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Board 267: Enhancing Urban Mobility: SmartSAT's Impact on Public Transportation Services and Commuting Experience

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Enhancing Urban Mobility: SmartSAT's Impact on Public Transportation Services and Commuting Experience

Abstract

Public transportation connects individuals to go to places for jobs, education, health, and various social and economic opportunities they need. In recent years, smartphones have emerged as integral tools in people's daily lives, and their applications have significantly transformed how individuals interact with public transportation services. The demand for mobility services on smartphone applications has also been increasing in urban areas, to enhance the quality of transportation services. However, many transit systems still rely on outdated technologies or third-party software, limiting their flexibility and customizability. The demographics of VIA's bus system in San Antonio (SA), TX, indicate the importance of public transportation for communities with limited incomes and no access to personal vehicles, particularly Hispanic or Latino residents living below the poverty line. SmartSAT is piloting a customizable mobile web application to address these challenges by providing real-time bus arrivals, seat capacity information, service change or update alerts, and a mechanism for riders to provide feedback on their experiences. It is designed to enhance public transportation services and improve the commuting experience for a diverse group of riders in San Antonio.

Two research studies were conducted to assess the impact of SmartSAT: a study on the analysis and evaluation of actual bus arrival times and a study on the commute experience of riders. From the data collected in field tests on piloting routes, the first study focused on the analysis of the difference between VIA's scheduled and actual bus arrival times. The findings indicated that certain routes exhibited very low average differences between their actual and scheduled arrival times, while a couple displayed a big average difference that showed significant delays and deviations from the scheduled timetable. Furthermore, some routes experienced small average delays in the afternoon, but the delays significantly increased in the evening. The rider experience study was focused on understanding the experiences of bus riders in public transportation, from collecting data on experiences with bus use, such as transfers, wait times, and perceptions of bus arrival times. The study found that there is a differential in the feelings of access to the city's public transit system held by poor, working-class, and Latinx communities in SA.

The intended outcome of the developed SmartSAT on the arrival time accuracy research is a more accurate prediction of bus arrival time on the routes. Findings can guide us on traffic management as predictable and reliable transit service can improve rider satisfaction and overall ridership. More accurate time scheduling on the routes will help riders handle the unreliability of transit services and reduce the time spent waiting for buses (especially delayed ones). The impact on the commute experience in social sciences is important as it allows for an understanding of how underserved and underrepresented communities in SA experience a crucial component of urban space, public transit. This will be especially beneficial for low-income individuals who heavily rely on public buses to commute to their jobs and educations in the city of San Antonio.

1. Introduction

Public transportation connects people to other people to places in jobs, education, and social and economic opportunities they need. Smartphones have become so important as a new normal means in daily life. Smartphone applications have transformed the way that people connect to opportunities using public transportation services. Many public transit systems operate based on the available tools and mostly old technologies. Their core applications often depend on the pre-built third-party software programs created by vendor companies, which makes the transit system difficult to customize in adopting changes. Given the benefits of fast but less costly implementation, a few disadvantages of using pre-built software include limited functionality, incompatibility, and scalability [1]. The demand for mobility services using smartphone apps is also increasing in urban areas to improve quality services [2, 3, 4]. However, providing sustainable quality services of transportation is yet another challenge [2, 3].

Providing accurate information on real-time bus arrivals and bus capacity is critical to reducing rider's wait time. Knowing arrival times at bus stops in real-time can allow riders to adjust their travel to minimize the waiting time and reduce the travel time [5, 6]. The development of such a system that provides critical information can benefit society by potentially improving rider experience and increasing their ridership and public transit share [6]. However, riders' waiting time at bus stops and irregular bus arrival information is often missing when historical data is used in analyzing the demand for mobility services on public transportation to find problems of improving services [3]. According to the research [7], commuters on public transportation in most American cities have disproportionately lower incomes than commuters who use automobiles. Transit agencies use surveys to evaluate commuters' perceptions, but the surveys lack collecting important data from low-income residents on complex mobility experiences [7]. To address these, some smartphone apps have been developed to collect residents' GPS-tagged and Quality of Service (QoS) data. However, these apps often fail to collect critical information to characterize complex trips, but also lack privacy protection and decision support systems [7]. Many cities also adapt their transportation resources to support the community during the coronavirus pandemic to help essential workers get to work more easily [8].

Many efforts have been made to address the above issues: Providing real-time tracking of metro buses in urban areas by automatically detecting bus stops, and accurately predicting bus arrival times using historical and real-time location data [6]; Making good travel time predictions for routes with the bus GPS data using artificial neural networks [21]; California's Orange County Transformation Authority (OCTA) launched the Transit app in 2020 to provide real-time bus capacity so riders can check enough available seats. During the COVID, OCTA limits the number of passengers on buses: up to 15 passengers for a regular 40-foot bus and up to 20 passengers for a 60-foot bus [19, 27]; The LA County Metropolitan Transportation Authority also partnered with the Transit to improve customer experience by providing accurate real-time bus arrival information [27, 8]. The NSF-sponsored Pitt Smart Living project developed a platform-integrated information system to increase the utilization and improve the quality service of public transportation with real-time information on arrival and utilization of relevant options of public transit [9, 10]. AC Transit for the Bay Area in California supports services by providing real-time bus arrivals and bus capacity and accepting rider's feedback [11].

2. Background on SmartSAT

SmartSAT (Smart San Antonio Transit) project has been developing a customizable mobile app for the San Antonio (SA) Metropolitan Public Transit to explore the above challenges on the critical services needed in the SA community. The project is designed to build and test a platform that easily adapts to the changes in functional requirements and plans for expansion and long-term goals. It intends to provide compatibility with other programs and devices by building an application infrastructure on the cloud. Through this development and testing, one of our goals is to investigate the rider's satisfaction and quality of ridership experience. The developed app intends to provide services with real-time bus arrivals, bus capacity info on seat availability, and interactive features to collect riders' feedback on the trip experience. The app is also being fully tested to ensure that the system is systematically tested for all aspects of security attacks and to protect rider data privacy and authentication.

2.1 Motivation

The analysis results of the "Who is Rider" pre-COVID survey in 2019 indicate: 61% of typical VIA riders are Hispanic or Latino and 20% Black or African American; 72% of the riders are employed in full-time and utilize VIA 5-7 days a week; 67% of them live at or below the federal poverty level making less than $25,000 per year; 58% of the riders do not have any motor vehicle in their household [26]. In the meantime, the 2019 US Census Bureau for the city of San Antonio reported: 64.25% of the population are Hispanic or Latino and 7.0% are Black or African American alone, and 17.8% are people in poverty [12]. As outlined in Table 1, providing public transportation service is important to those groups of Hispanic or Latino and Black or African Americans and those who live at the poverty level, in particular.

Table 1. Demographics for City of San Antonio and VIA Transit Riders

	Hispanic or Latino	***Black or African American***	***Persons in Poverty***	***Full Time Employee***
VIA Riders	61%	**20%**	**67%**	**72%**
City of San Antonio	64.25%	7%	17.8%	N/A

Two research on the developed application involve the on-time performance of bus arrivals at stops and rider's commuting experiences. The research on the ridership experience focuses on those who live at the poverty level to address any impact of their racial and ethnic status' role in the use of the VIA Transit system. Currently, VIA's bus system offers various service levels to meet the different needs of riders [13, 14]. Metro Service is one of them and 51 fixed routes are under this service. They operate every 30 or 60 minutes and run more frequently during the morning and afternoon peak times. SmartSAT project conducts a pilot study, where several VIA bus routes are being experimented to investigate the feasibility. The selected routes cover different directions on the map of the city of San Antonio. For example, Route 30 travels between the downtown and eastern side of SA, Route 51 travels between the downtown and southern side of SA, Route 64 travels Between the downtown and western side of SA, and Route 93 travels Between the downtown and northern side of SA. Routes 30 and 51 are fixed operating every 30 minutes and running more frequently in the morning and afternoon while Routes 64 and 93 are designed for commuters traveling on expressways, as express service.

2.2 Distinct Services

In addition to the above-mentioned efforts to the demand for mobility services using smartphone apps, Google Maps also has transit app services whose purposes and target users are different. They offer the best route options for driving, transit, walking, etc., targeting a broader audience, including travelers and visitors. It provides bus arrival times for major stops only, and general feedback options on crowdedness, temperature, and accessibility, but lacks specific bus capacity information. It also offers alerts on maps to keep users updated on transit-related information [20]. SmartSAT has distinct purposes and target users. It aims to better serve the needs of current SA transit riders, especially those who live in poverty, and rely on public bus transportation to get to their places [**20**]. The developed app intends to provide real-time information on bus arrival times for all stops on the rider's route, including bus capacity details with limited seats, which can contribute rider's wait and travel time, and ensure accessibility [15, 13, 16]. Additionally, the app provides a secure platform for gathering rider-specific feedback through surveys and comments for rider experience research. The information can then be utilized by city planners to make informed data-driven decisions about transit allocation and improve overall transit services that will ultimately benefit all San Antonian residents**.**

3. SmartSAT – A Customizable Application for San Antonio Transit Pilot

3.1 Purpose and Key Functionalities

The purpose of SmartSAT is to make critical services available and to improve the service and rider experiences for SA transit users who mainly depend on public buses for their work, education, health, leisure, or other reasons, especially those in poverty. A system architecture of the SmartSAT is presented in [20, 22, 23]. The application is designed in a way that: 1) A rider uses the app to choose a route and ride from a bus stop and a destination stop and receives real-time bus arrivals, 2) A bus driver monitors seats and notifies availability the system when there are very limited seats with 3, 2, 1, or 0 seats available. 3) The development team and administrators deploy emergency alerts and schedule changes to instantly notify riders through their phones. 4) Rider's feedback and comments on commute experience are collected through a well-designed survey questionnaire. *The major functionalities of the application include:*

- Real-time bus arrivals at stops for six piloting VIA bus routes
- Seat availability alerts with limited seats (<=3)
- Instant alert messages on important schedule and route changes
- Secure data and feedback collections from riders on their commute experience
- Multiple routes display in the admin view

The app is developed on a Django and Gunicon web server running on a Google Cloud serverless platform using a Docker container. Providing Real-Time Bus Arrivals has been implemented with Google Maps Platform web services. Google Maps JavaScript API is the main API to retrieve the latest Maps and Routes in the development, where real-time traffic conditions are constantly updated with routes [17]. Directions for transit are obtained by Direction API, and Distance Matrix API is used to calculate travel times based on real-time traffic and distance for multiple stops on a route. Utilizing these APIs, we can conveniently build customized transit maps to fit our project needs. For the Bus Capacity with Limited Seats, a bus driver monitors seats and notifies the system when very limited seats of 3, 2, 1, or 0 are available. This can be done with a simple, easy-to-use interface on a touchscreen tablet attached to a dashboard area of the bus after boarding is complete at a stop. The seat information is provided in real-time in the rider's app using the different colors of the bus icon displayed on a route screen (Figure 2 (a) & (b). When VIA services are detoured, changed, or canceled due to severe weather or construction, alerts for suspended, changed, or detoured services are posted on the VIA website, or riders should call customer service to verify the most up-to-date information. In extraordinary circumstances, they may change services without notice [18]. SmartSAT system sends instant alerts to the developed app's registered riders for important updates and essential changes such as service schedules, route changes, ridership reminders, and other unexpected changes in service (e.g., sporting events, natural disasters). This can help prevent riders from missing vital information that results in wasted time. To collect data on ridership experiences and the impact of SmartSAT, we deploy survey instruments for data collection. These are for an in-app user experience survey to assess the user's interpretation of and engagement with the application.

3.2 User Interface

Figure 1 presents an admin view that provides a comprehensive display of all active routes selected by the admin. These are organized under the selection menu on the left side of the interface. This view enables administrators to have complete oversight of all routes and track the real-time locations of the buses at a time. Figure 2 illustrates some of the screens showcasing the key functionalities: (a) An Express Service route 64 with a bus in yellow, indicating less than 3 seats available and the bus is moving between 'stop 4' and 'stop 5'. A rider selected 'stop 9' for detailed information on when the bus will arrive at that stop. (b) Metro Service Route 64 with the bus in red, indicating the seats available, and the bus has passed 7 stops, currently stopped at 'stop 8', and is moving forward ahead stops to 'stops 9, 10, 11, so on'. (c) Detailed information on the selected 'stop 28' with stop name & ID, and an expected arrival time.

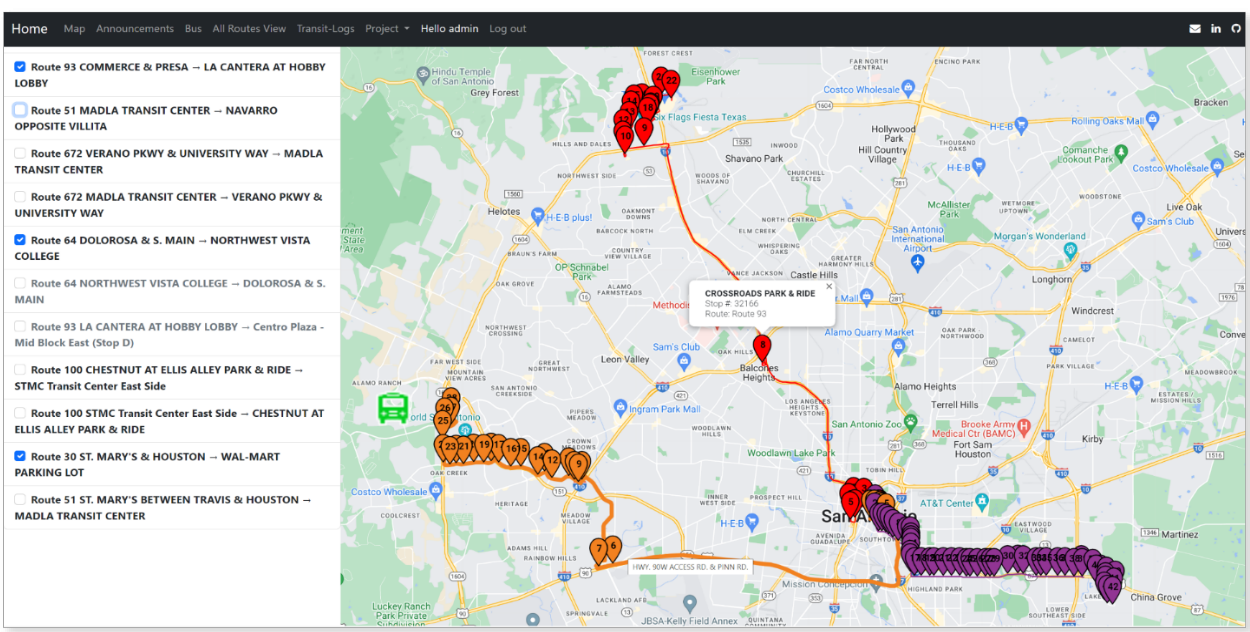
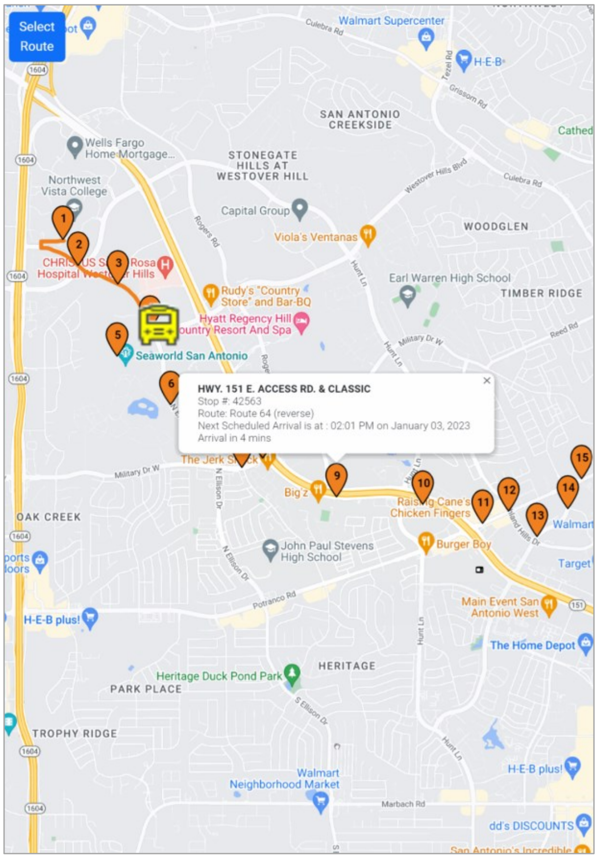
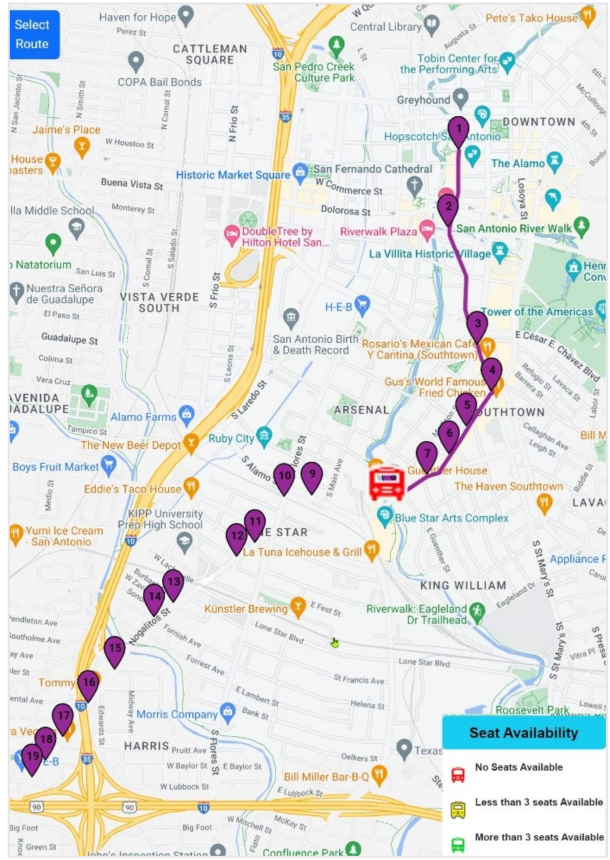


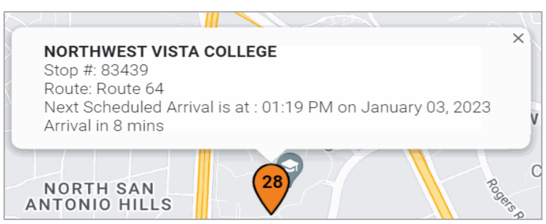
Figure 1. An admin view displaying all selected routes.



(a) Express Service Route 64.

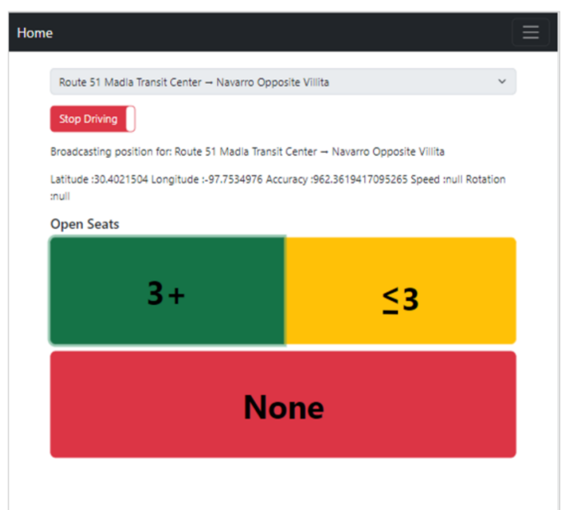


(b) Metro Service Route 51.



(c) Detailed information on a selected stop.

(d) Bus icons in different colors for seat availability in rider view.



(e) A touch-screen interface for notifying seat availability in rider view.

Figure 2. Illustrative screens of SmartSAT showcasing main functionalities.

(d) A popping window on the bottom right corner of the map display, showing bus icons in different colors for seat availability: a red bus in the route means 'no seats available', a yellow means 'less than 3 seats available', and a green bus in the route is for enough seats available. These are for riders when checking their route and bus arrival information on stops on that route. (e) presents a simple touch-screen interface for notifying seat availability by a driver when the bus has limited seats available. The default is a bus in green on the map. Whenever the driver selects one of those, the bus icon in the route where the driver is running is instantly changed, notifying the riders of the seat availability in real time.

4. Research on Bus Arrival Time and Reider Experience

4.1 Bus Arrival Time

The development of accurate and real-time information such as arrival times by public transportation brings many benefits to society like improving rider experience and increasing ridership. Therefore, it enables daily commuters to handle the unreliability of transit services. In this regard, data analytics could be leveraged to measure the prediction accuracy of the arrival times and transform the data collected about the transportation service and rider experience into actionable insights for the benefit of society. For example, exploring how dependable the service is by looking into how many buses arrive at their destination point on time. As a preliminary study, we used a sample dataset of VIA Transit of early departure, on-time, late arrival, and on-time performance (OTP) metrics by route. The dataset is available on SmartSA Datathon 2020 [25]. The data is useful to examine how dependable the service is by looking into how many buses arrive at their destination point on time. We used it and ran a multivariate regression using the Ordinary Least Squares (OLS) technique to predict the total number of on-time buses (OnTime variable). Results revealed that route, early departure, late arrival, on-time performance (OTP), and AverageDwellTime (i.e., "the average amount of time a bus is stopped at the curb to serve passenger movements, including the time required to open and close the doors" [1]) are significant predictors with (0.78) R-2 value.

4.4.1 Bus Arrival Time Adherence Using Public Data

The main goal of this study is to provide an accurate prediction of bus arrival times at all bus stops for the several VIA routes under study. The study explored a public dataset of San Antonio public buses [24] to evaluate their adherence to schedule, using deep neural networks and regression models to predict bus adherence to scheduled times [5]. The results of the study indicated that there are a few characteristics that can significantly influence delays in bus arrival and departure times. Those include, for example, part of the day, the direction of the bus as well as its location. The results also revealed better performance of neural network models as compared to regression models [5].

4.4.2 Bus Arrival Time Adherence Using Collected Data

To examine how well several bus routes within the San Antonio Transit System adhere to their scheduled times, we used data analytics to assess the punctuality of several bus routes within the San Antonio Transit System and predictive analytics models to evaluate the performance of public bus transportation in the city of San Antonio. To achieve these, using the developed SmartSAT app, we conducted field studies to gather data on the actual arrival times of the bus's four routes (30, 51, 64, 93) that cover different directions of SA areas, from/to north, south, east, or west to/from Downton. The analysis of data shows that different routes and specific parts of the day show variations in how well they stick to their schedules. The study used predictive analytics models to evaluate the performance of public bus transportation in the city of San Antonio. We used time point stops as the target variable in order to evaluate their impact on the overall performance of the system. We also evaluated methods for the detection of potential bus-time savings and reported several examples of possible savings.

The results demonstrated that the best routes in adherence to the schedule are Route 30 and Route 30 Reverse. These routes have extremely low average differences between actual and scheduled arrival times (0.0021 and 0.0035 minutes, respectively). The buses on these routes are highly punctual and tend to adhere closely to the scheduled timetable. The worst Routes in Adherence to Schedule were Routes 93 and 51. Route 93 has the highest average difference between actual and scheduled arrival times (4.85 minutes). Buses on this route tend to experience the most significant delays or deviate the most from the scheduled timetable. Route 51 also has a relatively high average difference (3.89 minutes), indicating a notable delay in bus arrivals compared to the scheduled times. The notable delays on these two routes occurred during the evening part of the day specifically identified times, from 4 pm to 6 pm, which can imply that traffic could contribute to the delays. Some routes demonstrated variability in Arrival Times. For example, Route 93 Reverse has the highest standard deviation (2.07 minutes), indicating a higher variability or inconsistency in the difference between actual and scheduled arrival times. Buses on this route may experience more fluctuation in their arrival times compared to other routes. Results also reported the routes with Minimal Delay. Route 64, along with Route 30 and Route 30 Reverse, has an average difference close to zero, indicating minimal delay or even instances of buses arriving earlier than scheduled. These routes demonstrate a high level of adherence to the schedule.

These findings emphasize the significance of monitoring and evaluating bus arrival times to identify areas that can be improved.

4.2 Rider Experience

Public transit systems are at the heart of the everyday functioning of large metropolitan spaces. San Antonio’s primary public transit system is VIA, which serves the seventh most populous city in the United States, with over 1.5 million people. What makes SA unique is that it has persistent problems with race and class inequality despite being one of the few large metropolitans that is a minority-majority with a Hispanic population greater than 63%. To address the social impact of poverty and racial/ethnic status’ role in the use of VIA Transit systems, we assessed the rider’s experiences. This was focused on understanding the experiences of bus riders and users of the SmartSAT application. In the first phase of this research, our goals were to understand the experiences of bus riders broadly, collecting data on experiences with bus use, such as transfers, wait times, and perceptions of bus arrival times. The research on rider experience was to address the question and hypothesis:

- RQ1: How do racial/ethnic and class-stratified communities in San Antonio access buses?
- H1: Local communities currently access buses through the use of Google Maps and through website maps/schedules, primarily on their smartphones.

The survey was initiated with ongoing data collection, interviews initiated with ongoing data collection on bus ridership experiences, access to buses, and city space. Data was collected for the phase one survey with 101 responses and 7 interviews. Addressing the RQ1 and a conformation of H1 as respondents have significant use of Google Maps and smart phones to access bus information and buses generally, 93.1 percent of respondents use internet-enabled smart phones to access their bus information, with 57.14 percent of respondents selecting Google as their first choice for accessing bus transit information [23]. Additional results show that Latinx and poor/working-class communities in San Antonio feel as though they have decreased or limited engagement with buses relative to other communities throughout the city. With a majority, 57.14 percent, of our respondents using Google as their first choice for bus information, 21.43 percent also use the existing transit phone app to access bus information. Despite this reliance on Google and the existing transit app, 82.14 percent expressed a need for a new app to be made available [23]. This means there is a significant gap between existing technology for accessing bus information and the bus user's desire for an improved means of accessing public transit information in San Antonio. As noted above, we found that there is a differential in the feelings of access to the city's public transit system held by the poor, working class, and Latinx communities in the city of San Antonio.

Analysis of data has yielded clear indications that for our predominantly Latinx (53.3%) and predominantly working class, 85% earning at or less than the annual median income for San Antonio, respondents there is significant difficulty in using and accessing public transit [23]. The reasons are numerous but based on our survey we have 52% of respondents using the bus to commute to work for three or more days with the remaining using it less than two days per week [23]. Such high usage of the bus indicates significant reliance upon the VIA transit system and issues of technology, with 94.4% using their smartphones and a majority of respondents using Google Maps to access bus information, we see that technology is significantly impacting their experiences with the public transit system. Most of the respondents live on the north side of the city and commute across the city to either the Westside or Southside of San Antonio. This results in a majority of respondents having commute times of greater than one hour (61%). Ultimately leading to greater difficulty in their daily lives as they are expected to be on time for work, school, and other activities. Generally, this illustrates that H1, is accurate and the majority of respondents use Google on their smartphones to understand the routes, arrival times, and other means of engaging the transit system. Additionally, it illustrates that within these Latinx and poor and working-class communities, there is a significant difficulty in gaining access to bus information and certain areas of the city spaces because of longer commute times and issues with accurate technology.

5. Conclusion and Future Works

This paper presents SmartSAT that is a piloting customizable mobile web application for San Antonio public bus transit, providing real-time bus arrivals, seat capacity information, service change or update alerts, and a mechanism for riders to provide feedback on their experiences. The overarching goal of the application is to enhance public transportation services and improve the commuting experience for a diverse group of riders in San Antonio. Toward this, two research studies were conducted to assess the impact of SmartSAT on the analysis and evaluation of actual bus arrival times and the commute experience of riders. From the data collected in field tests on piloting routes, the first study focused on the analysis of the difference between VIA's scheduled and actual bus arrival times. The findings indicated that certain routes exhibited very low average differences between their actual and scheduled arrival times, while a couple displayed a big average difference that showed significant delays and deviations from the scheduled timetable. Furthermore, some routes experienced small average delays in the afternoon, but the delays significantly increased in the evening. The rider experience study was focused on understanding the experiences of bus riders in public transportation, from collecting data on experiences with bus use, such as transfers, wait times, and perceptions of bus arrival times. The study found that there is a differential in the feelings of access to the city's public transit system held by poor, working-class, and Latinx communities in SA.

From the results of analyzing the data from the phase one survey, we constructed Phase two survey instruments and, thus plan to begin collecting data. The data collection process is focused on addressing the following research question and hypothesis:

- RQ2: How will issues of race and class be reduced by the introduction of applications, such as SmartSAT, aimed at clearer and more functional schedules for buses?
- H2: SmartSAT will provide greater accuracy of scheduling with real-time updates on arrival/departure times and bus capacity, thus enabling greater ease of use of transit systems for those populations that depend on the buses.

In phase two, the goal is to determine whether or not the implementation of our new app will improve rider experiences with the transit system. Additionally, the study would also look into insights on whether using SmartSAT app can increase the amount of people that took the public transportation service.

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