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An Empirical Analysis on the On-Time Performance and Crowding Levels of Bus Transportation: The Development of the Philippine Automated Roadway Access Public Operation (PARA PO)

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Abstract:

This study explored the critical relationship between bus punctuality, crowding levels, and transportation efficiency within the field of public bus transportation. The research proposed a technological intervention in a bus tracker application. The study sorted out insights into terminal efficiency and service quality through a systematic evaluation involving manual observation and surveying. Statistical tests, including the Chi-square and Kendall's Tau, underscored a significant association between time delays and crowding levels at bus terminals, emphasizing the need for interventions to enhance scheduling efficiency. Additionally, the research conducted pilot testing of the Philippines Automated Roadway Access—Public Operation (PARA PO) Application, demonstrating its readiness and effectiveness in providing commuters with accurate arrival time estimations. Alpha and Beta testing phases utilizing Paired T-Test and Mean Analysis revealed promising metrics and positive user experiences, indicating the application's potential to improve transportation efficiency and commuter satisfaction. The study concluded with recommendations for integrating research insights into transportation policy development, enhancing the bus tracker application, and fostering collaboration between stakeholders to address reliability and punctuality issues in public bus transportation.

Keywords **—public transportation, bus punctuality, crowding levels, transportation engineering, bus tracker application, commuter satisfaction, empirical analysis, pilot testing, transportation efficiency**

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I. INTRODUCTION

The United Nations launched the Sustainable Development Goals (SDGs) in 2015 with 17 goals and 169 targets. The 11th goal focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. SDG 11 also includes providing universal access to basic services, including transportation. Access to basic services like public transportation is a better option for low-income communities. This helps lessen poverty and social marginalization in terms of power, time, and space.

Public transport is a convenient way to move people from one place to another cheaper and faster. It is a more convenient way of traveling, though it increases pollution and congestion. In the Philippines, the Metro Manila is the Light Rail Transit (LRT), and Metro Rail Transit (MRT) is the only formal public transportation considered. The rest of the transportation is privately owned. When traveling medium to long distances, or from provinces to inter-cites, riding public utility buses (PUB) is the only practical way compared to private vehicles. The Philippine bus system is a vital means of transportation in the Philippines, acting as the primary transportation route for millions of people around the country. It connects towns and cities, rural areas, and various regions of the Philippines. There are various vehicle types, such as regular buses, air-conditioned buses, and premium or deluxe buses. Service quality, comfort, and price can vary depending on the type of bus. Buses operate a wide range of routes in the Philippines, from local city routes to long-distance intercity and provincial routes [5]. According to Victory Liner, the seating capacity of their air-conditioned bus ranges from 45 to 49. Thus, it is convenient for commuters and other motorists since a single unit can accommodate a large quantity [6]. Public transportation in the Philippines is still unsystematic, so the need for transportation management is evident.

Transportation management involves coordinating and optimizing the movement of people and goods. It aims to ensure efficient, safe, and reliable transportation systems [7]. It is like a symphony conductor, ensuring that different elements work harmoniously to achieve smooth, reliable, and safe transportation. From planning routes and schedules to monitoring traffic flow, transportation management strives to enhance overall efficiency. Essentially, public transportation management works to create a well-coordinated and accessible network, ensuring that people can move around their communities with ease [8].

Meanwhile, effective bus transportation management seeks to minimize delays, reduce congestion, and enhance overall system performance. Additionally, transportation managers oversee maintenance schedules and driver assignments to guarantee the safety and efficiency of public buses. Employing strategies like improved infrastructure and technology integration, transportation management plays a key role in creating smoother, more organized, dependable bus services and more accessible travel experiences for everyone [9].

The Transportation Management System (TMS) supports all transportation processes digitally by ensuring effective transportation operations and operating conditions and guaranteeing on-time services. Some of the important components of TMS include sustainability, which uses the system's impacts on the economy, environment, and general social well-being, as evaluated by system effectiveness and efficiency through route planning [10]. Improved service quality and cost savings are all possible with an efficient TMS. One of the features of TMS is that it enhances transport operations and provides visibility into everyday operations, resulting in on-time delivery. With same-day shipping and real-time tracking becoming standard features rather than extras, a strong TMS is now essential to a successful supply chain [11]. In 2023, the global bus market reached 47.1 billion dollars in 2022 and is expected to increase to 71.5 billion dollars by 2028, indicating a growth rate of 6.8 percent. Based on information technology (IT), TMS is currently in the early phases of revolutionizing transportation systems. It has revolutionized other industries, including government, healthcare, and education. Due to their broad impact on people's lives and their ability to provide essential applications and services to improve transportation safety and mobility, as well as to optimize the use of time and available transportation resources, intelligent transportation systems have attracted much attention in recent years from academia, industry, and standardization bodies [12]. Transit buses have the largest market share among different types of buses. These are large vehicles designed to transport multiple commuters from one place to another within a town, city, and/or metropolitan area. It usually travels on predetermined itineraries, with planned stops along the way. Passengers board and disembark at these locations, and the buses run on time or based on their schedule. Transit buses are essential in public transportation networks because they provide an economical and convenient means for people to commute within cities and provinces [13]. The growing acceptance of buses among people as an affordable means of long- and short-distance commutes boosts the market's expansion.

With that, as time passes, transportation is vitally needed, which is why the emergence of buses is important. The growth of the bus industry, or the number of buses in a particular area or region, can be influenced by various factors, including population growth, urbanization, economic conditions, public transportation policies, and environmental concerns. Based on IMARC Group, in 2023, the global bus market reached up to 47.1 billion dollars in 2022 and is expected to increase to 71.5 billion dollars by 2028, indicating a growth rate of 6.8 percent. Transit buses have the largest market share among different types of buses. These are large vehicles designed to transport multiple commuters from one place to another within a town, city, and/or metropolitan area. It usually travels on predetermined itineraries, with planned stops along the way. Passengers board and disembark at these locations, and the buses run on time or based on their schedule. Transit buses are essential in public transportation networks because they provide an economical and convenient means for people to commute within cities and provinces [13]. The increasing popularity of buses among individuals as a cost-effective mode of commuting long and short distances strengthens the market's growth.

1.2 Review of Related Literature

1.2.1 Access to transportation

One of the requirements of an expanding population in a region is having access to locations and services using transportation. In addition to that, the most important outcome of the transportation system is its accessibility. Transportation accessibility has grown to be essential in developing and assessing the transportation system in terms of mobility and sustainability. Aside from the transportation system itself, the perceived accessibility of transportation significantly impacts travel satisfaction. It can enhance the overall quality of life, economic opportunities, and community well-being [14]. In the literature, the well-known definition of accessibility is the ease with which travellers can reach any activity using a particular transportation system [15]. Buses, jeepneys, taxis, trains, vans, and rails are some of the accessible transportation modes in the Philippines [16].

Bus frequency varies significantly across the globe, where factors such as urbanization, population density, and infrastructure influence the high demand of commuters; they implement well-established schedules to improve their bus system transportation. Having limited resources is one of the hindrances that results in less frequent bus services and less predictable schedules in less developed regions [17]. In 2022, the number of registered buses in the Philippines was recorded at 13,360 units. Bus frequency in the Philippines is diverse, ranging from populated urban areas that result in high frequency to rural areas where buses may be less frequent due to lower demand. Bus frequencies in Metro Manila can range from a few minutes to 30 minutes or more, depending on the route, time, and day. More frequent bus services can be expected during peak hours. In order to enhance the bus frequency across the country, improving the transportation system, infrastructure, and services is still ongoing [18].

1.2.2 Commuters' perspective

Commuters' perspectives, satisfactions, and experiences heavily rely on the forms of transportation they use. Several studies have shown that factors such as time spent waiting, travel length, and mode of transport choice all influence commute satisfaction. Commuters must often carefully manage their time to ensure they arrive at their destination punctually [19]. This includes public transportation like buses, significantly impacting their ability to reach their destinations effectively. Philippine commuters often have mixed feelings about buses; they face challenges such as overcrowding and delayed schedules but still choose this type of vehicle because of its affordable fares. Despite challenges, buses remain a crucial part of the daily commute for many Filipinos [20].

In Malaysia, a study was conducted to show the user behaviour of a real-time GPS tracking application based on accessibility, reliability, comfort, safety, security, customer satisfaction, and customer loyalty. It shows how commuters were affected by using the application. The current study has produced empirical proof of a real-time GPS monitoring application improving consumer satisfaction and loyalty, increasing public transit ridership. In conclusion, the results showed that using the real-time GPS monitoring app improved accessibility. Real-time GPS tracking software boosted reliability, comfort, safety, security, and customer loyalty [21].

1.2.3 Bus commuters' status in the Philippines

One of the leading public transportation modes in the Philippines is the bus, garnering a total percentage of 29% from the Philstar survey in 2022. Meanwhile, when it comes to longer trips, the bus is the most preferred public utility vehicle. With about 75% of commuters in the Philippines depending on them for travel, public utility buses are by far the country's most popular form of transportation. This high utilization is explained by the accessibility, particularly for trips between cities, and it is expected to increase further due to the provinces' fast urbanization [22]. Meanwhile, there are two main bus terminals in Pampanga: Dau in Mabalacat and San Fernando in the capital city. The Dau terminal sits at the end of NLEX, offering easy access for locals and tourists heading to destinations like Baguio, Pangasinan, and more. Similarly, San Fernando Terminal provides buses for long trips and connections to nearby towns. Both terminals manage high passenger volumes by implementing efficient systems, ensuring a smooth travel experience [23].

However, in addition to this widespread reliance on buses, the Philippine commuter scene faces major challenges. The daily commute is characterized by overcrowding on buses, jeepneys, and railroads, especially during peak hours. This congestion impacts both short—and long-distance travel, causing passengers discomfort and raising safety concerns [24]. Despite these challenges, buses continue to be the backbone of transportation for millions of Filipinos, facilitating their daily travels to places of employment, education, and other locations. [25].

1.2.4 On-time performance of bus transportation

Rapid urbanization continues to impact ongoing development and the growth of urban populations significantly. With this population growth comes increased congestion on the roads. On-time performance in transportation is pivotal in addressing challenges arising from rapid urbanization and the subsequent rise in urban populations. Timely and efficient transportation alleviates road congestion, sustains development, and plays a critical role in bus transportation. The multifaceted importance of punctuality in bus services includes minimizing passenger wait times, enhancing overall system efficiency, and fostering reliable commuting experiences [26]. Delays in transportation lead to economic inefficiencies and increase traffic congestion, elevating air pollution and fuel consumption. Without real-time navigation tools, commuters rely heavily on punctual bus services to navigate growing urban landscapes [27]. Statistics underscore the significance of on-time performance, indicating that delays in transportation could result in substantial economic losses and hinder the overall quality of life in rapidly urbanizing areas [28]. With that, Free Capital supported the idea that prioritizing punctuality in bus transportation is crucial for reducing congestion, improving accessibility, fostering public trust, optimizing economic efficiency, and mitigating environmental impacts associated with fuel consumption and emissions [29]. Overall, emphasizing on-time performance is key to building a sustainable, efficient, and passenger-friendly public transit system amid urbanization and increased vehicular traffic.

In Malaysia, bus services underwent evaluation based on their punctuality, also known as on-time performance (OTP), in different areas such as Johor Bahru, Bandaraya Melaka, and Seremban, where the OTP was recorded at 66.17%, 56.15%, and 71.04%, respectively. The average percentage of on-time departures for all routes daily was calculated at 71.04%. Evaluating each state provided an outcome quality of service (QOS) grade of D, indicating that bus on-time performance requires continuous monitoring due to inconsistent adherence to schedules, highlighting lower reliability in service. This evaluation using OTP data allows transportation authorities to pinpoint service issues, enabling scheduling, route optimization, and resource allocation adjustments to improve punctuality and service quality, aiming to enhance public transportation efficiency and minimize congestion, positively impacting the lives of Malaysians [30].

On-time bus performance in the Philippines is often challenging due to various factors, such as populated streets and limited and narrow roads that cause delays in arrival and departure. Additionally, frequent road repairs and maintenance work contribute to disrupting bus schedules. The lack of a reliable public transportation infrastructure further compounds the issue, making it difficult for buses to stick to their schedules. Poorly maintained vehicles and insufficient fleet management practices can result in breakdowns and unexpected stops [31]. Moreover, bus companies' lack of consistent schedules makes coordinating efforts more difficult. Insufficient signage and information at bus stops and terminals further increases the problem, as passengers may struggle to determine when their bus will arrive [32]. Overall, the on-time performance of buses in the Philippines is influenced by a combination of infrastructure shortcomings, organizational factors, and overpopulated terminals.

1.2.5 Crowding level of bus transportation

One of the major problems bus transportation faces is overcrowding, which affects both service effectiveness and passenger safety. The International Association of Public Transport (UITP) reported that 15% of bus riders encounter overcrowding during peak hours globally. This percentage means that millions of people experience discomfort and possible safety risks daily. In addition to causing physical strain, overcrowding causes stops to remain open for longer, reducing the bus system's overall effectiveness [29]. Only the number of seats should be used as a capacity [33]. Thus, terminal capacity is affected by the density of standees and number of seats used. The global crowding situation shows how urgently improved transportation management and intervention programs are needed for better service quality and passenger experience [34].

The overcrowding problem in bus transportation is even more severe in the Philippines. Based on the study made by the Department of Transportation and Communications (DOTC), more than 70% of buses in major cities like Metro Manila ran over capacity during peak hours. This alarming number has a wider effect on air quality and traffic congestion, indicating pressure on passenger comfort and safety. The Philippines overcrowding situation adds to longer travel times, decreased operational effectiveness, and heightened commuter annoyance [35].

1.2.6 Effects of delays and congestions at bus terminals

In an op-ed piece, the public transportation crisis was characterized as "dehumanizing." In 2015, the Employers Confederation of the Philippines asserted that these delays and congestion led to a diminished productivity rate. Commuters endure double the fatigue as a consequence of substandard public transportation. Meanwhile, in 2018, the Japan International Cooperation Agency (JICA) stated that the continuous increase in transportation problems would cost the country's economy $5.4 billion. JICA described the transportation situation as a "deadly spiral," causing billions of dollars in economic losses [24].

Delays and congestion during bus commutes in the Philippines create significant challenges. They cause lateness at work, leading to decreased productivity. Prolonged periods on crowded buses bring commuters physical exhaustion and mental stress. Additionally, this situation impacts the economy due to wasted fuel, increased operational costs, and late arrivals, which affect business efficiency. Health-wise, exposure to crowded and polluted environments leads to respiratory issues and stress-related ailments. Ultimately, these issues drastically impact individuals' quality of life by consuming personal time and affecting family and leisure activities. Addressing these problems is crucial for improving commuters' well-being and enhancing the transportation system's efficiency [37].

1.2.7 Technological advancement in transportation

Transportation systems have significantly evolved over the years due to technological improvements. Different public vehicles have been developed and innovated to improve transportation. In 2018, the utilization of technology in transportation was evident in the operation of Grab in Southeast Asia, where it merged with Uber. Grab provides ride-hailing services through their mobile application, which allows customers to book private cars and rideshare. Like Uber, the application's features involve the details of the driver, car, payment mode, and real-time location tracking for both the passenger and driver. Grab has incorporated real-time tracking features since it aims to offer safe and reliable taxi rides for commuters in Malaysia [38].

Meanwhile, the Philippines also has app-based motorcycle ride-hailing platforms such as Angkas, Joyride, and Move-It. Their application features the details provided by the driver, the motorcycle registration, and real-time tracking. It was launched for commuters who are experiencing congested traffic in Metro Manila [39].

1.2.8 Introduction of tracking technology

The vehicle tracking system is the technology that determines the location of a vehicle using various methods, such as the Global Positioning System (GPS) and other navigation systems that operate via satellite and ground-based stations. Modern vehicle tracking systems use GPS technology to monitor and find our vehicles anywhere on the planet, but other types of automatic vehicle location technology are also sometimes used [40]. The GPS is a satellite-based navigation system that has been in use for over four decades. It was created for military use. It is utilized in geology, navigation, farming, precision mapping, and surveying, with more uses on the way [41].

A vehicle tracking system assists public transportation users in their movements by providing real-time information on the locations of vehicles in transit. A vehicle tracking system was developed as a component of an advanced public transportation system to improve commuting on an urban arterial. The developed system is based on wireless technologies such as GPS and the Global System for Mobile Communication module. It records and displays real-time vehicle location using a GPS-based greedy forwarding algorithm and computes route distance information [42]. The GPS Tracking System for Public Transportation is primarily intended to assist commuters in traveling without difficulty. It is developed in such a way that it provides a user-friendly experience. With a glance at the display screen, the traveler receives all the information about forthcoming buses and their arrival times. Bus tracking allows organizations to keep track of each bus and its route [43].

The native Android app is a location-aware application that gives real-time arrival information for nearby public transportation stops. The Android operating system includes built-in localization features that use a fusion of sensor data from GPS, Wi-Fi, and cell-tower localization to provide a rapid position fix on a user's phone. This location information can access real-time arrival information for a nearby stop in a fraction of the time [44]. Based on a study conducted in India, tracking all vehicles in real-time with GPS offers relevant information to consumers about traffic congestion, arrival time, and the projected time required to reach their destinations. Users can view real-time bus, rail, and metro locations, time standards, and other information [45].

1.2.9 Importance of roadway access

Access Management (AM) has been used to alleviate the ever-present problem of traffic congestion. By prescribing permissible spacing and combinations of access connections for a given property, good AM balances site access needs with the need to safely and efficiently use the transportation network. When done correctly, AM will continue to improve traffic safety and operations. The optimization of traffic operations near the access point is one of the key aspects of access management [46]. In 2001 and 2003, the American Association of State Highway Transportation Officials Policy on Geometric Design of Highways and Streets—the first U.S. policy—extended its discussion of access management. Numerous other countries have implemented these policies due to access management techniques' proven operational and safety advantages. It highlights the importance of managing traffic conflicts through functionally built roadway networks with different degrees of access and mobility, which is becoming increasingly apparent due to these improvements [47].

A study has been conducted in Malaysia on a proposed application for a roadway access on-campus public transportation monitoring system. The system's objective is to assist users in using university buses to navigate the campus and encourage students to use public transportation. The web application provides the bus's roadway access and the estimated arrival time. As an outcome, the students have managed their time better through the use of the proposed application because waiting a long time for the bus to arrive is inconvenient. The students could monitor the roadway access and estimated time of arrival of the bus, which gave them time management to prepare for the bus' arrival [48].

A study was proposed in Iraq; it is an application for an intelligent real-time public transportation monitoring system based on the Internet of Things (IoT). Its primary objectives are to follow the whereabouts of buses in real time, estimate their expected arrival time, and measure their speed and distance. The suggested application aims to assist bus commuters in reducing the time they spend waiting at the bus station, much like the study in Malaysia. The proposed system comprises a microcontroller, a GPS module, and a mobile application. The accuracy analysis of location, distance, and arrival time was conducted by testing the application on multiple roads in Mosul city for several days at different times [49].

Based on the presented literature, understanding the correlation between the on-time performance of buses and crowding levels at bus terminals remains necessary. Moreover, GPS tracking proves its efficiency in providing accurate vehicle location information. Both GPS and roadway access enhance transportation in terms of vehicle booking and real-time tracking. Despite the active use of GPS real-time tracking, it is not fully utilized due to its limitations. It is currently only applied to taxis, motorcycles, and metros, provided buses are one of the most accessible inter-city transportation. However, there is a lack of technology incorporation in bus management systems to enhance punctuality. Therefore, there is a clear gap in understanding the correlation between bus punctuality and crowding levels at terminals, the utilization of GPS real-time tracking, and technology integration into bus systems for better roadway access.

1.3 Statement of the Problem

The study focused on the then-current understanding of bus transportation, which faced a gap in addressing the correlation between crowding levels and on-time performance. There was a significant need to assess these dynamics comprehensively, recognizing a lack of empirical analysis within the transportation engineering domain. A systematic evaluation was required to pave the way for effective interventions. The study emphasized the need for empirical analysis to gain deeper insights into the relationship between deficient on-time performance and crowding levels, laying the groundwork for a bus-tracking application.

1.4 Objectives of the Study

The study aimed to improve the reliability of public transportation roadway access, leading to the development of a transportation engineering-focused bus tracker app. Specifically;

1.4.1. To assess bus terminals' on-time performance and crowding levels through manual observation and identify the correlation between passengers' crowding levels and the buses' punctuality.

1.4.2. To provide an estimated arrival time and enhance the OTP by developing a mobile application.

1.4.3. To conduct a pilot test of the Philippines Automated Roadway Access—Public Operation (PARA PO) application to ensure its reliability in providing an estimated time of arrival for buses.

1.5 Significance of the Study

The results of this study are beneficial to the following individuals:

Commuters. The product of this study could help commuters by providing them with an application for convenient and efficient public transportation. This would help them avoid congestion at terminals and catch buses easily.

Bus companies. The development of the application could serve as a stepping stone to embark on an innovative bus system in the country.

Community. The outcome of this study could help the community to have efficient public transportation, improve transit systems, and promote sustainable mobility options.

Government. This study could benefit different government agencies by assisting them in addressing the country's transportation system concerns.

The Future Researchers. The result of this study could serve as reference material for conducting similar studies. They may find relevant readings that may be of great help to them.

1.6 Scope and Delimitation

This study analyzed the on-time performance of bus transportation and its potential connection to escalating crowding levels, primarily addressing knowledge gaps in these critical areas. The study involved a thorough examination of both crowding dynamics and on-time performance in bus transportation to understand their implications for public transportation roadway access. The researchers carried out manual observations. Specifically, this analysis focused on the bus route from San Fernando to Olongapo.

This study also included the development of the Philippine Automated Roadway Access Public Operation (PARA PO) application, which served as the answer to adjusting the accuracy of bus arrivals and departures. The PARA PO application was limited to certain functions, such as bus tracking and estimated arrival time. It did not have the feature of counting passengers or making seat reservations. The application only worked on a mobile network or the internet. The application was developed by the application developer chosen by the researchers. In addition, this study did not cover any traffic management adjustments such as bus rerouting or passenger' drop-off.

1.7 Conceptual Framework

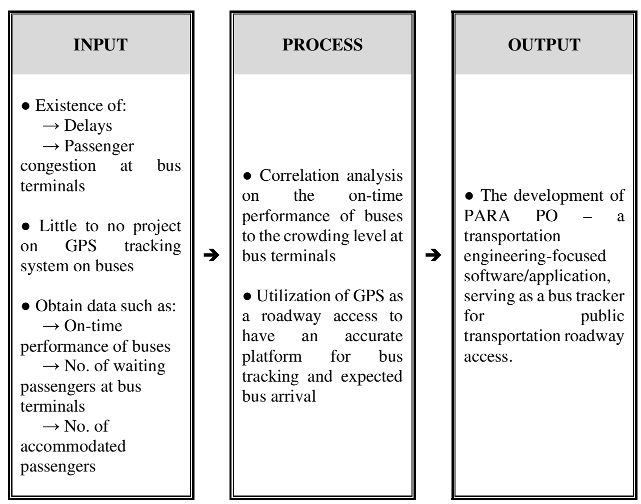


Fig.1 Conceptual Framework

Figure 1 presents the conceptualization guiding the progression of the study. Depicted in the diagram is the incorporation of delays and passenger congestion at bus terminals as important inputs shaping the overall framework. Subsequently, the focus shifted to analyzing the correlation between the on-time performance of buses and crowding levels at bus terminals. The evolution of the PARA PO application, coupled with pilot testing, also emerged as a dynamic process variable. Following a thorough evaluation of the application, further study was conducted on the PARA PO application within the framework.

1.8 List of Terms

Roadway Access. interpreted as a means of entering another road or a new access way of the road on which vehicles can travel and for avoiding existing congestion on common roads. Roadway access can improve vehicle operations and lessen traffic congestion.

Transportation Management. the handling, controlling, and supervising of the movements of goods, information, and people. It plays an important role in the transportation industry and enhances vehicle routes for better travel.

Transportation Management System. a platform that uses technology to execute the proper transport operations.

II. METHODOLOGY

This chapter outlines the methodology used in conducting the empirical analysis of bus transportation's punctuality and crowding levels within the framework of the Philippine Automated Roadway Access Public Operation (PARA PO) Application, detailing the methodological framework, research design, system design, research locale, research instrument, data collection methods, data analysis, and ethical considerations applied to explore the relationship between punctuality and crowding levels in bus terminals.

2.1 Methodological Framework

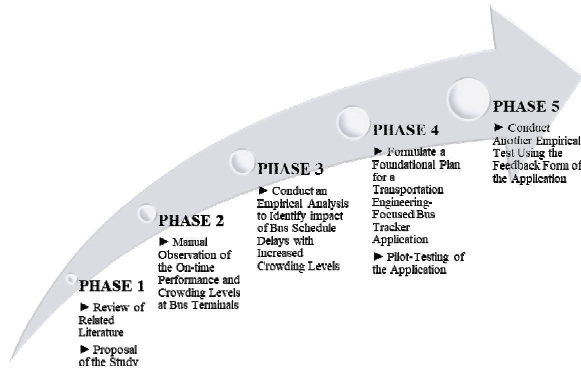


Fig. 2 Methodological Framework

The framework for this study involves five sequential phases. Initially, the framework emphasizes obtaining essential information sources, encompassing scholarly articles and related literature, to comprehensively understand the significance of evaluating traffic, the on-time performance of bus transportation, passenger crowding at bus terminals, and the lack of GPS usage on buses. This understanding forms the foundation for proposing the study. Phase 2 progresses by manually observing the on-time performance and crowding level of bus transportation at bus terminals. Afterward, an empirical analysis of the relationship between bus schedule delays and increased levels of crowding was conducted in Phase 3. Phase 4 involves developing the bus tracker application and implementing the PARA PO application with the chosen participants. Data was collected using benchmarked questionnaires and statistical techniques for effective data interpretation.

2.2 Research Design

A mixed method involving qualitative and quantitative methodologies was utilized as the research design. One of the study's aims was to evaluate the on-time performance of bus transportation by manual observation and identify the causes of delays leading to crowding. This approach allowed the researchers to analyze an extensive range of concepts, laying the groundwork for developing a bus tracker application that contributes to a better travel experience for our commuters.

2.3 System Design

The system was composed of an Android application with two interfaces: one for the bus operator and the other for the passengers. The real-time location of the bus allowed users to track the bus using the application, and acquiring the real-time location involved using a smartphone with GPS function, connecting the device to the internet, and downloading and operating the application. The bus operators are accountable for this process. After properly operating the tracking device through the smartphone, the application generated reliable and accurate information used by the system to process the data needed to show the real-time location and estimated time of arrival of the bus. The data acquired from the bus operator's application (GPS for real-time bus location) was directed to the application's passenger interface via the cloud server. Subsequently, the application's users could track the bus's location in real-time.

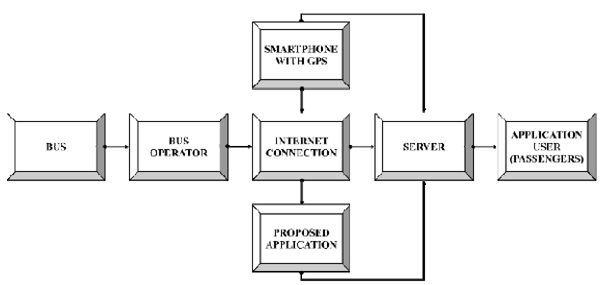


Fig.3System Design Diagram

2.3.1 PARA PO Bus Tracker Application Features

The PARA PO Bus Tracker Application was developed to address the challenge of improving the precision of bus arrivals and departures while prioritizing commuter satisfaction and transportation efficiency. The application offers tailored functionalities for both commuters and bus drivers through a user-friendly approach. The following functionalities lay the groundwork for exploring its features, each carefully crafted to streamline the travel experience for all commuters.

2.3.1.1 Functionality for Commuters' Interface

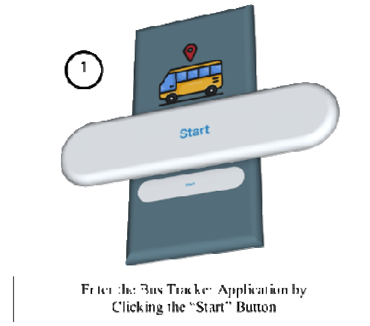
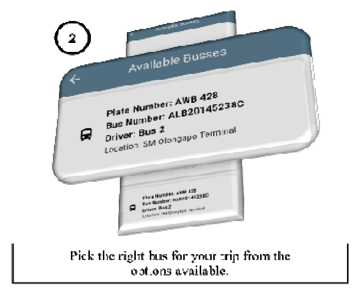


Fig. 4 Commuters' Login for User Interface



5. Bus Selection Process

Fig. 8 Bus Navigation and Information Display

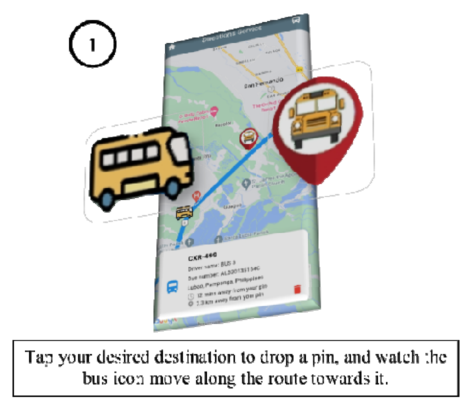


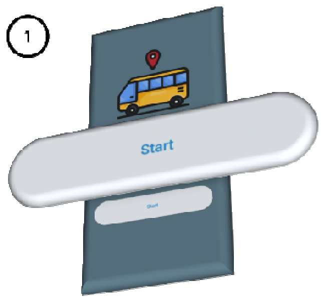
Fig. 6 Bus Navigation and Information Display

After pinning the location, a bar below shows bus information, including ETA and distance.

Fig. 6 Bus Navigation and Information Display

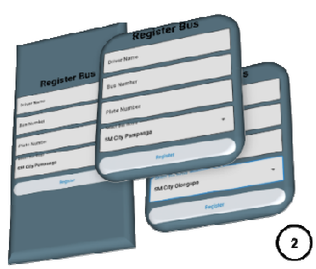
2.3.1.2

2.3.1.3 Functionality for Bus Driver's Interface



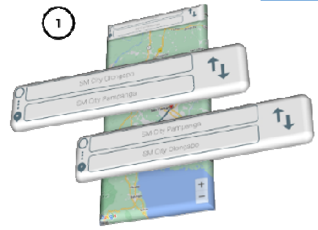
Enter the Bus Tracker Application by Clicking the "Start" Button

Fig. 7 Bus Drivers' Login for Bus Interface

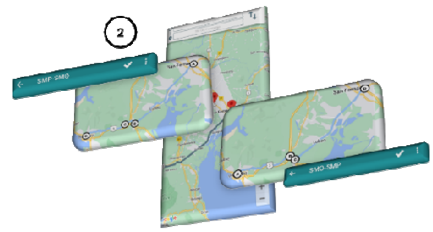


Register the bus with driver details, bus number, plate number, and select route start point.

Fig. 7 Bus Drivers' Login for Bus Interface



The route pane above displays the driver's route, with top pin as starting point and bottom pin as end point.



Navigation adjusts automatically to bus direction, keeping commuters informed if it's approaching or has passed.

Fig. 8. Bus Route and Navigation Overview

2.4 Research Locale

The bus terminals of San Fernando and Olongapo were utilized to manually observe the on-time performance of bus transportation at bus terminals. These terminals were chosen to analyze the increasing congestion and delays experienced by commuters at bus terminals, stops, and within bus schedules. Additionally, only passengers traveling through the route of San Fernando-Olongapo participated in the study.

2.5 Research Instrument

In evaluating the on-time performance of buses at bus terminals, timetable observation of bus schedules was employed. They were recorded during observations using timetables to compare the planned arrival times with the actual arrival times. It recorded specific time points and the number of passengers waiting at bus terminals. The results were used to evaluate whether buses adhered to their schedules, arrived and departed punctually, or experienced delays. Additionally, a survey questionnaire was utilized to assess the waiting time of the passengers before and after using the application.

Meanwhile, to analyze the general experience of PARA PO users, a 4-point Likert scale feedback form was also utilized. This questionnaire served as an instrument to gauge the initial impact of the application on bus service reliability. A study from China conducted by Olivares et al. was benchmarked in creating foundational questions in this study to strengthen the questionnaire further.

2.6 Data Collection Methods

2.6.1 Manual Observattion

The researchers observed both San Fernando and Olongapo terminals to collect the real-time bus comings and the crowding situation. They compared the actual arrival to the posted schedules of the bus companies along with the piling up of commuters in the terminal. This observation took place for exactly seven days, at least eight hours per day.

Meanwhile, a convenience sampling technique was used to select the participants for the pilot testing. In pilot testing, samples with sizes varying from 10 to 40 per group were assessed for their suitability in yielding estimates that are accurate enough to satisfy a range of potential objectives [51]. A survey questionnaire was utilized to assess the application's waiting time and efficiency level.

2.6.2 Testing Procedures

2.6.2.1 Alpha Testing

The researchers first evaluated the application in the alpha testing phase of software testing before making it available to a larger audience [52]. In the program's development process, alpha testing helped the researchers find bugs, malfunctions, and other problems. Through this process, the researchers assessed the effectiveness of the features, functionality, and user interactions [53]. This process ensured the software was created by adhering to the project's original goals and the users' expectations. Furthermore, it was examined by the software specialist to confirm the accuracy and operation of its features. It ensures that the features applied to the application adhere to the necessary specifications and standards [54]. As for the researchers, this process is regarded as internal testing since it allows them to use the application independently before launching it to the research participants.

2.6.2.2 Beta Testing

In software development, beta testing was the second phase of testing, during which a small group of target users tried out the product. A representative sample of the target population was given the opportunity to try out the product before it was released to assess its usability [55].

In conducting beta testing for the PARA PO bus tracker application, researchers actively engaged 25 respondents to evaluate its functionality and usability. It was recommended that this number of questionnaires be disseminated during the pilot testing phase to gather substantial feedback and data [56]. Researchers served as the operators using the bus driver application interface. They boarded the bus to be detected by the commuters using the application. Once the respondents were found, they were given access to the application. They downloaded it, used it to select a bus, and waited at a bus stop or nearby bus point along the selected route from San Fernando to Olongapo. Using the commuter's application interface, respondents tried to predict the arrival of the bus, estimated the time to their location, and estimated the arrival time at their destination. Commuters also received notifications when the selected bus was within 5 minutes of their location. Upon completion of the testing phase, insights gathered contributed to refining the application for enhanced user experience and efficiency in public transportation.

2.7 Data Analysis

A Chi-square test was used to assess the association or independence between categorical variables in treating the data from timetable observation. The Chi-squared test helped analyze whether there was a significant relationship between on-time performance and crowding levels at bus terminals. Additionally, Kendall's Tau analysis was utilized to determine the strength and direction of the association between the two variables. In this analysis, variables represented ordinal categories to assess further whether there was a significant association between the ordinal variables representing different time slots or levels of crowding.

Meanwhile, a mean analysis was employed to analyze the commuter feedback gathered. Mean analysis calculates the mean (average) scores based on the Likert scale. The mean scores were used to summarize the commuters' satisfaction or dissatisfaction levels to evaluate the main point of the responses.

2.8 Ethical Consideration

The researchers followed the ethical standards throughout the process. They have prioritized data security and user privacy upon collecting the information needed, adhering to the Data Privacy Act 2012. It was also highlighted that the participation of the respondents was voluntary and made sure that they fully understood their take on the study.

III. RESULTS AND DISCUSSION

3.1 Manual Observation

During the manual observation, the researchers assessed the on-time performance and crowding levels at the City of San Fernando and Olongapo bus terminals. This was done to check the relationship between crowding levels and bus punctuality. The Chi-squared test was used to test the statistical analyses. These tests were conducted to provide insights into the efficiency and quality of the terminals' service.

3.1.1 Chi-Squared Test

The Chi-squared test aided the researchers in determining the relationship between the variables. The researchers compared the observed and expected frequencies relating to bus crowding levels and punctuality.

3.1.1.1 Set up Hypotheses

The null hypothesis (H0) states that there is no association between time delays and crowding, while the alternative hypothesis (H1) affirms that there is a significant association.

3.1.1.2. P-Value using Chi-Squared Process

TABLE 1. Observation Data at Olongapo and San Fernando Terminal

This table presents the raw data from observations at the Olangapo and San Fernando Terminals. Each column shows the crowding level: High Crowding, with 50 plus passengers waiting, and Low Crowding, with less than 50 passengers waiting. Each data is categorized into two sub-columns: bus number on the left and time delays on the right.

TABLE 1.1.
Observation Data at Olongapo Terminal: Bus Number and Time Delay by Crowding Level

OLONGAPO TERMINAL			
High Crowding (>50)		Low Crowding (<50)	
Bus No.	Time delay (mins)	Bus No.	Time Delay (mins)
1	10	7	22
2	17	8	12
3	22	9	16
4	12	10	14
5	20	18	23
6	35	19	28
11	6	20	21
12	15	21	17
13	13	22	21
14	8	23	27
15	15	30	18
16	11	31	17
17	16	32	24
24	16	33	11
25	19	34	18
26	25	35	23
27	21	36	24
28	16	43	14
29	9	44	18
37	17	45	26
38	15	46	22
39	24	47	21
40	12	48	28
41	17	49	19
42	20	50	21
51	16	58	26
52	19	59	7
53	13	60	21
54	17	61	19
55	19	62	22
56	14	72	22
57	21	73	22
63	13	74	19
64	16	81	16
65	28	82	19
66	11	83	24
67	1	84	31
68	15	85	23
69	17	86	22
70	22	87	24
71	24	88	29
75	13	89	20
76	17		
77	24		
78	33		
79	12		
80	17		
90	23		
91	17		
No. of bus = 49		No. of bus = 42	

TABLE 1.2.
Observation Data at San Fernando Terminal: Bus Number and Time Delay by Crowding Level

SAN FERNANDO TERMINAL			
High Crowding (>50)		Low Crowding (<50)	
Bus No.	Time delay (mins)	Bus No.	Time delay (mins)
1	15	6	16
2	20	7	13
3	18	8	22
4	23	9	17
5	21	10	20
12	26	11	15
13	18	20	21
14	32	21	23
15	19	22	15
16	21	23	12
17	25	24	24
18	29	25	26
19	17	28	18
26	32	33	16
27	38	34	28
29	16	35	26
30	20	36	17
31	22	37	21
32	24	38	23
40	31	39	19
41	32	42	22
43	19	47	17
44	21	48	21
45	25	49	23
46	29	50	25
55	28	51	12
56	18	52	24
57	21	53	26
58	29	54	32
59	30	62	28
60	19	63	16
61	24	64	18
68	34	65	26
69	38	66	29
70	24	67	31
71	26	77	23
72	22	78	15
73	27	79	12
74	31	80	24
75	25	86	33
76	29	87	28
81	26	88	26
82	32	89	18
83	28	90	23
84	18	91	20
85	21	92	16
96	16	93	27
97	17	94	21
		95	28
		98	24
No. of bus = 48		No. of bus = 50	

TABLE 2. Instances by Crowding Level and Time Delay at Olongapo & San Fernando Terminal

The table shows the time delays at Olongapo and San Fernando Terminals. These are categorized as High and Low Crowding conditions. High congestion is observed for all the delay intervals, specifically the 16-23.4 minutes. There were 23 incidents observed at Olongapo, while 21 incidents were in San Fernando. It was also noticed that even during low congestion, there were still 26 cases in Olongapo and 24 cases in San Fernando. This only highlights the need to manage the crowd and have efficient bus time operations.

TABLE 2.1.
Distribution of Instances by Crowding Level and Time Delay at Olongapo Terminal

OLONGAPO TERMINAL						
		TIME DELAY (MINS)				
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38
CROWDING LEVEL	High Crowding	3	16	23	5	2
	Low Crowding	1	4	26	10	1

TABLE 2.2.
Distribution of Instances by Crowding Level and Time Delay at San Fernando Terminal

SAN FERNANDO TERMINAL						
	TIME DELAY (MINS)					
	1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38	
CROWDING LEVEL	High Crowding	0	1	21	17	9
	Low Crowding	0	7	24	16	3

TABLE 3. Observed Values by Crowding Level and Time Delay at Olongapo Terminal

The table presents the additional rows and columns for calculating "observed values" when conducting the Chi-square Test. The row indicates 49 high crowding and 42 instances of low crowding at the Olongapo terminal. In the San Fernando terminal, there were 48 instances of high crowding while 50 instances of low crowding. In addition, the columns provide the delay frequencies across the time intervals, with the highest delay occurring at 16-23.4 minute intervals. It has 49 instances at Olongapo and 45 instances at San Fernando Terminal. The total number of instances is 182 at the Olongapo terminal and 196 at the San Fernando terminal.

TABLE 3.1.
Calculation of Observe Values by Crowding Level and Time Delay at Olongapo Terminal

OLONGAPO TERMINAL							ROW TOTAL
		TIME DELAY (MINS)					
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38	
CROWDING LEVEL	High Crowding	3	16	23	5	2	49
	Low Crowding	1	4	26	10	1	42
COLUMN TOTAL		4	20	49	15	3	182

TABLE 3.2.
Calculation of Observe Values by Crowding Level and Time Delay at San Fernando Terminal

SAN FERNANDO TERMINAL							ROW TOTAL
		TIME DELAY (MINS)					
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38	
CROWDING LEVEL	High Crowding	0	1	21	17	9	48
	Low Crowding	0	7	24	16	3	50
COLUMN TOTAL		0	8	45	33	12	196

TABLE 4. Expected Values by Crowding Level and Time Delay at Olongapo Terminal

This table presents the expected values derived from observations at the Olongapo and San Fernando Terminals, categorized by crowding level and time delay in minutes. Each cell in the table represents the expected count, calculated using the formula "Row Total multiplied by Column Total, then divided by the Grand Total" as part of the Chi-Squared test's expected value computation. For instance, under High Crowding at the Olongapo Terminal, the expected count for delays between 1 and 8.4 minutes is 1.0769; for delays between 8.5 and 15.9 minutes, it is 5.3846; for delays between 16 and 23.4 minutes, it is 13.1923; for delays between 23.5 and 30.9 minutes, it is 4.0385; and for delays between 31 and 38 minutes, it is 0.8077. Similarly, under Low Crowding at the Olongapo Terminal, the expected counts for the respective time delay intervals are 0.9231, 4.6154, 11.3077, 3.4615, and 0.6923. Correspondingly, at the San Fernando Terminal, the expected counts for each time delay interval under high and low crowding are 0, 1.9592, 11.0204, 8.0816, 2.9388, and 0, 2.0408, 11.4796, 8.4184, and 3.0612, respectively. These expected values represent the frequencies anticipated if there were no association between crowding levels and time delays, providing a basis for comparison with the observed values to assess the degree of association between these variables.

TABLE 4.1.
Calculation of Expected Values by Crowding Level and Time Delay at Olongapo Terminal

OLONGAPO TERMINAL						
		TIME DELAY (MINS)				
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38
CROWDING LEVEL	High Crowding	1.076923077	5.384615385	13.19230769	4.038461538	0.807692308
	Low Crowding	0.923076923	4.615384615	11.30769231	3.461538462	0.692307692

TABLE 4.2.
Calculation of Expected Values by Crowding Level and Time Delay at San Fernando Terminal

SAN FERNANDO TERMINAL						
		TIME DELAY (MINS)				
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38
CROWDING LEVEL	High Crowding	0	1.959183673	11.02040816	8.081632653	2.93877551
	Low Crowding	0	2.040816327	11.47959184	8.418367347	3.06122449

TABLE 5. Difference between Observed and Expected Values

The table illustrates the Chi-Square values calculated from observations at the Olongapo and San Fernando Terminals, categorized by crowding level and time delay in minutes. Each cell in the table represents the Chi-Square Value, computed using the formula "The square of the difference between the observed value and the expected value, divided by the expected value," as part of the Chi-Squared test's calculation. For high crowding at Olongapo Terminal, significant associations are indicated by values of 3.4341 for delays of 1–8.4 minutes, 20.9275 for delays of 8.5–15.9 minutes, 7.2914 for delays of 16–23.4 minutes, 0.2289 for delays of 23.5–30.9 minutes, and 1.7601 for delays of 31–38 minutes. Under low crowding at the same terminal, the respective values are 0.0064, 0.0821, 19.0900, 12.3505, and 0.1368. Similarly, at San Fernando Terminal, significant associations for high crowding are shown by values of 0 for delays of 1–8.4 minutes, 0.4696 for delays of 8.5–15.9 minutes, 9.0371 for delays of 16–23.4 minutes, 9.8417 for delays of 23.5–30.9 minutes, and 12.5013 for delays of 31–38 minutes. Under low crowding at the same terminal are 0, 12.0508, 13.6556, 6.8281, and 0.0012. These Chi-Square values quantify the discrepancy between observed and expected data in each cell, aiding in assessing the degree of association between crowding levels and time delays.

TABLE 5.1.
Calculation of Difference between Observed and Expected Values by Crowding Level and Time Delay at Olongapo Terminal

OLONGAPO TERMINAL						
		TIME DELAY (MINS)				
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38
CROWDING LEVEL	High Crowding	3.434065934	20.92747253	7.291433057	0.228937729	1.76007326
	Low Crowding	0.006410256	0.082051282	19.09000523	12.35042735	0.136752137

TABLE 5.2.
Calculation of Difference between Observed and Expected Values by Crowding Level and Time Delay at San Fernando Terminal

SAN FERNANDO TERMINAL						
		TIME DELAY (MINS)				
		1 - 8.4	8.5 - 15.9	16 - 23.4	23.5 - 30.9	31 - 38
CROWDING LEVEL	High Crowding	0	0.46960034	9.03707483	9.841733663	12.50127551
	Low Crowding	0	12.05081633	13.65559184	6.828064317	0.00122449

TABLE 6. Chi-Square Statistic, Degrees of Freedom, and P-value

In analyzing the data from both the Olongapo and San Fernando terminals, several key statistical measures were derived to assess the association between crowding levels and time delays. Firstly, the "Chi-Square Statistic, X²" was computed by summing the squares of the differences between observed values and expected values, each divided by the corresponding expected value, across all contingency table cells. This value quantifies the overall discrepancy between observed and expected values and follows a Chi-squared distribution. The "Degrees of Freedom, df" was then determined by multiplying the number of rows minus one by the number of columns minus one, representing the independent pieces of information in calculating the Chi-squared value. Lastly, the p-value was computed using the right-tailed chi-square distribution function in Microsoft Excel, incorporating the Chi-squared statistic (X²) and the degrees of freedom (df). The obtained p-value indicates the probability of observing a Chi-squared value as extreme as, or more extreme than, the one observed, assuming no association between the variables. For the Olongapo Terminal, the Σ Chi-Square Value, X², is 65.4422, with 4 degrees of freedom and a p-value of 2.07634E-13. Similarly, for the San Fernando Terminal, the Σ Chi-Square Value, X², is 64.3854, with 4 degrees of freedom and a p-value of 3.46685E-13. These results suggest a significant association between crowding levels and time delays at both terminals, as indicated by the exceedingly low p-values, leading to the rejection of the null hypothesis of no association

Based on the calculated p-values for both the Olongapo and San Fernando terminals, which are 2.07634E-13 and 3.46685E-13, respectively, significantly lower than the conventional threshold of 0.05, the researchers reject the null hypothesis (H0) and accept the alternative hypothesis (H1). This indicates a significant association between time delays and crowding at both terminals. The low p-values, practically close to zero, suggest that the observed associations between time delays and crowding are highly unlikely to have occurred by chance alone, providing strong evidence in favor of the alternative hypothesis. Therefore, bus arrival delays contribute to the crowding observed at these terminals.incorporating the Chi-squared statistic (X²) and the degrees of freedom (df). The obtained p-value indicates the probability of observing a Chi-squared value as extreme as, or more extreme than, the one observed, assuming no association between the variables. For the Olongapo Terminal, the Σ Chi-Square Value, X², is 65.4422, with 4 degrees of freedom and a p-value of 2.07634E-13. Similarly, for the San Fernando Terminal, the Σ Chi-Square Value, X², is 64.3854, with 4 degrees of freedom and a p-value of 3.46685E-13. ***These results suggest a significant association between crowding levels and time delays at both terminals, as indicated by the exceedingly low p-values, leading to the rejection of the null hypothesis of no association***

TABLE 6.1
Calculation of Chi-Square Statistic, Degrees of Freedom, and P-value for Olongapo Terminal

	Chi-Square Statistics, X²	Degrees of Freedom, df	P-value
Olongapo Terminal	65.44224415	4	**2.07634E-13** < 0.05 ✓

TABLE 6.2
Calculation of Chi-Square Stats., Degrees of Freedom, & P-value for San Fernando Terminal

	Chi-Square Statistics, X²	Degrees of Freedom, df	P-value
San Fernando Terminal	64.38538131	4	**3.46685E-13** < 0.05 ✓

3.1.2 Kendall's Tau

Kendall's Tau served as a statistical measure for evaluating the strength and direction of the association between two variables. In this study, Kendall's Tau is mainly used to discover the relationship between passenger crowding levels and bus punctuality.

3.1.2.1 Observational Study at Olongapo Terminal

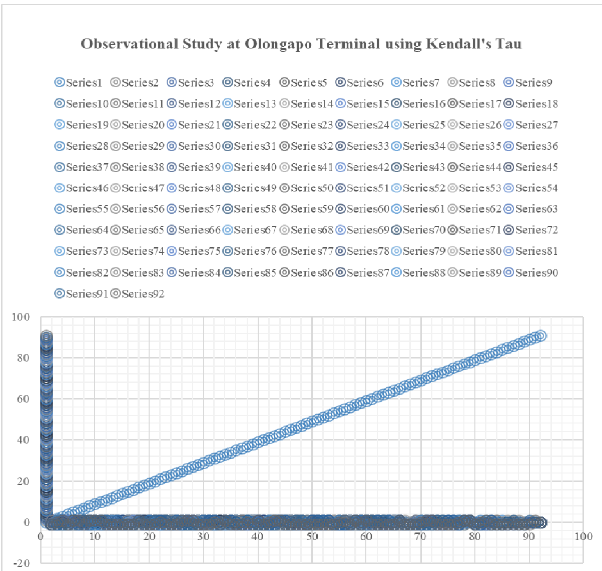


Figure 9. Observational Study at Olongapo Terminal using Kendall's Tau

The graph shows the results at the Olongapo terminal between passenger congestion and bus arrival delays. The data included 91 observations, resulting in 3,847 pairs for analysis

The calculated Kendall's Tau coefficient, a measure of association, is 1, indicating a perfect positive association between crowding and bus arrival delays. This means that terminal overcrowding tends to increase while bus delays increase.

Additionally, the relationship is confirmed by the z-statistics of -3.452255808 and the corresponding p-value of 0.00055592. When the p-value is less than the significance level of 0.05, there is a statistically significant correlation between variables.

In summary, the data indicates that delayed bus arrivals are one of the main causes of Olongapo terminal congestion. Congestion increases with delay, so it is important to consider and address bus arrival times to reduce traffic issues at the terminal.

3.1.2.2 Observational Study at San Fernando Terminal

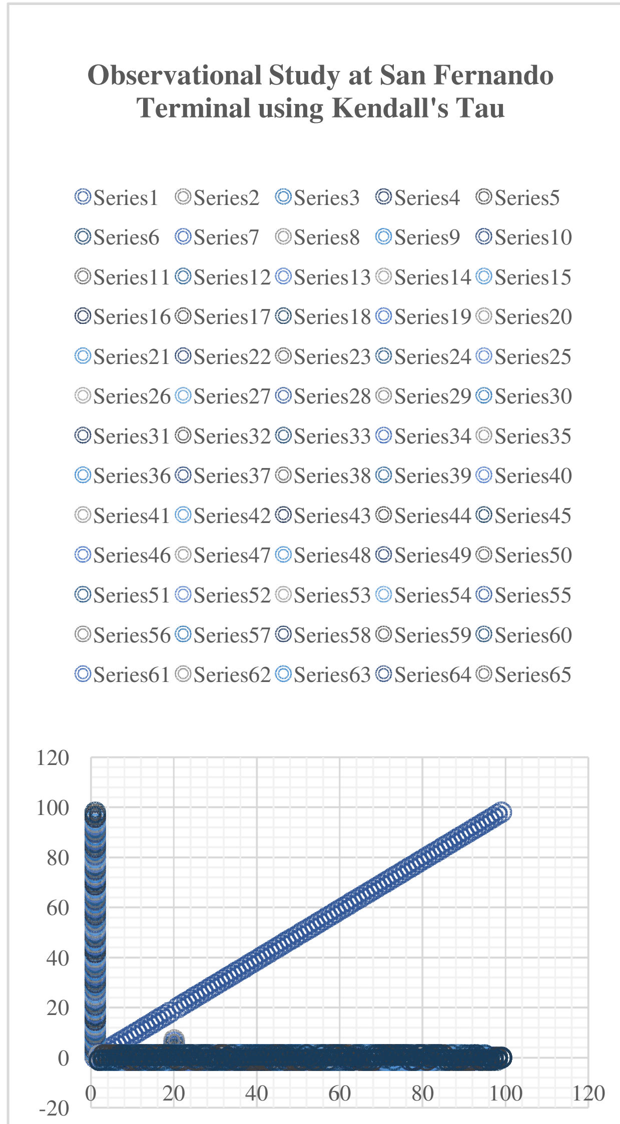


Figure 10. Observational Study at San Fernando Terminal using Kendall's Tau

The graph highlights the importance of the bus arrival time delay as a contributing factor to crowding, providing strong evidence from an observational study at the San Fernando terminal. The analysis of 98 observations, or 4476 pairs, provided insight into the correlation between these variables.

Kendall's Tau coefficient had a low value of 0.16, which indicates a positive correlation between crowding and bus punctuality.

Furthermore, the corresponding p-value of 0.02797629 and the z-statistic of 2.197618696 indicate a statistically significant relationship. This means the crowds increase as the buses' arrival time is delayed.

This highlights the importance of developing policies to improve bus schedules and reduce delays, which will improve overall terminal efficiency and experience.

3.2. Pilot Testing

Pilot testing and manual observation were conducted to assess the readiness and performance of the bus tracking application before deployment. This testing underwent alpha and beta testing phases to evaluate the features, functionality, and user experience. It also helped the researchers identify and resolve issues regarding the application.

3.2.1.1. Software Professional

The senior developer at Scrubbed Tech Center, Mr. Jason Cleophas, carefully reviewed and tested the bus tracking application. The application's correctness and functionality were assessed, and it was proven to meet the standards and requirements. It was approved for further testing and evaluation.

3.2.1.2. Internal Testing

During the internal testing phase, the researchers evaluated the bus tracker's performance and reliability for accuracy and effectiveness. This phase included a comprehensive assessment of its metrics, arrival time, update frequency, and notification status across bus routes. The data collected during this phase are crucial in determining its accuracy and functionality based on its purpose and user experience.

TABLE 7. PARA PO Bus Tracker Application Performance Metrics and Internal Testing Performance Summary

BUS 1

Checkpoint	ETA	Actual	Discrepancy	No. of Updates	Initial Notification	Final Notification
CP1	10:34	10:35	1 second	2	Yes	Yes
CP2	10:50	10:51	1 second	3	Yes	Yes
CP3	11:04	11:04	0	4	Yes	Yes
CP4	11:23	11:23	0	5	Yes	Yes
	Average:		0.5 second	3.5 ≈ 4	Yes	Yes

BUS 2

Checkpoint	ETA	Actual	Discrepancy	No. of Updates	Initial Notification	Final Notification
CP1	11:07	11:10	3 seconds	5	Yes	Yes
CP2	11:33	11:33	0	3	Yes	Yes
CP3	11:41	11:41	0	5	Yes	Yes
CP4	11:56	11:56	0	5	Yes	Yes
	Average:		0.75 second	4.5 ≈ 5	Yes	Yes

BUS 3

Checkpoint	ETA	Actual	Discrepancy	No. of Updates	Initial Notification	Final Notification
CP1	12:46	12:46	0	3	Yes	Yes
CP2	12:58	12:59	0	2	Yes	Yes
CP3	13:09	13:08	1 second	7	Yes	Yes
CP4	13:20	13:20	0	2	Yes	Yes
	Average:		0.25 second	3.5 ≈ 4	Yes	Yes

	Overall:		1.5 seconds	4.3 ≈ 4 to 5	Yes	Yes

The tables show the average deviation by which each bus arrives at its designated stop or checkpoint. Tire #1 had an error of 0.50 seconds, Tire #2 had an error of 0.75 seconds, and Tire #3 had an error of 0.25 seconds. The total average arrival discrepancy for the three buses was 1.5 seconds. This data shows the difference between each bus's actual and scheduled arrival time.

The table also shows the average number of updates each bus performance received per trip. Bus #1 received about 4 updates, Bus #2 received about 5 updates, and Bus #3 received about four updates. On average, each bus trip received 4 or 5 updates. These updates show how often the bus tracking app notifies the system of the bus location.

The departure and end notification status of each bus is also displayed. The first and final notices were issued on Bus Nos. 1, 2, and 3, which shows that the buses were successful in informing the system of their arrival and departure times.

These data came from internal testing that the researchers did to assess the accuracy and dependability of the bus tracker application before distributing it to commuters for trial after a software expert had validated the application. The bus tracker app seems accurate and dependable based on the data gathered, with few variations in arrival times and regular notification updates from every bus. As such, it is considered prepared for distribution to commuters for additional testing and input. The regularity of updates reinforces the decision, the uniformity of arrival time data, and the effective dissemination of notifications by every bus.

3.2.2. Beta Testing

The researchers conducted beta testing to refine the PARA PO bus tracker application, especially the delays and overcrowding features. The testing phase also helped improve the application's aesthetics, making it user-friendly.

3.2.2.1. Paired t-Test Comparisons in Analyzing Bus Tracker Application Impact on Commuters' Time Metrics

TABLE 8
TIME EXPECTED TO BE ON BOARD

Pairs		Mean	N	Standard Deviation	Standard Deviation Error Mean	T	df	P-Value
Time Expected to be on Board	Before	1287.80	25	415.065	83.013	2.749	24	.001
	After	1279.88	25	413.330	82.666			

TABLE 8. Comparison of Estimated Time of Arrival Before and After Application Usage Among Commuters

TABLE 8
TIME EXPECTED TO BE ON BOARD

Pairs		Mean	N	Standard Deviation	Standard Deviation Error Mean	T	df	P-Value
Time Expected to be on Board	Before	1287.80	25	415.065	83.013	2.749	24	.001
	After	1279.88	25	413.330	82.666			

The table illustrates the paired-sample t-test result of the survey questionnaire for the respondents. The results showed a reduction in the expected time before using the application (M = 1287.80, SD = 415.065) compared to after using it (M = 1242.72, SD = 413.330). This proves that the estimated arrival time from the application is less than the expected time for commuters to be on board. Additionally, a value of t (24) = 2.749, p = 0.011 < 0.05 indicates a significant difference in expected time on board before and after using the application.

TABLE 9. Comparison of Departure Times Before and After Application Usage Among Commuters

TABLE 9
TIME LEAVING THEIR PLACES

Pairs		Mean	N	Standard Deviation	Standard Deviation Error Mean	T	df	P-Value
Time Leaving Their Places	Before	1213.80	25	419.281	83.856	-6.727	24	0.000
	After	1242.72	25	418.676	83.735			

For the second question in the survey, the researchers investigate the departure time of commuters from their locations to their usual pick-up points. Results indicated a significant increase in time spent leaving their places, shifting from before app usage (M = 1213.80, SD = 419.281) to (M = 1279.88, SD = 418.676) afterward. The t-test yielded a statistic of t (24) = -6.727, with a p-value of 0.000, indicating significance below the 0.05 threshold. This suggests a notable difference in the time people leave their places before and after using the application, with users leaving later after using PARA PO.

TABLE 10. Pre- and Post-Implementation Comparison on the Effect of App Usage on Commuters Arrival Times at Bus Stops

TABLE 10
ARRIVAL TIME AT THE BUS STOP

Pairs		Mean	N	Standard Deviation	Standard Deviation Error Mean	T	df	P-Value
Arrival Time at the Bus Stop	Before	1655.04	25	2018.954	403.791	0.957	24	0.348
	After	1242.72	25	418.676	83.735			

The third part of the survey questionnaire, focusing on commuters' arrival time at bus stops, revealed no significant decrease in arrival time from before (M = 1655.04 minutes, SD = 2018.954) to after (M = 1271.96 minutes, SD = 416.109) using the app (t(24) = .957, p = .348, one-tailed). This suggests that the application usage did not lead to a statistically significant change in commuters' arrival time.

TABLE 11. Pre- and Post-Implementation Comparison on the Effect of App Usage on Bus Waiting Times at Bus Stops

TABLE 11
WAITING TIME AT THE BUS STOP

Pairs		Mean	N	Standard Deviation	Standard Deviation Error Mean	T	df	P-Value
Waiting Time at the Bus Stop	Before	22.96	25	7.328	1.466	13.177	24	0.000
	After	6.28	25	3.600	0.720			

Moreover, the analysis yielded a significant difference in waiting times at the bus stop before and after using the application $t(24) = 13.177$, $p < .001$ (two-tailed). This indicates that the waiting time at the bus stop significantly decreased after using the app. Specifically, the mean waiting time before using the app was $M = 22.96$ minutes ($SD = 7.328$), whereas after using the app, the mean waiting time decreased to $M = 6.28$ minutes ($SD = 3.6$).

3.2.2.2. Mean Analysis of PARA PO Bus Tracker Application Assessments

TABLE 12. User Interface Assessment with PARA PO Bus Tracker Application

TABLE 12
USER INTERFACE

Item	Frequency				Mean	Standard Deviation	Interpretation
	SD	D	A	SA			
User Interface							
1. Easy navigation	0	0	0	25	4.00	0.000	Strongly Agree
2. Appealing colors and design	0	0	3	22	3.88	0.332	Strongly Agree
3. Quick loading and response	0	0	8	17	3.68	0.476	Strongly Agree
4. Satisfactory overall UI	0	0	2	23	3.92	0.277	Strongly Agree
Overall					3.87	0.163	Strongly Agree

The table shows an assessment of the User Interface, where the navigation through different features received a frequency of 25 for "Strongly Agree," with a mean of 4.00 and a standard deviation of 0.000, interpreted as "Strongly Agree." Regarding the visual appeal, 22 users strongly agreed, while 3 agreed, resulting in a mean of 3.88 and a standard deviation of 0.332, also interpreted as "Strongly Agree." Additionally, the application's loading speed was positively rated, with 17 users strongly agreeing and 8 agreeing, leading to a mean of 3.88 and a standard deviation of 0.476, interpreted as "Strongly Agree." In terms of overall satisfaction with the user interface, 23 users strongly agreed, and 2 agreed, yielding a mean of 3.92 and a standard deviation of 0.277, interpreted as "Strongly Agree." The final overall mean for the user interface category was 3.87, with a low standard deviation of 0.163, leading to the interpretation of strongly agreeing with the satisfactory nature of the interface.

TABLE 13. Accuracy of Information Assessment with PARA PO Bus Tracker Application

TABLE 13
ACCURACY OF INFORMATION

Item	Frequency				Mean	Standard Deviation	Interpretation
	SD	D	A	SA			
Accuracy of Information							
1. Accurate bus locations	0	0	2	23	3.92	0.277	Strongly Agree
2. Reliable arrival times	0	0	8	17	3.68	0.476	Strongly Agree
3. Timely notification updates	0	0	6	19	3.76	0.436	Strongly Agree
Overall					3.79	0.317	Strongly Agree

The table depicts the findings within the context of the Accuracy of Information, where users indicated high satisfaction with the bus tracker application's performance. For displaying the current location of buses, 23 users strongly agreed, and 2 agreed, resulting in a mean of 3.92 and a standard deviation of 0.277, interpreted as "Strongly Agree." Regarding the reliability of estimated arrival times, 17 users strongly agreed, and 8 agreed, with a mean of 3.68 and a standard deviation of 0.476, also interpreted as "Strongly Agree." Furthermore, 19 users strongly agreed, and 6 agreed for timely notification updates on bus routes, leading to a mean of 3.76 and a standard deviation of 0.436, interpreted as "Strongly Agree." Overall, the category received a mean rating of 3.79 with a standard deviation of 0.317, indicating a strong consensus of satisfaction with the accuracy of information provided by the bus tracker application.

TABLE 14. Commuters' Experience Assessment with PARA PO Bus Tracker Application

TABLE 14
COMMUTERS' EXPERIENCE

Item	Frequency				Mean	Standard Deviation	Interpretation
	SD	D	A	SA			
Commuters' Experience							
1. Effective journey planning	0	0	1	24	3.96	0.200	Strongly Agree
2. On-time bus catches	0	0	0	25	4.00	0.000	Strongly Agree
3. Improved bus service experience	0	0	0	25	4.00	0.000	Strongly Agree
4. Enhanced bus schedule awareness	0	0	0	25	4.00	0.000	Strongly Agree
Overall					3.99	0.050	Strongly Agree

In addition, all 25 users strongly agreed that they could navigate the bus on time with the application. This resulted in a mean of 4.00 and a standard deviation 0.000, defined as "strongly agree." Alternatively, the majority of the respondents (25) strongly agreed that the use of bus service and their overall experience in the field has increased, and their knowledge of policies and procedures has increased. This resulted in a mean of 4.00 for both items and a standard deviation of 0.0000 for both items, defined as "strongly agree."

IV. SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of Findings

The study was conducted through observation and surveying, which were divided into two (2) parts. The first part of the study was manual testing, which analyzed the correlation between passenger crowding levels and bus punctuality using statistical tests like the Chi-squared and Kendall's Tau, yielding insights into terminal efficiency and service quality. In contrast, the second part was the pilot-testing of the PARA PO bus tracker application to evaluate its readiness, functionality, and user interactions, ensuring it meets desired standards, identifies and addresses issues, and minimizes risks associated with deployment, ultimately enhancing transportation efficiency and commuter satisfaction.

In the initial part, the proponents oversaw the manual observation of 189 buses at Olongapo and San Fernando Terminals over seven days. The findings revealed significant insights into the relationship between crowding levels and bus punctuality. Through statistical analyses, including the Chi-squared test and Kendall's Tau, researchers identified a clear association between time delays and crowding levels at both terminals. The Chi-squared test results unequivocally rejected the null hypothesis, with p-values practically close to zero, affirming a substantial link between time delays and crowding. Moreover, Kendall's Tau coefficients further supported this association, demonstrating a positive correlation between bus arrival delays and terminal congestion. These findings underscore the importance of addressing bus punctuality to alleviate crowding issues, highlighting the need to enhance scheduling efficiency and improve overall service quality at the terminals.

Meanwhile, pilot testing of the PARA PO application was conducted in the latter part of the study. The pilot testing phase of the aforementioned bus tracker application, encompassing alpha and beta testing, provided comprehensive insights into its readiness and effectiveness prior to full-scale deployment.

During alpha testing, validation of the PARA PO application was conducted by a single software professional, who confirmed the application's functionality and accuracy, with minimal discrepancies in arrival times and consistent notification updates from all buses. Internal testing involves the evaluation of the bus tracker application's performance and reliability at checkpoints using three buses to test its readiness, revealing promising metrics such as arrival discrepancy, update frequency, and notification status, indicating a high level of reliability.

For beta testing, 25 participants were enlisted to test the application on the commuters' interface, and eight buses were allocated for the bus drivers' interface. This phase delved deeper into the application's impact on commuters, showcasing notable improvements in time management and overall satisfaction. Paired t-test comparisons revealed a significant reduction in expected time on board and waiting time at bus stops after using the application. The mean analysis of user assessments highlighted strong agreement with the user interface, accuracy of information provided, and positive experiences with journey planning and catching buses on time.

These findings collectively indicate the bus tracker application's readiness for wider dissemination and real-world use, demonstrating its potential to enhance transportation efficiency and commuter satisfaction in transportation engineering.

4.2 Conclusion

Transportation engineering is one of the many sectors that improve a community's mobility and involves applying technology to the traffic flow system. A well-constructed transport system for both the public and private sectors helps the community become more sustainable and livable. However, due to the evolving civilization, transportation demands and problems surge. Traffic flow becomes denser due to the overuse of private vehicles and the lack of public transportation utilization. Subsequently, despite its significance and reoccurring problems, transportation management still lacks improvement and technological advancement, specifically in public transportation. The presented research offers an in-depth understanding of the application of technological advancement to public bus transportation and how it improves its reliability for civilization. Specifically, enhancing bus on-time performance and understanding its correlation to crowding levels.

There is enough evidence to support the claim that there is a significant correlation between bus on-time performance and crowding levels at bus terminals. Since both variables were found to be directly proportional, poor bus punctuality could be one of the sources of crowding. Using an application to produce an accurate estimated arrival time for buses helps commuters decrease their waiting time at bus terminals and bus stops. Additionally, less waiting time and accurate schedules could lead to lower crowding levels at bus terminals.

The result of this research will serve as a platform for systematic improvement in bus transportation management. Transportation engineers and bus companies may utilize the findings to enhance bus service reliability and punctuality. This can lead to the development of an organized platform for structured communication between commuters and bus servers. Researchers may make use of the data to identify further issues and focal areas in transportation engineering management.

4.3 Recommendation

Given the results of the study, the following are the recommendations of the researchers for the study:

1. Integrating the study's insights regarding the correlation between passenger crowding and bus punctuality into transportation policy development at both local and regional levels, aiming to improve scheduling efficiency and service quality to alleviate congestion and enhance commuter satisfaction;
2. Continuous monitoring and analysis of bus punctuality and crowding levels due to the dynamic nature of transportation systems, emphasizing regular assessments to identify emerging trends and issues, enabling timely interventions and adjustments in service delivery;
3. Collaboration between transportation engineers, bus companies, and local authorities, highlighting joint initiatives to develop coordinated strategies addressing reliability and punctuality issues in bus transportation and to explore additional factors influencing transportation efficiency and commuter satisfaction; and
4. Launching promotional campaigns to increase awareness and encourage adoption of the bus tracker application among commuters, highlighting the benefits such as reduced waiting times and improved journey planning through marketing efforts.

Given the results of the study, the following are the recommendations of the researchers for the further development of the Bus Tracker Application:

1. Broaden the application's functionality, we include wide coverage of bus routes, pick-up points, and bus terminals.
2. Connect with local transportation authorities or private bus affiliations to further improve and strengthen the security and safety of commuters while using the application.
3. Apply additional features such as seat reservation. User log-in, live traffic updates, live traffic updates, list of routes and schedules, and cash integration system.
4. Further testing of the PARA PO application before launching it to a wider audience to ensure that all its functionalities are properly working;
5. Emphasize the necessity of ongoing testing and refinement of the bus tracker application to ensure sustained performance and user satisfaction, suggesting regular updates based on user feedback and technological advancements;
6. Enhance the accessibility and user experience of the application for individuals with diverse needs, including those with disabilities and limited technological literacy, through intuitive design and clear instructions to attract a wider user base; and
7. Integration of the bus tracker application with existing transit systems and

infrastructure to provide comprehensive transportation solutions.

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