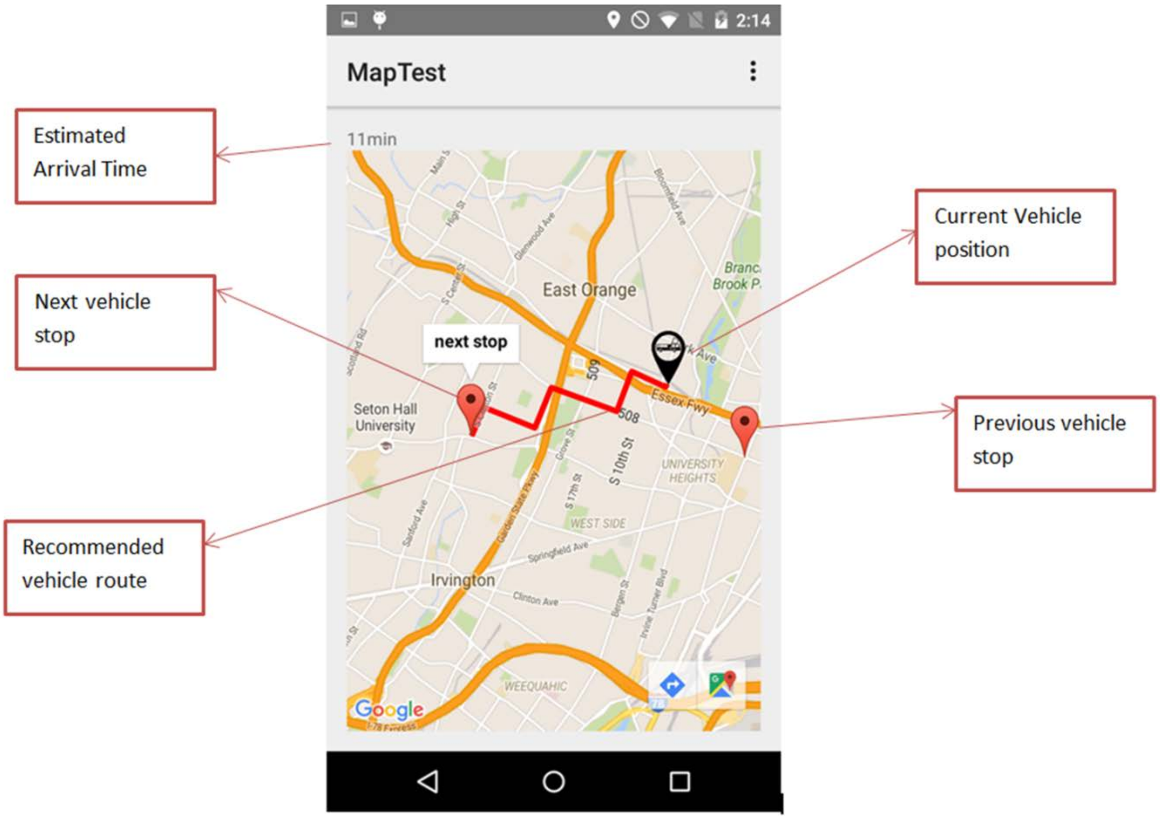

Figure 3 Navigation Tool for the Mobile Application

Service Manager

The service manager is computer system embedded with a SQL database and software developed by the research team to conduct automatic service management. The service manager builds a roster for each transit driver on a daily-basis to provide passenger information such as pick-up location, pick-up time, and contact number for text message and/or phone call. Table 1 show the hypothetical ADA customer information, which is typically collected from the user while scheduling a ride. The data was manually fed into the service manager database to be retrieved by the mobile application during the test. Once the mobile application obtains vehicle position from the embedded GPS receiver, it sends a query to the service manager to obtain the next passenger information such as pick-up location (e.g., either address or geocode), pick-up time, and notification preference. It is noted that the next pick-up locations are further used for the mobile application to calculate the estimated arrival time to the next passenger. Once the estimated arrival time is equal to the desired advance notification time as shown in the last field of Table 1, the mobile application sends a triggering message to the service manager. With the triggering message, the service manager places a request for Twilio to make a phone call to the ADA customer by using a programmable voice message or SMS text: e.g., ***Dear Mr. "Name" your scheduled bus service will arrive in "ETA" minutes***. Employing Twilio Cloud Communication API (29), an automated voice call is initiated by sending a secured Hypertext

Transfer Protocol (HTTP) request which is placed by the service manager based upon the triggering message from the mobile application.

Table 1 ADA Customer Information for the service manager

ID	Name	Geocode	Address	Phone #	Pick-up Time	Date	Notification Preference
1	John Smith	45.7859, -74.33456	123 Davidson Rd	896-989-XXXX	13:10:00	5/10/2016	10 min
2	Rodger Mccline	45.7859, -74.33456	1467 Grove St	332-669-XXXX	13:35:00	5/10/2016	5 min
3	Chris Timms	45.7859, -74.33456	1445 Bloomfield Av	369-998-XXXX	14:05:00	5/10/2016	15 min
4	Orlando Rodriquez	45.7859, -74.33456	1238 Central Av	336-987-XXXX	14:20:00	5/10/2016	20 min
5	Monica Isaacs	45.7859, -74.33456	168 Harrison Rd	698-963-XXXX	14:45:00	5/10/2016	15 min

Figure 4 conceptually illustrates the interaction between the mobile application and the service manager of the smart arrival notification system that the research team developed.

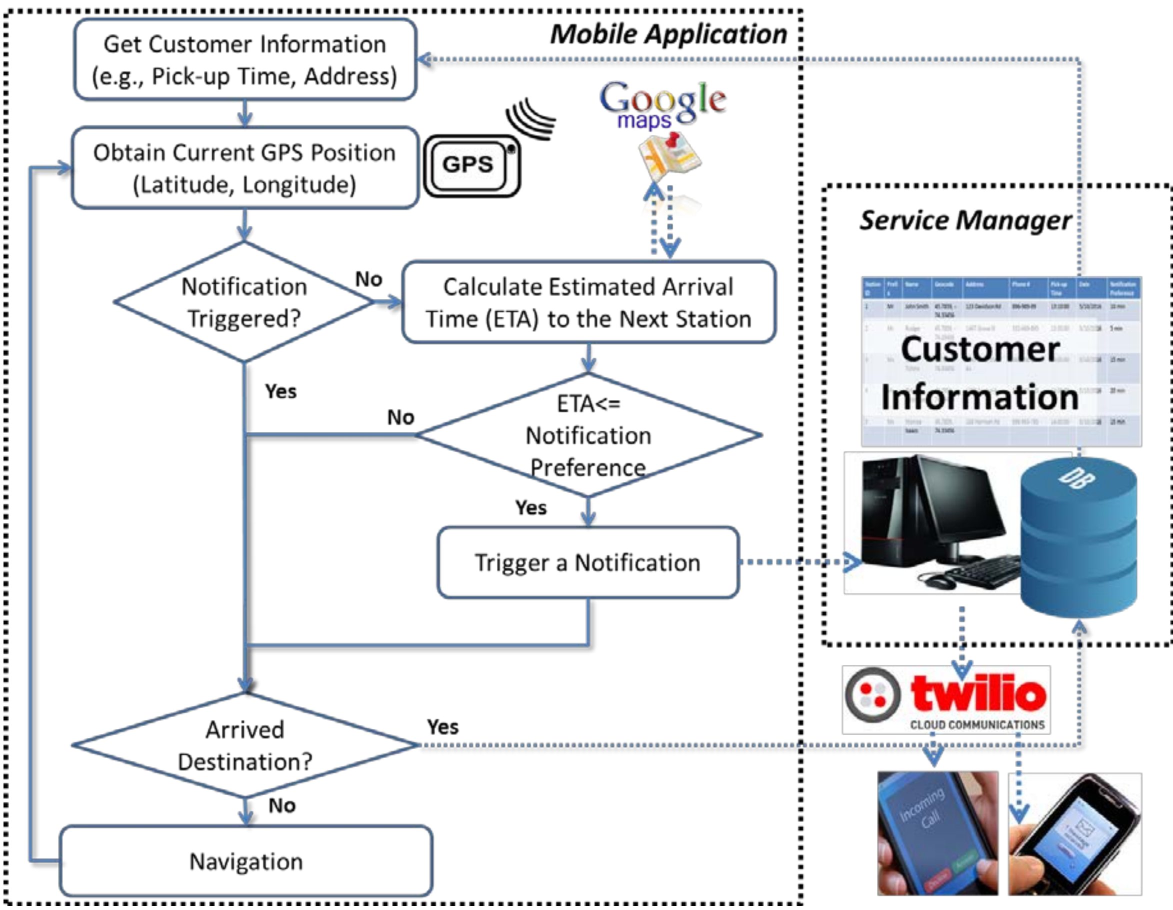

Figure 4. Interaction between the mobile application and service manager of the notification system

FINDINGS

Evaluation Design

The performance of the proposed arrival notification system was examined through the field test by taking into consideration different prevailing traffic conditions. To measure the performance, passenger waiting time at each pick-up location was collected. The test site, designated in Essex County, New Jersey, covered several locations corresponding to typical ADA passenger distribution for a paratransit agency. The test site comprises a highly urbanized area in the downtown of Newark and multiple suburbanized areas with slightly lower traffic congestion conditions as shown in Figure 5. The test started at University Hospital in the Newark downtown area and went through several townships using urban highway (i.e. Garden State Parkway), signalized arterials (i.e., US-22), and local streets in the county.

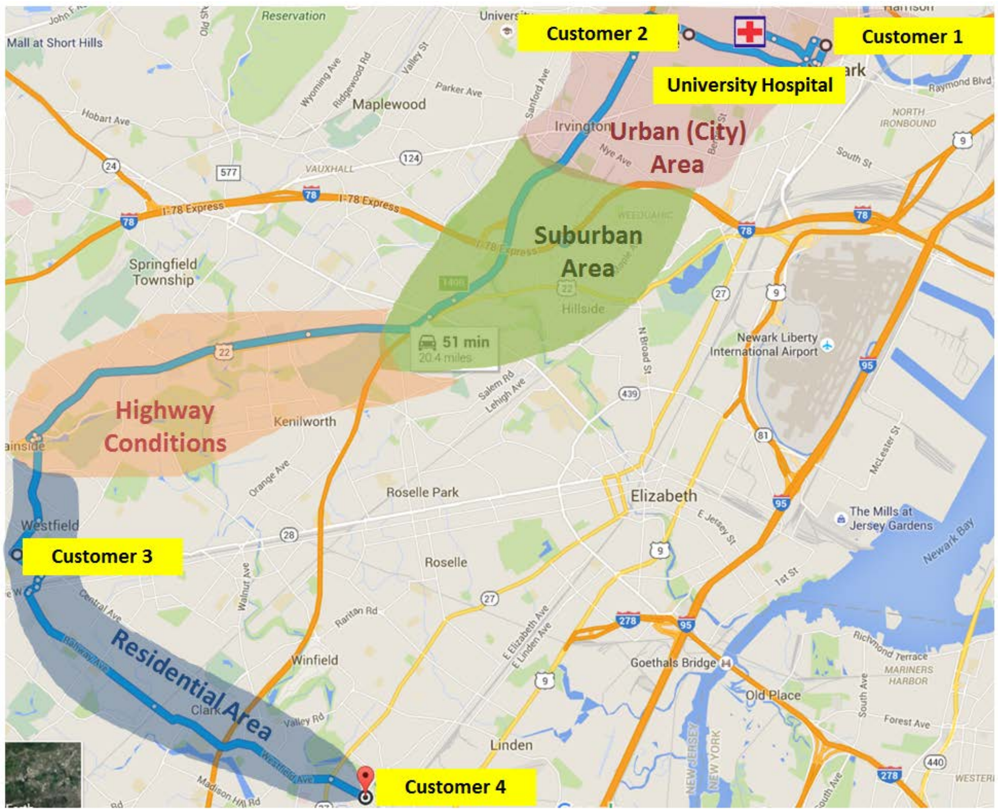

Figure 5 Notification system test site

A total of four hypothetical ADA passengers were assumed to be coming to the designated pick-up address as summarized in Table 2. For the base case where no notification is used, the scheduled pick-up time for each ADA passenger was determined based on field traffic congestion conditions experienced by the research team. For the case of the notification system, the preferred advance notification time was set to 10 minutes for every ADA passenger. That is, a notification call is placed when the transit vehicle is within the 10-minute proximity of the pick-up location. In addition, it was assumed that the ADA passengers arrive 5 minutes after the notification call was received. On the other hand, the ADA passengers without the notification system were assumed to arrive at the pick-up location 20 minutes prior to the scheduled pick-up time as it is required by most paratransit agencies following the ADA protocol.

Table 2 Scheduled passenger pick-up times and locations

Passenger	Scheduled Passenger Pick-up Time for the Base Case	Preferred Advance Notification Time (Min)	Pick-up Address
1	11:49 AM	10	120-125 Bergen Street, Newark
2	12:05 PM		443-450 South Orange Avenue, South Orange
3	12:35 PM		422-430 Prospect Street, Westfield
4	12:55 PM		1744-1747 Whittier Street, Rahway, NJ

Results

Tables 3 and 4 summarize the passengers' waiting times measured from the cases 1) without and 2) with the notification system, respectively. For the base case without the notification system, it was observed that the passenger waiting times are ranging from 16 to 23 minutes as shown in Table 3 and Figure 6. Furthermore, the differences between the scheduled and actual pick-up times appeared up to 3 minutes for the passengers 1 and 2. That is, although the passengers reach the pick-up locations at the scheduled pick-up time, they would need to wait additional 3 minutes to be picked up due to the uncertainty of prevailing traffic congestion condition.

Table 3 Field test results for the base case (without notification system)

Passenger	Scheduled Pick-up Time	Actual Vehicle Arrival Time	Time Difference (Scheduled-Actual)	Passenger Arrival Time at the Pick-up Location	Passenger Waiting Time (Min)
1	11:50 AM	11:53 AM	+3 min	11:30 AM	23
2	12:05 PM	12:08 AM	+ 3min	11:45 AM	23
3	12:35 PM	12:34 PM	-1 min	12:15 PM	19
4	12:55 PM	12:51 PM	-4 min	12:35 PM	16
Mean					20.3

On the other hand, the results shown in Table 4 and Figure 6 clearly demonstrate that the notification system achieves substantial reduction in passenger waiting time. During the test, it was observed that the test vehicle arrived 8 to11 minutes after the notification call was placed. Knowing that the preferred notification time for the call is given by 10 minutes, these arrivals produced 1 to 2 minutes difference, which resulted in dramatic waiting time reductions ranging from 3 to 6 minutes. Compared to the base case yielding average 20.3 minutes of passenger waiting time, the notification system produced promising benefits reducing the average waiting time by 16 minutes. In addition, from the maximum 1-minute of time difference between estimated and actual pick-up time, the notification system helped improve the punctuality of ADA paratransit service. By utilizing smart arrival notification all passengers can benefit throughout waiting time reduction due to shared-ride nature of paratransit. Beside passenger benefits, transportation provider benefits are also expected through increased attractiveness of the service, which can further produce increase in ridership. In addition, smart notification system can produce significant savings for the paratransit fleet due to reduction in dwelling time of vehicles.

Table 4 Advanced passenger notification field test results

Passenger	Call Placed Time	Estimated Pick-up Time	Actual Pick-up Time	Time Difference (Estimated-Actual)	Passenger Arrival Time at the Pick-up Location	Passenger Waiting Time (Min)
1	11:44 AM	11:55 PM	11:53 AM	-2 min	11:49 AM	4
2	12:00 PM	12:10 PM	12:08 AM	-2 min	12:05 PM	3
3	12:23 PM	12:33 PM	12:34 PM	+1 min	12:28 PM	6
4	12:42 PM	12:52 PM	12:51 PM	-1 min	12:47 PM	4
Mean						4.3

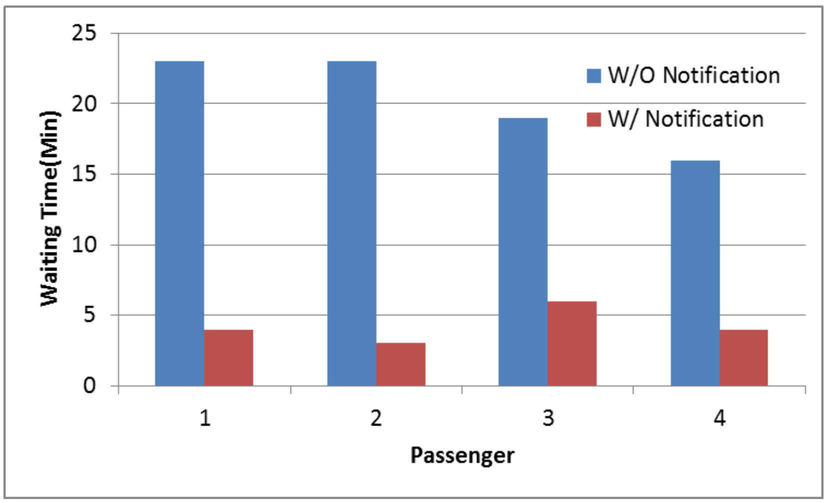

Figure 6 Passenger waiting time w/o and w/ notification system

In addition to the field test a focus group was conducted with a group of potential end users. The focus group was comprised of six autistic adults that had agreed to discuss the technology. The session was held on October 23, 2016 in Oradell, NJ. The study participants were able to hear the audio and see the text for the vehicle arrival time. The two participants that were actively using paratransit supported the project and wanted to have it available to them. One participant commented about wanting a more personalized text messages rather than the standard one that was displayed. Several of the participants who occasionally used paratransit services through it would be helpful. One participant commented that the call did not help when the vehicle was late and running outside of the time window. Even knowing the bus would be late was problematic if it was after the pick-up window. Some of the study participants said they would like to be able to track the route of the vehicle. One participant said that this would allow him to wait inside for his vehicle's arrival rather than staying outside. A study participant noted that sometimes the vehicle is at another house down the street and by notification would let him know to look around and no longer be counted as a no-show. Finally, one participant asked if the trip time could also be provided for riders. In summary, the focus group members liked the technology and said it would improve the services that they are currently being offered.

CONCLUSIONS

Existing paratransit services in large American cities are experiencing difficulties to maintain on-schedule arrival time determined by dispatchers and fleet managers. Adverse traffic conditions along the route are often unpredictable, thereby resulting in high variation of the vehicle arrival time. Many paratransit agencies are forced to develop strict policies that require customers to be prepared for boarding within 5 minutes of the vehicle arrival. On the other hand, those agencies cannot guarantee exact time of the vehicle arrival, resulting in wide pick-up time window ranging from 20 to 40 minutes. In order to board vehicle on time, ADA passengers usually arrive at the pick-up location much earlier. For passengers with different health difficulties, such long waiting time might become unacceptable.

The main idea behind the development of the proposed smart arrival notification system was to decrease unnecessary waiting time for ADA passengers. Discovered by the field evaluations for the proposed notification system, the waiting time can be significantly reduced if the passengers have accurate information for the vehicle arrival time. During the test, for 4 locations in Essex County, New Jersey, waiting time was reduced by 15 to 20 minutes depending on location. Such reduction in waiting time can certainly improve the quality of paratransit services for ADA passengers and decrease the potential dangerous conditions. Field test revealed that the accuracy of an arrival time prediction is within 1 minute, which significantly reduces passenger waiting time and increases passengers' confidence that the transit vehicle will arrive as notified. By using accurate notification system, ADA passengers can spend less time outdoors and leave the place where they reside in a more convenient fashion.

RECOMMENDATIONS

By taking into consideration the prevailing traffic congestion condition, this study primarily focused on developing automatic notification system to reduce ADA passengers waiting time based on presumed pick-up schedules. Thus, minimal effort to deal with optimal pick-up schedule was conducted for the field evaluation. However, it must be noted that the proposed notification system could be enhanced by employing advanced scheduling techniques in the future.

It is recommended for the next part of this project is to conduct a small-scale deployment to a paratransit system that includes a user feedback component. Through conducting the real world deployment with current users on a day-to-day program would allow for any necessary modifications needed for the systems requirements. This will also provide an understanding on how to Smart Arrival Notification system interfaces with various dispatching and routing software.