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Enhancing Commuter Accessibility in Tacloban's University Belt, Philippines

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Abstract. Public transportation is critical in supporting urban mobility, providing economic benefits, and reducing environmental impacts. However, Tacloban City, particularly its University Belt Area, faces significant transportation challenges, including traffic congestion, inadequate infrastructure, and accessibility disparities among transit stops. While many studies broadly explore urban transportation systems, this research distinguishes itself by addressing accessibility within a localized context, combining commuter perceptions with traditional metrics. By focusing on Tacloban City's University Belt Area, this study fills a gap in understanding transit accessibility in densely populated, commuter-reliant urban areas. This research evaluates six transit stops—TS-1 (LNU), TS-2 (LNHS), TS-3 (EVSU), TS-4 (Card Bank), TS-5 (LBC), and TS-6 (LVD)—through data collection from 599 respondents and 10 days of traffic volume counts. Using Geographic Information System (GIS) heatmaps and statistical tools like Spearman's Correlation, ANOVA-Kruskal Wallis, and Dunn's Test, the study identifies patterns and variations in accessibility during peak and off-peak hours. Findings reveal that 83% of commuters experience waiting times of 10–20 minutes during peak hours at underperforming stops like TS-5, compared to 5–10 minutes at high-performing stops like TS-2 and TS-3. Additionally, 60% of TS-5 users report travel times exceeding 5 minutes, unlike other stops where travel times are predominantly within 0–5 minutes. Recommendations include increasing public transport availability, optimizing schedules, and enhancing pedestrian pathways and transit facilities. The findings provide actionable insights for policymakers to prioritize investments and design equitable urban transportation solutions, contributing to a more sustainable and accessible transportation system for Tacloban City and serving as a framework for addressing similar challenges in other urban areas.

Keywords: Accessibility; Traffic congestion; Transportation ecosystem; University belt area; Tacloban City.

1.0 Introduction

Public transportation is crucial to society's infrastructure, providing financial benefits, making travel more straightforward, and boosting opportunities and property value. It also contributes to reducing air pollution, easing traffic congestion, and supporting job opportunities. These modes of transportation, such as trains and buses, follow set routes and fares and are essential in urban areas where private cars are heavily relied upon prices (Dmitry Ryabchikov et al, 2022). Public transportation plays a critical role in addressing societal challenges and decreasing dependence on individual vehicles (Dušan Teodorović & Janić, 2022).

Despite its importance, personal transportation's substantial contribution, especially private cars' use to greenhouse gas emissions, tends to be consistently disregarded (Gače et al., 2023). Residents in densely populated urban areas keenly feel the negative consequences of vehicle emissions. As technological advancements rapidly progress alongside a growing middle class, the ownership of cars is expected to rise. This increasing trend in car ownership poses an elevated threat of environmental pollution (Li et al., 2022). Consequently, public transportation becomes progressively vital in addressing and mitigating the environmental consequences associated with individual vehicle usage.

The public transportation sector in the Philippines encompasses a wide range of vehicles, including traditional bicycles, tricycles, modern buses, and taxis. In addition to playing a crucial role in daily mobility, this transportation mode is a significant economic pillar for rural inhabitants (Asael, 2023). Commuters benefit from public transportation as it provides a convenient and cost-effective means to reach destinations more quickly than private vehicles, contributing to the reduction of environmental damage caused by private car use (Zimmermann et al., 2023). However, this positive perception does not universally apply to Metro Manila, where many Filipinos view public transportation negatively (Chelcie & Kardi, 2016).

The entire Philippine public transport system faces challenges characterized by outdated equipment, insufficient financial security for operators, and a lack of a proper structure to support ongoing development and modernization (M2.0 Communications Inc., 2022). Using private vehicles provides a level of comfort and privacy that public transportation cannot replicate. Individuals in control can regulate cleanliness, temperature, and music choices within their vehicles, resulting in a travel experience customized to individual preferences. Furthermore, private transportation is commonly perceived as a safer alternative, especially during late hours or in areas with questionable security conditions (Vista Residences, 2023).

In 2022, approximately 1.27 million private cars were registered in the Philippines. The number of registered private cars in the country gradually increased year-on-year from 2020 (Statista Research Department, 2023). Additionally, 77 percent of the population opts for private vehicles (Freeman, 2016). This preference is fueled by poorly maintained highways, inadequate road infrastructure, and the lack of efficient public transportation options, resulting in higher travel time, vehicle operation costs, and overall reduced accessibility within the city (Montemor et al., 2023).

However, the seemingly attractive attributes of private transportation, including autonomy and convenience, come at a significant cost, as highlighted by Limos (2022). Corresponding to this statement, Alamri et al. (2023) stated that inadequate public transportation can also result in several problems, including parking challenges and lengthier commute times. It can also have a negative social impact, isolating individuals, especially the elderly, the disabled, and non-drivers. The expenses associated with fuel, maintenance, insurance, and parking fees contribute to the financial burden of private vehicle ownership (Limos, 2022). Moreover, the surge in private vehicles exacerbates traffic congestion, causing delays and environmental concerns.

Moreover, Tacloban City is one of the places affected by land transportation disadvantages. According to the 2023 Census, the city has a population density of about 261,642, making it the most populous city in Eastern Visayas. It is also visited vastly as it is the busiest and most progressive city in Region 8. The city's population triples during business hours due to the influx of residents from nearby Leyte and Samar municipalities who are available for the city's utilities and services. Demand for transients has steadily increased because of its central location for business, education, health, and leisure activities (City Government of Tacloban, 2019). This situation is particularly noticeable in the Tacloban University Belt Area (TUBA), which accommodates many structures and services. Consequently, transportation accessibility within the TUBA is strained as the existing public vehicles struggle to meet the high demand, especially during peak hours when the influx and departure of students and workers in the University Belt Area intensifies.

Literature on accessibility, especially in urban transportation systems, has been extensive. Sharaf Alkheder et al. (2021) and Tong et al. (2015) highlight data-driven approaches and spatial analysis as the basis for understanding accessibility. The quantitative approaches employed by both studies to assess accessibility through tools such as spatial interaction models and network analysis underpin their results. This study, however, takes a different approach as it is local-scale user perception added by qualitative methods inspired by the work of Cheng and Chen (2015). Through a structured combination of quantitative and qualitative methods, the researchers hope to offer a less partial overview of how accessibility is experienced, both as a collection of objective metrics and as a group of subjective perceptions. Furthermore, inspiration was drawn from Albacete et al. (2015) in using multiple accessibility metrics to provide a more comprehensive assessment. Their study stresses the need to consider specific requirements regarding travel time, distance, or transfer frequency when assessing accessibility. Albacete et al. (2015) compared two accessibility measurement techniques, SAL and PTWAI, in Helsinki. Access to various urban facilities, including education, healthcare, shopping, and the like, was used similarly in both methods. According to the study, PTWAI had a more detailed and nuanced understanding of accessibility, whereas SAL had a more general perspective. SAL typically overestimated accessibility while PTWAI gave a milder evaluation. This study contributes to the literature on accessibility by bringing together these three elements, which we hope will provide valuable insights for local policymakers and urban planners.

The importance of evaluating accessibility in urban transportation through a Geographic Information System based analysis in the Tacloban University Belt area includes addressing several key issues and contributing to the enhanced quality of urban mobility and planning. This study will be helpful for students, commuters, local business owners, policymakers, and the entire community. Better access to educational facilities will help students and teachers, which may facilitate increased enrolment, improved attendance, and a more conducive learning environment. This study may help the commuters as it provides information on the public transport accessibility within the Tacloban City University Belt area, which may lead to improved transportation facilities, lesser travel time, and overall convenience of everyday transportation. Accessible transportation will enhance consumer flow and encourage frequent visits to local businesses and shops. This can lead to better sales and revenue for these companies. Moreover, the research could offer valuable data and correspondence to city planners and policymakers to help make better urban transport infrastructure and regulation choices. The study's outcome will allow the community to approach local authorities and demand that their transport needs be integrated into their services.

2.0 Methodology

2.1 Research Design

This study used the quantitative research method design to assess and analyze urban transportation in the Tacloban City University Belt Area. It used Slovin's formula to identify the number of respondents and stratified random sampling to ensure representation from different user groups and demographic backgrounds.

2.2 Research Locale

This study was conducted in Tacloban City, a heavily urbanized coastal region in the Eastern Visayas, particularly in the University Belt Area of the city. Six distinct areas comprise the University Belt Area: a section of Ninoy Aquino Avenue, Paterno Street, Athletic Road, Salazar Street, Sta. Cruz Street and Avenida Veteranos Street, then classified six (6) transit stops at TS-1 (LNU), TS-2 (LNHS), TS-3 (EVSU), TS-4 (Card Bank), TS-5 (LBC), and TS-6 (LVD).

2.3 Research Participants

Stratified random sampling was considered for data collection. Assuming the population to be normally distributed, Slovin's Formula, given by Almeda, Capistrano, and Sarte (2010), was used to determine the sample size. According to Stephanie Ellen (2020), Slovin's Formula enables a researcher to select a sample from the population while maintaining a specified level of accuracy. It guides the researcher regarding the necessary sample size to achieve satisfactory precision in the results. The equation determined a minimum sample size of 600 participants across all study zones. A total of 600 individuals, evenly distributed among the zones, completed an eleven-page questionnaire. After rigorous data cleaning, including removing incomplete responses and those lacking crucial data, 599 usable questionnaires were retained from each of the six transit stops for subsequent analysis.

The respondents of this study were students, faculties, office workers, and residents within a buffer of a 50m radius from the transit stops within the Tacloban City University Belt Area. The demographic profile of the respondents was categorized according to their residency and/or workplace location near the transit stops.

Respondents were selected by the researchers based on their likelihood to provide relevant and valuable information and meet the researchers' criteria, including students, employed individuals, and commuters in the University Belt Area.

2.4 Research Instrument

This study examines transportation accessibility in the Tacloban City University Belt Area through structured questionnaires and GIS-based analysis. The questionnaire focuses mainly on the dynamics of transportation accessibility, specifically on the timestamp during weekdays, considering peak and off-peak hours, waiting time, and travel time to the transit system. It is divided into six parts: demographic information, regularly used mode of transportation, available mode of transportation, waiting time, travel time to transit stop, and multimodal commuter experience, including their overall experience during the daily commute, traffic congestion, parking, limited public transportation options, and safety concerns. Data regarding the transportation ecosystem—mode of transportation—was obtained from a traffic count survey. Utilizing Geographic Information System (GIS) technology, the research aims to create heatmap analyses to visualize spatial patterns of transportation demand and identify areas with varying levels of accessibility. Ultimately, the study sought to suggest a transportation accessibility strategy in the Tacloban City University Belt Area based on the collected data and GIS insights.

2.5 Data Gathering Procedure

Data Collection

The researchers drafted a letter of authorization to collect CCTV footage from different barangays to count the traffic volume of all vehicles passing through a specific intersection every 30 minutes using the classified traffic volume count survey from the Department of Transportation - Philippines. Traffic volume was measured using vehicles per hour (veh/hr) or vehicles per day (vpd), which comprises the transportation ecosystem data and, eventually, obtain the peak and off-peak hours based on the time interval with the highest number of vehicles. The researchers conducted a Ten (10) day traffic Count trial between 6 AM and 7 PM from the selected intersections.

Data collection was conducted through the administration of a questionnaire. This involved developing a structured set of questions to gather information regarding transportation options, waiting periods, travel times to transit stops, demographics, etc. Researchers visited schools and offices to distribute these questionnaires. Before administering the questionnaire, respondents were provided with a brief explanation of the study's objectives and the purpose of each question. They were then instructed to complete the questionnaire to the best of their knowledge. The data collected from participants' responses to this questionnaire will be used for further analysis.

Accessibility Score Assignment

This phase used the "waiting time and travel time to transit stops" data and the proximity of respondents to the nearest transit stop where they board a vehicle obtained from the survey. These data were added to identify the accessibility score (see Table 1) for each transit stop (Albacete et al., 2015).

Table 1. *Accessibility Score Assignment*

Accessibility Score	Travel time to Transit Stop and Waiting time (minutes)
0	>60
1	40-60
2	20-40
3	10-20
4	0-10

Heatmap Analysis

The intensity of accessibility within each transit in the university belt area is visualized using a heatmap analysis using the Quantum Geographic Information System (QGIS) to construct a transportation accessibility management strategy. Based on the amount of time spent waiting and traveling to the transit stops, the researchers employed the accessibility score. A heatmap analysis requires several steps to be taken. This entails obtaining the coordinates of every transit stop to generate a shapefile, adjusting the color ramp based on accessibility, as shown in Table 2, and defining a buffer to restrict the analysis radius inside the transit stop.

Table 2. *Color Ramp for Heatmap*

Color Code	Accessibility Score	Description
	0	Very low accessibility
	1	Low accessibility
	2	Medium accessibility
	3	High accessibility
	4	Very high accessibility

2.6 Data Analysis

Spearman's correlation was used to correlate the accessibility score and transportation ecosystem data. The researchers correlated the accessibility score to the number of vehicles, the accessibility score to the number of transportation infrastructure, and the accessibility score to the cost of transportation. The researchers also used ANOVA-Kruskal Wallis and Dunn's Test to compare the accessibility scores of each transit stop. The findings of this correlation were used to identify the gap in transportation ecosystem data regarding accessibility score per transit stop.

2.7 Ethical Considerations

For ethical reasons, the researchers sought participants' permission, the interviewees were recorded through an audio recorder to capture the data precisely. Moreover, the researchers understand that such information shall remain classified. Hence, the gathered data must be kept confidential between the researchers and other involved parties and must remain anonymous for their safety, which is by the Data Privacy Act of 2012 and its implementing Rules and Regulations (IRR) effective 2012, and other pre-existing laws, all personal information provided were used accordingly and exclusively and remained strictly for research purposes only. Hence, the gathered data must be kept confidential between the researchers and other involved parties and remain anonymous for their safety.

3.0 Results and Discussion

3.1 Transportation Ecosystem Data- Traffic Count Volume

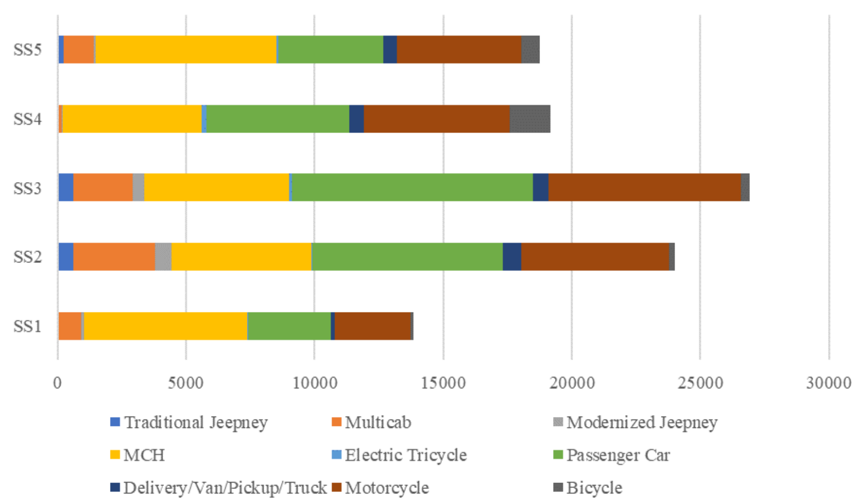

Figure 1. *Average Traffic Volume Based on the Type of Vehicle in Different Intersections*

An analysis of traffic data across five intersections within the Tacloban City University Belt Area, shown in Figure 1, reveals several key insights regarding vehicle types and their contribution to congestion. The study highlights the dominance of private vehicles, particularly passenger cars and motorcycles. The low volume of traditional jeepneys, modern jeepneys, and utility vehicles (UV) Express suggests that these modes of public transport may be limited or even absent in the area, potentially contributing to the reliance on private vehicles and MCHs. These findings align with Limos' study (2022), highlighting the negative consequences of private vehicle use, such as increased congestion, delays, and environmental concerns. Further investigation into public transport availability and optimization strategies could mitigate traffic issues and promote sustainable commuting practices within the Tacloban City University Belt Area.

Table 3 shows the intersection throughput during morning and afternoon peak hours and off-peak hours. Overall, traffic volume is highest during the morning peak period (7 AM-9NN) and afternoon peak period (4:00 PM - 6:00 PM) across all intersections, which aligns with the beginning and end of the workday for many, leading to a higher concentration of commuters going to work and traveling home. Traffic patterns are influenced by factors such as work schedules and weekend effects (Mohammed et al., 2023). Thus, understanding these patterns is crucial for traffic management and intersection design, as they impact road capacity and congestion levels.

Table 3. *Intersection Throughput (Morning and Afternoon Peak Hours, Off-Peak Hours)*

Description	AM Peak (time)	PM Peak (time)	AM Off-Peak (Time)	PM Off-Peak (Time)
Sta. Cruz – Salazar Street	1,284 (8-9 AM)	1,319 (5– 6 PM)	535 (6-7AM)	1071 6PM-7PM)
Salazar – Avenida Veteranos	2,192 (7AM– 8AM)	2,418 (4– 5 PM)	1176 (6-7AM)	1996 (12NN-1PM)
Avenida Veteranos – Paterno Street	2,410 (7AM – 8AM)	2,516 (4 –5 PM)	1020 (6-7AM)	2266 (1-2PM)
Paterno Street – Sta. Cruz	1,600 (8 - 9AM)	1,925 (4– 5 PM)	104 (6-7AM)	1497 (6-7PM)
Athletic Road Intersection	1,603 (8– 9 AM)	1,785 (4– 5 PM)	97 (6-7AM)	178 (6-7PM)

3.2 Mode of Transportation

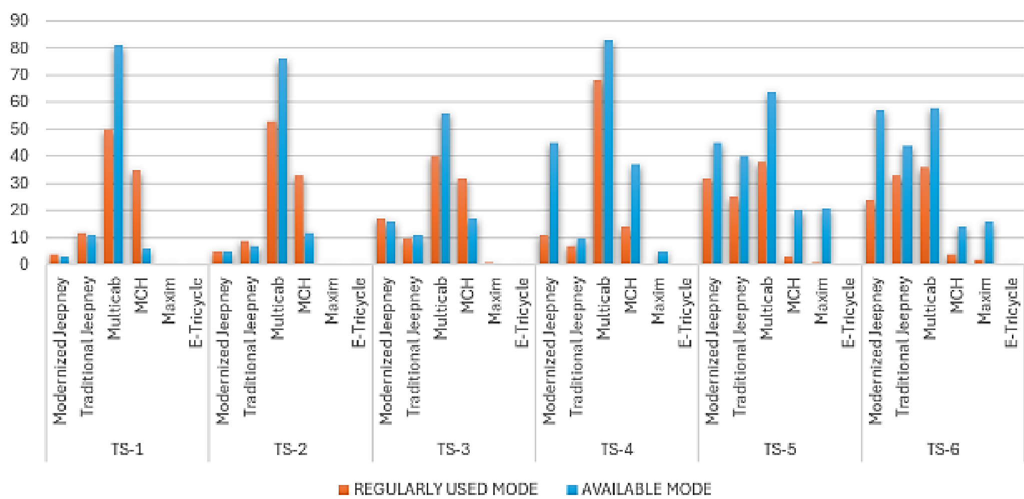

Figure 2. *Distribution of Regular Use Mode vs. Available Mode of Public Transportation per Transit Stop*

A distinct pattern emerges across multiple transit stops (TS-1 to TS-6), elaborated by the commuters' preference in specifying their need for transportation mode about the availability of such public service at various transit stops, as depicted in Figure 2. By their nature, public transportation modes are more available than commonly used at most public transit stops. There are always traditional jeepneys and modernized jeepneys, which are extensively utilized at transit stops TS-3 and TS-5) and serve as the most prospective transit option. At the same time, modes such as multicabs and modernized jeepneys have high availability relative to one another but relatively low usage at specific stops — suggesting the possibility of gaps between why the commuter wants to travel and what is available or what is available and what they choose.

Trends specific to transit stops are also visible. This equilibrium of availability and usage by commuters at TS-1 means that E-Tricycles and Maxim (app-based transportation services) meet commuters' expectations. On the other hand, TS-3 is characterized by its reliance on Traditional Jeepneys, which are available and widely used. As for TS-6, it stands out, with low regular usage for all modes despite being available, potentially indicating a lower demand for commuters or an accessibility issue affecting this stop.

The gap between availability and usage can highlight inefficiencies or potential areas for improvement. Availability of specific transportation modes at a transit stop or station means those modes are available or provided for commuters to use there, and usage can be understood as the actual tendency of commuters to use these modes. In situations where availability considerably outstrips usage (like multi cabs in some locales), it points to underused supply. It potentially presents opportunities for remedies, including better route alignment, more efficient scheduling, and awareness campaigns to increase ridership. By understanding these dynamics, urban planners can better design transport services that match commuter preferences.

3.3 Waiting Time in each Transit Stop

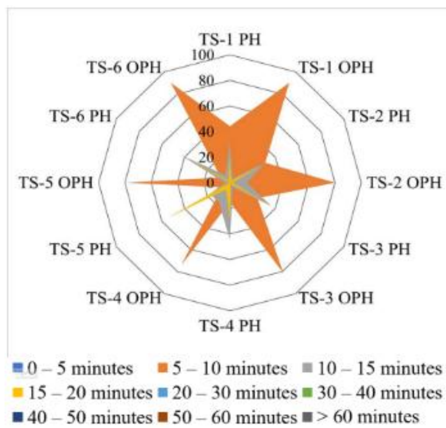

Figure 3. *Respondents' Waiting Time in each Transit Stop*
Note: PH stands for PEAK HOURS, while OPH stands for OFF-PEAK HOURS

The results present considerable differences in waiting times across stops of transit (TS-1 -> TS-6) for peak (PH) versus off-peak hours (OPH) presented and illustrated in Figure 3. Overall, waiting times are lower during off-peak hours, with most respondents indicating 5–10-minute rides as transportation flow is optimized. It usually takes longer at peak hours, about 10–15 minutes. Notable patterns include TS-1, with wait times for peak and off-peak matching between 5–10 minutes, and TS-2 and TS-4, which have mixed waits of 5–10 minutes and 10–15 minutes during peak, but shorter during off-peak. TS-3 is noticeably different, with longer waits (10–15 minutes) during peak hours and shorter waits (5–10 minutes) off-peak.

TS-5 stands out with longer waits (15–20 minutes) during peak hours, while it follows the trend of shorter waits (5–10 minutes) during all off-peak hours. TS-6, like many, follows the familiar pattern of longer peak-hour waits (10–15 minutes) and shorter off-peak waits (5–10 minutes). These results underscore the impact of peak-hour congestion on transit efficiency, and off-peak hours typically provide quicker service. The discrepancies from the expected travel times, especially at TS-5, could indicate localized inefficiencies or elevated demand at specific stops.

3.4 Time Travel to Transit Stop

Based on the data collected, the time needed to travel from each transit station and the far range shows that travel times for most transit stations (TS-1, TS-2, TS-3, TS-4, and TS-6) are in the 0–5-minute range. This trend suggests a well-planned transit system where stops are conveniently located for a significant portion of the population. The exception is TS-5, which experiences a dominant travel time of 5-10 minutes, suggesting either a more dispersed population or a less centralized transit stop location.

The TS-2 and TS-3 stops exhibit extremely low variability, as close to all respondents traveled 0-5 minutes, illustrating their exceptional accessibility. On the other hand, the TS-5 and TS-6 distributions are more spread out, with respondents commuting 10-15 minutes or longer. This indicates an opportunity for optimizing stop placement or other infrastructure to minimize travel times.

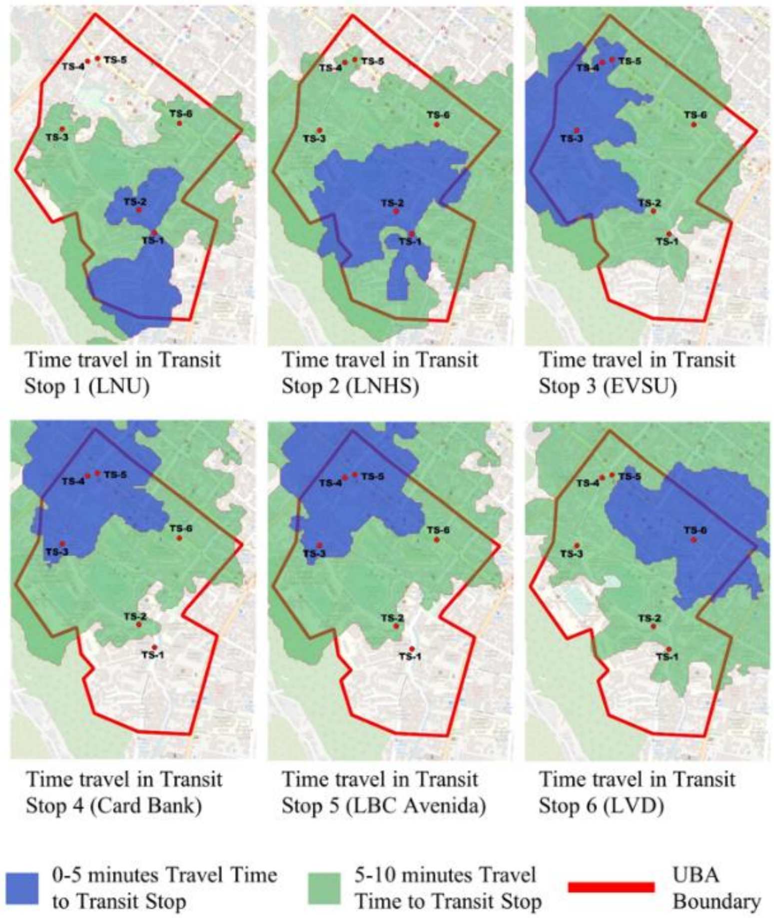

Figure 4. *QGIS-Generated Travel Time to Transit Stop*

The commutes from workplaces/schools are very similar to the ones from residences, supporting the conclusion that transit stops are more or less evenly distributed between residential and job areas. Stops TS-2 and TS-3 are standout examples of this, and their accessibility is experienced equivalently by both groups. Concurrent respondent data corroborated with QGIS modeling (see Figure 4), enhancing the authenticity of the findings. This agreement may indicate that GIS-based data can be a predictor of planning stop locations in the future.

3.5 Multimodal Commuter Experience

The research findings revealed that commuters experience stress daily, with mean scores ranging from 2.21 to 2.59. Stress is attributed to traffic congestion, crowded public transportation, delays, and long commuting times. The standard deviation ranges from 0.624338 to 0.811558, indicating low and high degrees of variability. Research consistently shows that commuting causes stress for workers, with factors like traffic congestion, long commute times, and unpredictability contributing to increased stress levels (Useche et al., 2023; Holland, 2016). The research findings also showed that vehicles are parked in designated spaces within the Tacloban City University Belt Area. Survey respondents agreed and moderately agreed that parking is available and that vehicles are appropriately parked in their areas. The mean scores for "Parking areas are available," "The vehicles are appropriately parked in their parking areas," and "The vehicles are appropriately parked in their parking areas" range from 1.00 to 1.37, indicating more significant variability in responses.

The findings also provided insights into how various areas or transit stops see the affordability, practicality, and ease of use of public transportation. Most respondents agreed or moderately agreed that using public transportation in their localities may satisfy their everyday mobility needs. Though opinions on transportation vary slightly throughout various transit stops, it is also perceived as more straightforward and less expensive. TS-6 shows the highest agreement among all the transit stops, suggesting that locals are more eager to use public transportation. However, the mean score at the TS-3 transportation level is marginally lower, particularly regarding the cost-effectiveness category, suggesting that residents may view using public transportation as slightly less expensive than using alternative locations. Recent studies have explored public transportation perceptions and usage across diverse communities. Watthanaklang et al. (2024) found that service quality, particularly responsiveness, convenience, and safety, significantly impacts perceived accessibility and intention to use public transport in Thailand. Matowicki et al. (2024) emphasize the roles of price and travel time in shaping transport choices throughout four European nations. Examining various elements related to public transportation, these studies highlight the intricate dynamics underlying users' interactions with public transport, indicating that service characteristics, affordability, accessibility, and other aspects significantly impact how people perceive and utilize transit systems.

The study revealed that safety concerns among commuters in the university belt area need improvement. The mean scores for "I have not encountered any obstruction to my destinations" range from 2.11 to 2.96, suggesting that some commuters encountered obstructions. However, the mean scores for "sidewalks are present in the area," "Pedestrian lanes are enough to accommodate the number of pedestrians," "There is a need for traffic signals in the area," and "There is a need for traffic signals in the area" range from 3.30 to 4.38, suggesting that sidewalks are safe, visible, and easy to access. The standard deviation ranges from 0.73 to 1.40, with most statements having a higher standard deviation, indicating more diverse data points. Pedestrian safety and mobility in cities are continually at the forefront of studies. In Ethiopia, this has led to narrow sidewalks or obstructions in sidewalks that forced pedestrians to share the road with vehicles, thus compromising safety (Gebremariam et al. (2024). Likewise, a Malaysian study highlighted the importance of enhancing safety and urban amenities and minimizing obstacles on sidewalks in order to uphold world-class city standards (Rashid et al., (2018). To mitigate these concerns, researchers suggest wider sidewalks to include proper zoning accompanied by in-place mains for utilities, thoughtful placement of light poles and trees, and push-button traffic lights at crosswalks (Gebremariam et al., 2024).

3.6 Heatmap Analysis Based on Accessibility Scores

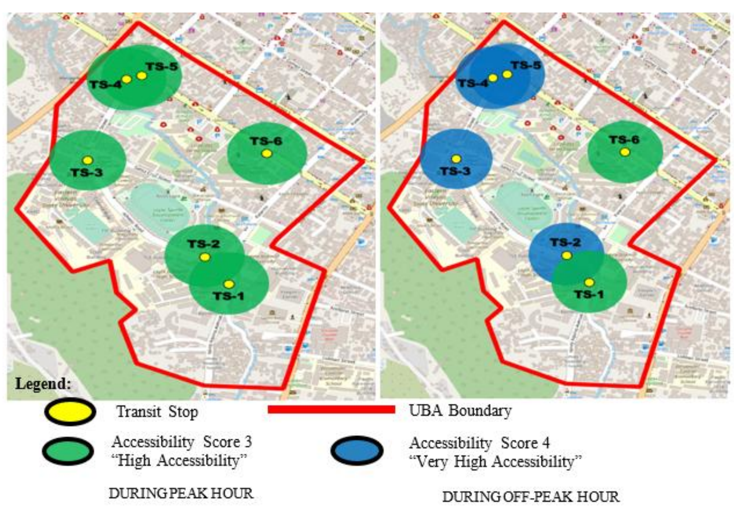

Figure 5. *Heatmap of Accessibility Score in each Transit Stop during Peak Hour vs Off-Peak Hour*

The heatmap analysis of transit stop accessibility (see Figure 5) reveals that the system performs well overall, with high accessibility scores across all stops during peak hours. However, none of the stops reach the "Very High Accessibility" level during these critical times, indicating room for improvement. During off-peak hours, stops such as TS-2, TS-3, and TS-4 excel, achieving very high accessibility scores, while TS-1, TS-5, and TS-6 maintain only high accessibility. This disparity suggests that specific stops benefit from better infrastructure or operational efficiencies while others lag, especially in off-peak scenarios. These findings highlight opportunities for enhancing service quality, infrastructure, and commuter convenience, such as reassessing routes to ensure they serve high-demand areas more effectively, reducing travel distances and time, using real-time passenger data to allocate resources dynamically to stops with higher demand to alleviate accessibility scores of transit Stop Reaching "Very High Accessibility" during peak hours.

To improve and alleviate the underperformance of TS-1, TS-5, and TS-6 during off-peak hours, enhancing pathways, lighting, and signage leading to these stops to encourage usage during less busy hours is encouraged. In maintaining Very High Accessibility at TS-2, TS-3, and TS-4 during off-peak hours, ensure that schedules and service quality are maintained, avoiding cost-cutting measures that could impact these high-performing stops, and market these stops for off-peak activities, such as leisure or errands, to maximize the value of the infrastructure. Additionally, investing in infrastructure upgrades tailored to each stop's unique challenges, such as bus shelters, seating, or digital information boards, enhancing connections between transit stops and other transport modes (e.g., bike racks, ride-sharing hubs) to boost overall accessibility and using real-time data analytics to identify emerging issues and optimize operations accordingly can enhance overall performance, reduce variability among stops, and elevate accessibility scores, particularly during peak hours. Such improvements will foster greater commuter satisfaction and create a more sustainable and efficient urban transit network.

3.7 Correlation Analysis

The findings revealed a weak positive correlation (r = 0.055) between vehicle demand and accessibility scores during peak hours, but not significant (r = - 0.136). This suggests that during peak hours, the demand for vehicles does not meaningfully influence accessibility scores. However, during off-peak hours, there was a weak negative correlation as areas with better accessibility saw slightly less vehicle demand. This implies a competitive relationship between vehicle usage and public transport accessibility, where higher reliance on personal vehicles might detract from public transport efficiency or usage. Moreover, it also showed that there is no significant relationship between peak accessibility scores and parking availability during peak hours, but a weak negative correlation (r = - 0.261) between parking availability and accessibility scores during off-peak hours, indicating that when the availability of parking spaces increases, public transport becomes less accessible.

The study also showed a weak positive correlation between the affordability of fares and accessibility scores during peak hours, which means that as fare affordability increases, public transport becomes more accessible. However, during off-peak hours, there was a weak negative correlation. Here, To make public transport more affordable, accessibility scores may see a slight decline. Research on public transport accessibility and affordability reveals complex relationships between fare policies, infrastructure, and equity. Studies show reduced fares can significantly improve accessibility, particularly for disadvantaged groups like older people and low-income individuals (Vecchio et al., 2022; Silver et al., 2023). However, the correlation between fare affordability and accessibility may vary during peak and off-peak hours. Expanding infrastructure, such as metro networks, tends to benefit middle and high-income groups more than low-income populations (Vecchio et al., 2022).

Moreover, there appeared to be a weakly positive correlation between pedestrian accessibility and accessibility scores during peak and off-peak hours, with increased accessibility corresponding to decreased scores. This suggests a varying relationship, where improved pedestrian access during peak hours slightly benefits overall accessibility, but the opposite occurs during off-peak hours. These results align with and extend existing research on pedestrian accessibility and walkability, shedding light on these relationships' temporal and contextual nuances.

Jardim et al. (2023) highlighted the relationship between walkability indicators and pedestrian flow, suggesting that street conditions and proximity to points of interest influence pedestrian travel patterns. The current findings corroborate this, as improved pedestrian accessibility during peak hours—likely due to higher pedestrian flow and optimized pathways—appears to benefit overall accessibility scores. The findings also resonate with Merlin and Jehle (2023), who call for more detailed pedestrian networks and consideration of individual walking capabilities. Improved pedestrian access during peak hours may cater to a broader demographic, enhancing accessibility for those with varying abilities. However, during off-peak hours, the lack of activity or infrastructure usage may reduce the perceived benefits of pedestrian accessibility.

In conclusion, the findings contribute to the broader understanding of pedestrian accessibility by highlighting its temporal variability. While improvements in walkability can enhance accessibility during peak periods, the off-peak decline underscores the importance of addressing spatial and temporal inequalities in pedestrian infrastructure.

3.8 Comparative Analysis

The post-hoc analysis (Table 4) demonstrates statistically significant differences in accessibility scores among peak and off-peak transit stops, signifying variability in performance across the network. TS-2 became the best-performing stop at peak hours, attributed to better infrastructure or location advantages. At the same time, TS-5 and TS-6 have the lowest accessibility scores, which surface problems like congestion or lack of connectivity. At off-peak hours, differences become more evident between strategies, with TS-2 still outperforming and TS-5 falling further behind. Some stops continue to adapt to changes in commuter demand better than others, while specific stops were found to need improvements to maintain this accessibility over 24 hours. The findings point to the necessity of targeted interventions to improve underperforming stops, including better infrastructure, more frequent service, and enhanced connectivity. High-performing stops such as TS-2 provide insight into replicating successful strategies across the network. Additionally, optimizing transit schedules to accommodate temporal differences in demand can help balance accessibility across all stops.

Table 4. *Comparative Analysis Between Differences in the Accessibility Scores Among Different Transits*

Grp.	Mean Rank	H-value	p-value	Decision	Interp.
		Accessibility Score – Peak			
TS-1	2.96	54.31	< 0.001	Reject the H_0	Significant
TS-2	3.15				
TS-3	2.97				
TS-4	2.70				
TS-5	2.70				
TS-6	2.60				
		Accessibility Score – Off Peak			
TS-1	3.47	96.16	< 0.001	Reject the H_0	Significant
TS-2	3.89				
TS-3	3.61				
TS-4	3.69				
TS-5	3.18				
TS-6	3.34				

**Significant at 0.05 level.*

Dunn's post-hoc test, shown in Table 5, underscores the spatial variability in accessibility during peak hours, with stops like TS-2 and TS-3 outperforming others due to potentially better infrastructure, connectivity, or service frequency. On the other hand, TS-4 and TS-6 are specific stops that need individual attention to make them more accessible. This mismatch between demand and supply would cause popular stops to be overcrowded while low-performing stops remain underutilized, lowering the overall system's efficiency.

Table 5. *Post–Hoc Test on Accessibility During Peak Hours*

Comparison	z	w_i	w_j	p	p_{bonf}
TS-4 – TS-3	-3.49	261	334	< 0.00	0.00
TS-4 – TS-5	-0.50	261	271	0.61	1.00
TS-4 – TS-2	-5.32	261	372	< 0.00	< 0.00
TS-4 – TS-1	-3.12	261	326	0.00	0.02
TS-4 – TS-6	0.80	261	244	0.42	1.00
TS-3 – TS-5	2.99	334	271	0.00	0.04
TS-3 – TS-2	-1.82	334	372	0.06	1.00
TS-3 – TS-1	0.37	334	326	0.70	1.00
TS-3 – TS-6	4.30	334	244	< 0.00	< 0.00
TS-5 – TS-2	-4.81	271	372	< 0.00	< 0.00
TS-5 – TS-1	-2.62	271	326	0.00	0.13
TS-5 – TS-6	1.30	271	244	0.19	1.00
TS-2 – TS-1	2.20	372	326	0.02	0.41
TS-2 – TS-6	6.12	372	244	< 0.00	< 0.00
TS-1 –TS-6	3.93	326	244	< 0.00	0.00

*α = 0.05

Transit authorities must address these issues by improving infrastructure at underperforming stops — investing in better walkways, shelters, and signage. Balancing commuter loads is a complex exercise, as transit schedules need to be optimized to boost the frequency of service at these specific stops at peak hours, and resources need to be reallocated dynamically based on real-time demand data. Also, effective strategies from high-performing stops should be benchmarked and replicated on the network for equitable access. For example, TS-2 significantly differed from TS-6 ($p<0.001$), suggesting that strategic planning is necessary to replicate high-performing stops across the network.

The post-hoc test during off-peak hours (see Table 6) suggests significant variations in accessibility scores between transit stops, echoing some trends evident in the data collected during peak hours while emphasizing distinctive differences. TS-4 was also one of the least accessible stops, having significantly lower accessibility than both TS-5 and TS-1 and TS-6 ($p<0.05$)—this persistent shortfall during peak and off-peak hours, reflects systemic issues, including inadequate infrastructure or limited connectivity. TS-3 is also less accessible than TS-5 and TS-6 ($p\approx0.04$), suggesting reduced accessibility during off-peak hours. TS-2, on the other hand, is much less accessible than TS-6 ($p<0.001$), further demonstrating TS-2's poor appropriateness for off-peak transit availability. The lack of marked difference between TS-4 and TS-5 indicates that, while still suboptimal, these stops have similar (and likely low even) levels of accessibility.

Table 6. *Post–Hoc Test on Accessibility During Off-Peak Hours*

Comparison	z	w_i	w_j	p	p_{bonf}
TS-4 – TS-3	0.38	340	331	0.69	1.00
TS-4 – TS-5	5.72	340	217	<.00	<.00
TS-4 – TS-2	-2.63	340	396	0.00	0.12
TS-4 – TS-1	2.95	340	277	0.00	0.04
TS-4 – TS-6	4.29	340	248	<.00	<.00
TS-3 – TS-5	5.35	331	217	<.00	<.00
TS-3 – TS-2	-3.03	331	396	0.00	0.03
TS-3 – TS-1	2.56	331	277	0.01	0.15
TS-3 – TS-6	3.92	331	248	<.00	0.00
TS-5 – TS-2	-8.37	217	396	<.00	<.00
TS-5 – TS-1	-2.78	217	277	0.00	0.08
TS-5 – TS-6	-1.42	217	248	0.15	1.00
TS-2 – TS-1	5.61	396	277	<.00	<.00
TS-2 – TS-6	6.94	396	248	<.00	<.00
TS-1 –TS-6	1.35	277	248	0.17	1.00
*α = 0.05					

Such accessibility issues during non-peak hours, especially at specific stops such as TS-4 and TS-3, show that systemic issues are at play beyond peak-hour congestion. Overall, temporal variations in accessibility needs instead fit the performance of TS-6 and TS-5 during these periods and demonstrate that location or even other factors can explain the success of tubes during these periods. However, reduced commuter volumes during off-peak hours may lead to underutilization of transit services, further emphasizing inefficiencies in the system. Specific service improvements should be implemented at low-performing stops to ensure improved accessibility and to maintain a reasonable frequency of service off-peak. Discounted fares or marketing campaigns can encourage off-peak transit use, particularly at stops with lower ridership. Also, making safety and accessibility commitments through investments in lighting, signage, and pedestrian paths at places like TS-4 can help resolve top barriers. Finally, evaluating the success factors of high-performing stops such as TS-6 and TS-5 can provide valuable insights for implementing similar improvements elsewhere. Transit planners can design a more equitable, efficient, and accessible transit system by addressing peak and off-peak challenges.

4.0 Conclusion

The University Belt Area in Tacloban City, known for its schools and educational institutions, business, recreation, and residence buildings, is facing transportation problems and traffic congestion. To study this problem, researchers conducted a broad analysis of the transportation accessibility in the study area, emphasizing six transit stops, which were TS-1 (LNU), TS-2 (LNHS), TS-3 (EVSU), TS-4 (Card Bank), TS-5 (LBC), and TS-6 (LVD). By employing surveys, traffic counts, and GIS-based heatmap analysis, the study uncovered large variations in accessibility scores due to considerations like peak/off-peak hours, infrastructure quality, and commuter demand. The evidence provided sheds light on improving urban transportation networks and denotes the path for further research objectives that are required to evaluate the overall transportation efficiency and individual segments that can enable improvement.

The traffic volume analysis revealed that the transportation ecosystem is dominated by private vehicles, contributing to congestion, particularly during peak hours. While public transportation like traditional jeepneys and multicabs is available, it is underutilized in some stops like TS-6. The mode of transportation analysis highlighted mismatches between availability and usage, suggesting the need for better resource alignment with commuter preferences. Waiting time analysis revealed that longer waits at TS-5 and TS-6 during peak hours reflect inefficiencies in service allocation.

Travel time to reach each transit stop indicates that most of the transit stops can be accessed within 0–5 min travel time except TS-5, which requires longer travel times, and this could be a result of stop placement issues as well as in-place infrastructure. Multimodal commuter experiences showed that congestion, delays, and limited parking led to commuter dissatisfaction. The correlation analysis showed weak relationships within the vehicle demand, parking availability, and accessibility scores initially determined, emphasizing that an integrated network approach is required. A heatmap was generated, and it reflected accessibility scores that were high during peak hours, as no stop achieved a designation of "Very High Accessibility," while disparities were noted to be more pronounced in off-peak hours and especially at TS-5 and TS-6.

The comparative analysis showed statistically significant variances in accessibility scores among transit stops based on peak and off-peak periods. Stops such as TS-2 and TS-3 always scored better because of better infrastructure and connectivity, while stops like TS-4 and TS-6 scored lower, indicating systemic gaps. Such differences imply that some stops have a more favorable opportunity to adjust to commuter demand over the course of the day than others, which still need to improve access significantly to overcome persistent accessibility problems.

To mitigate the effects of these findings, the study suggests several specific interventions. The infrastructure needs to be upgraded with better pedestrian pathways, improved lighting, more bus shelters, and better signage. More units should be added to public transport, and more units should be scheduled at underperforming stops such as TS-5 and TS-6 to reduce congestion and wait time. Stricter policies regulating the use of private vehicles, such as congestion pricing or designated parking zones, can continue to enhance accessibility. The relevant heatmap analysis and comparative results should be incorporated within the long-term urban planning strategy to prioritize resource allocation and guide infrastructure investment meaningfully.

Future research must examine how meteorological factors, such as rain or extreme heat, affect accessibility in Tacloban City. A possible application of traffic simulation models to improve service schedules and optimize the distribution of resources would be possible. Urban management needs to adopt inclusive strategies incorporating social, cultural, and disability issues so that all population strata can access transport systems equally. Moreover, bringing together stakeholders, such as local authorities, private sector actors, and commuters' groups, in joint planning initiatives can ensure that transport policy responds to the local community's needs.

By implementing these recommendations, Tacloban City can develop a more efficient, equitable, and sustainable transportation system, enhancing commuter satisfaction and addressing long-standing mobility challenges. This study provides a robust framework for future interventions and serves as a model for improving urban mobility in other cities facing similar issues.

5.0 Contributions of Authors

HME – conceptualization, formal analysis, investigation, methodology, supervision, visualization, writing – original draft, writing – review & editing.
CBL, LR, PM, AP – editing, writing, supervising, data analysis, encoding, fieldwork.

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7.0 Conflict of Interests

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