URBAN BUS SYSTEM: ROUTE DESIGN AND PLANNING OPTIMIZATION TOWARD A SMART AND SUSTAINABLE CITY

Nguyen Hong Phuc

Faculty of Industrial Management, College of Engineering, Can Tho University, Can Tho City, Viet Nam

Email: nguyenhongphuc@ctu.edu.vn

Abstract

The rapid urbanization in Can Tho, a key city in Vietnam's Mekong Delta, has increased the demand for an efficient, sustainable public transportation system. This study focuses on optimizing the urban bus system, particularly integrating electric buses, to meet the transportation needs of over 110,000 university students while supporting the city's smart and sustainable city goals by 2025. A data-driven approach incorporated traffic flow analysis, emissions data, and a survey of 200 students from six universities. The results reveal significant potential for electric buses to replace the current diesel fleet, reducing emissions by 53.85% and enhancing transportation service quality. Four optimized bus routes were designed, covering 18 stops with improved efficiency and minimized travel distances. The proposed system can achieve a 95% service level, significantly reducing air pollution and contributing to environmental sustainability. This study provides policymakers actionable insights into promoting green transportation and achieving long-term urban mobility goals.

Keywords: *Smart City, Smart Transportation, Bus Route and Capacity Planning, Simulation-Based Optimization.*

I. Introduction

As urban areas grow, efficient public transportation becomes increasingly critical to support economic activity and environmental sustainability. In Can Tho City, a key urban center in Vietnam's Mekong Delta, urban expansion has increased traffic congestion and rising pollution levels. With over 110,000 students enrolled across six major universities in the city, the demand for reliable and affordable transportation is evident. The city's infrastructure has struggled to keep pace with its rapid urbanization, leading to reliance on private motorbikes and inefficient public bus systems, contributing significantly to traffic jams and air pollution. As Can Tho aims to transform into a smart city by 2025, enhancing its public transportation system, particularly with green and sustainable options, is a priority.

The current bus system in Can Tho, composed largely of diesel-powered buses, faces multiple challenges. These include limited routes, outdated schedules, and frequent mechanical breakdowns. All of them contribute to a low rate of public bus usage. Many students and daily commuters still prefer motorbikes, given the unreliability and inconvenience of the bus network. However, this trend exacerbates traffic congestion, especially during peak hours, and increases the city's overall carbon footprint. The development of electric buses presents a viable solution to these challenges, offering a cleaner and more efficient mode of transportation. Electric buses reduce emissions and address noise pollution and operational inefficiencies seen in conventional buses.

This study aims to optimize the urban bus system in Can Tho by designing an electric bus network that enhances service efficiency, reduces environmental impact, and caters specifically to the needs of students. To achieve this, we conducted a comprehensive survey among 200 students from six universities in the city. Data on traffic patterns, user preferences, and emissions levels were collected to inform the optimization model. The model was then used to simulate different route designs, ensuring that the proposed electric bus system can meet demand efficiently during peak and off-peak hours while minimizing travel distances and operational costs.

The findings of this study highlight the feasibility and benefits of transitioning to an electric bus network in Can Tho. Carefully designed routes and strategically placed bus stops enable the proposed system to reduce CO2 emissions by up to 53.85% compared to the current diesel fleet. The study provides crucial insights for policymakers, transportation planners, and environmental advocates as they work toward making Can Tho a smarter, more sustainable city. In addition to addressing the immediate transportation needs of students, the optimized bus network lays the foundation for future expansions across the city, contributing to broader urban development and sustainability goals.

2. Literature review

2.1. Domestic Publications

The shift toward sustainable transportation in Vietnam has received significant attention in recent years. Various studies have explored the role of public transportation in reducing emissions and improving urban mobility. According to Nguyen et al. (2020), electric buses in urban centers like Ho Chi Minh City can reduce carbon emissions by up to 50%. Their findings suggest that integrating electric buses into existing transportation networks is a cost-effective way to promote environmental sustainability in Vietnam. Other domestic studies, such as the research by Pham and Le (2021), highlight the potential of electric buses to reduce air pollution and improve public health in cities experiencing rapid urbanization. These studies underscore the importance of strategic urban planning and government support in facilitating the transition to greener transportation options.

Furthermore, Vo and Tran (2022) conducted a comprehensive review of Can Tho's transportation infrastructure, noting the challenges posed by the city's reliance on motorbikes and diesel-powered buses. Their research emphasized the need for a shift toward electric bus systems, which could help alleviate traffic congestion and improve air quality. While the study was primarily focused on policy recommendations, it also identified potential barriers to adoption, such as high initial investment costs and public resistance to new transportation modes. Despite these challenges, the researchers concluded that public awareness campaigns and subsidies could play a pivotal role in encouraging the adoption of electric buses.

2.2. International Publications

Globally, many researchers have widely studied electric buses as a solution to urban transportation. One of the most cited works in this field is that of Li et al. (2019), who investigated the environmental and economic benefits of using electric bus networks in major Chinese cities. The authors developed an optimization model to reduce operational costs while ensuring minimal environmental impact. The resulting model showed that electric buses can reduce carbon emissions by over 60% compared to traditional diesel buses. Similarly, Zhang et al. (2020) conducted a study regarding electric buses operating in Shanghai. The study demonstrated that the transition to electric buses significantly reduced noise pollution and greenhouse gas emissions in highly populated areas.

Several European countries have made significant progress in integrating electric buses into their public transportation systems. A study by Smith and Johansson (2021) examined the impact of electric buses in Stockholm, Sweden. The study revealed that the city's electric bus network reduced emissions by 45% while improving service reliability. The authors highlighted the importance of government subsidies and infrastructure development in supporting the large-scale deployment of electric buses. Additionally, a study by Brennan (2022) explored the challenges faced by European cities in transitioning to electric buses, noting that infrastructure and charging stations are critical factors in the successful adoption of these systems. Their findings are aligned with the global trend toward sustainable urban mobility solutions.

3. Data collection and analyses

This research employs a simulation-based optimization approach to develop an optimized bus route system for Can Tho. Data on traffic flow, emissions status, and user feedback were collected through a survey conducted among students from six universities in Can Tho. The survey collected 200 responses from September 26, 2024, to October 7, 2024. The key variables analyzed included student transportation preferences, bus route demand, peak travel times, and the environmental benefits of transitioning to electric buses.

According to Fig 1, 88.5% of students prefer using motorbikes for daily travel. Motorbikes are overwhelmingly used as their first choice due to several factors, such as convenience, flexibility, and the ability to navigate traffic efficiently. Walking is the second most common mode of transportation, accounting for 9.5% of students. This number shows that those living close to their university choose walking as the first option. Other modes of travel, such as bicycles or electric bicycles (1.5%) and cars (0.5%), are significantly less popular.

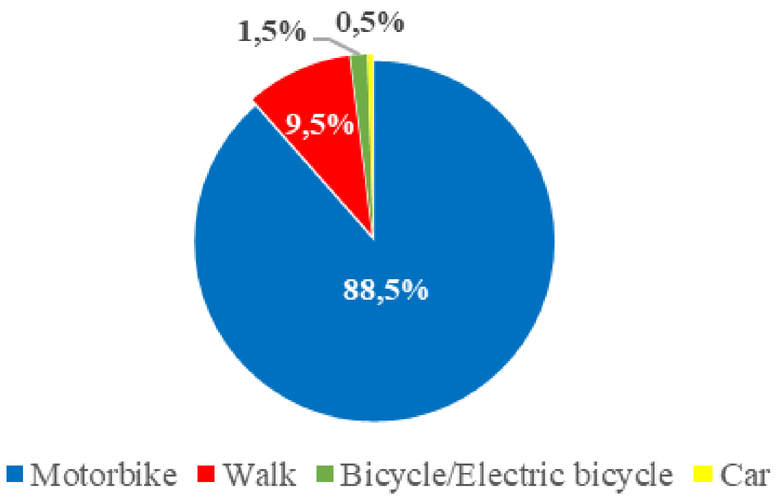


Fig. 1. Personal mode of transport used to commute to university.

Despite ongoing efforts to promote public transport, only 33% of students have reported using buses at some point, as given in Fig 2. Among those who have experienced traditional bus services, key motivating factors include perceived safety, group travel preferences, and the desire to save time by avoiding traffic congestion or parking issues, as given in Fig 3. However, the remaining majority who rely on motorbikes reflect certain challenges in shifting commuting habits toward sustainable modes like public transport. These barriers involve concerns about route coverage, schedule flexibility, or the availability of bus stops near the university. Encouraging students to adopt electric buses or bicycles could reduce traffic congestion and minimize carbon emissions. However, achieving this shift requires addressing the students' demand for convenience, time efficiency, and safety, and improving the reliability of electric bus services.

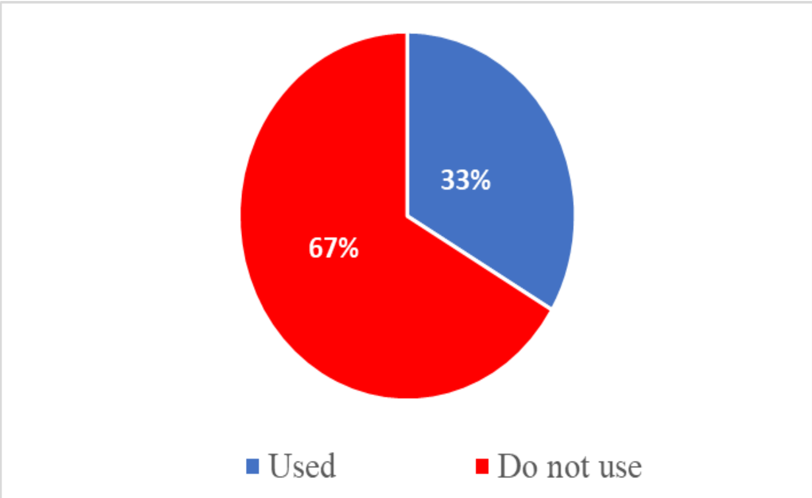


Fig. 2. Usage statistics of future buses.

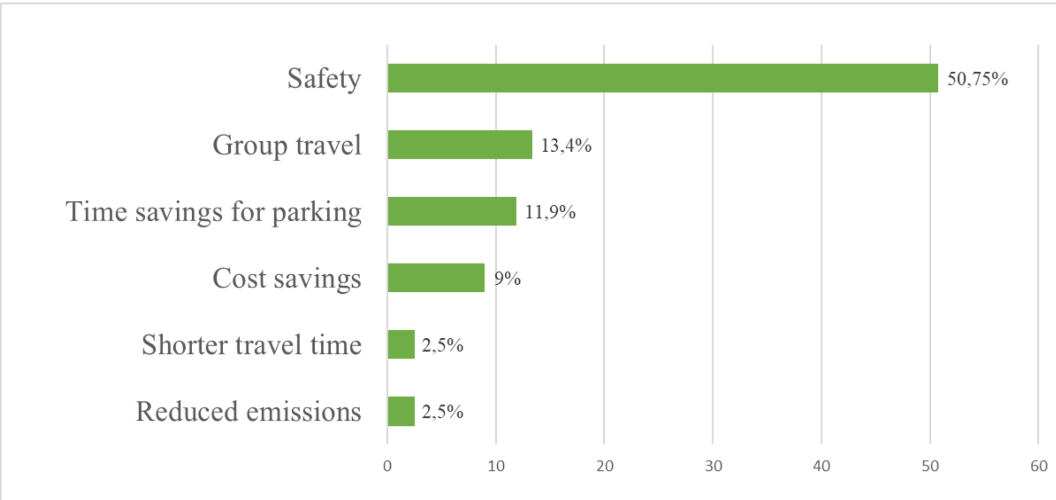


Fig. 3. Most important factors of traveling by buses

Analysis of survey responses revealed that 84% of students prefer electric buses due to safety (59%), group travel convenience (14.5%), and reduced environmental impact (6.5%), as given in Fig 4. and Fig 5. The demand for electric buses is high due to their ability to significantly address traditional buses' shortcomings, such as excessive emissions, frequent mechanical failures, restricted route coverage, and inflexible schedules. In contrast, the remaining 16% indicated no demand to adopt electric buses for public transit needs.

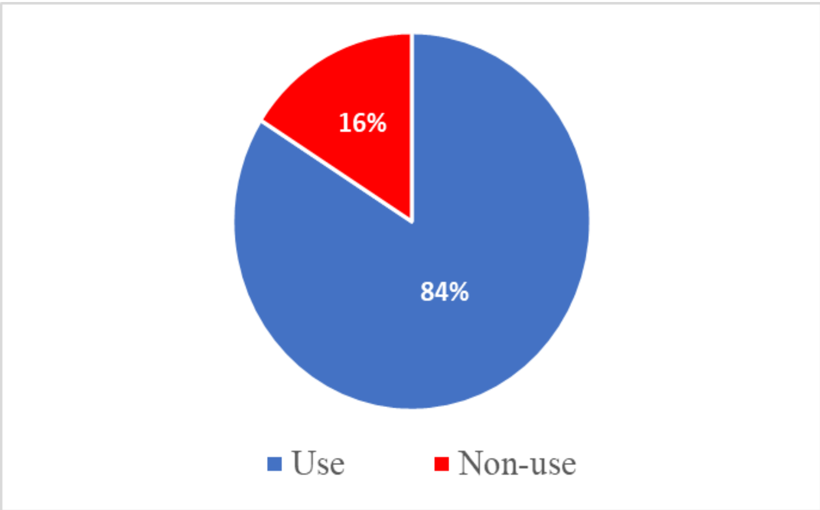


Fig. 4. Usage statistics of future electric buses

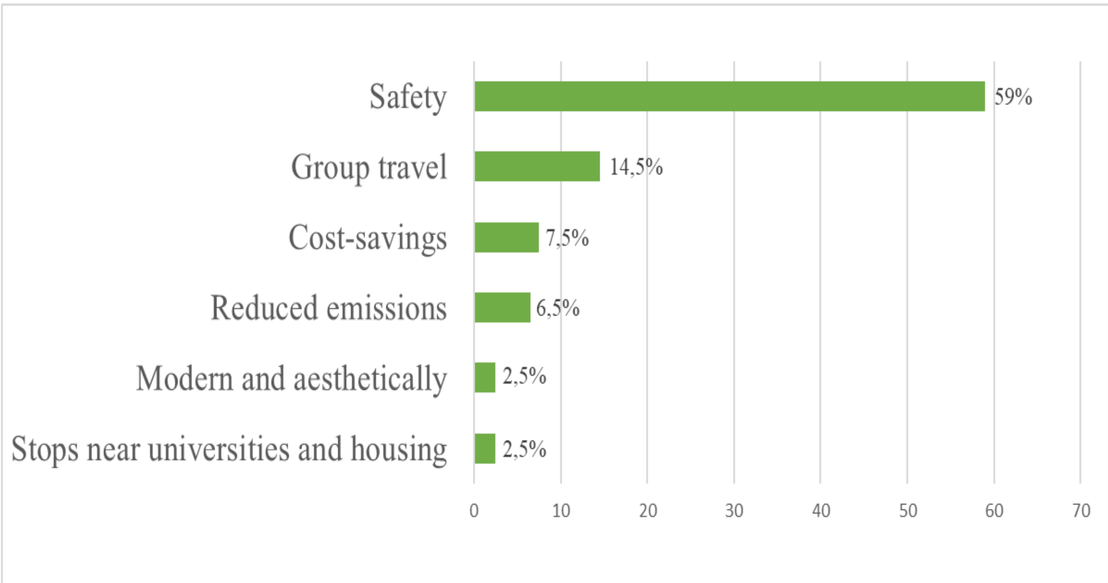


Fig. 5. Most important factors of traveling by electric buses.

According to Fig 6, peak travel times are 6:00 - 8:00 (50.5%) and 12:00 - 14:00 (34%) due to these periods aligning with students' daily academic routines. First, the 6:00–8:00 time slot corresponds to the beginning of the educational day. Classes typically start at 7:00 or 8:00, making this period critical for students commuting from housing to university and avoiding heavy morning traffic and possible delays. Additionally, electric buses provide a more affordable and environmentally friendly alternative to personal vehicles or traditional public transportation. The second peak (12:00 - 14:00) reflects mid-day breaks when students move between academic sessions, dining areas, or afternoon classes, often beginning around 1:00 PM to 2:00 PM. The relatively lower demand than the morning peak (34%) can be attributed to students' varying schedules. Therefore, the study underscores the need to plan electric bus operations to align with student demand. Increasing bus frequency during these two peak periods could improve service quality, reduce wait times, and encourage public transportation use.

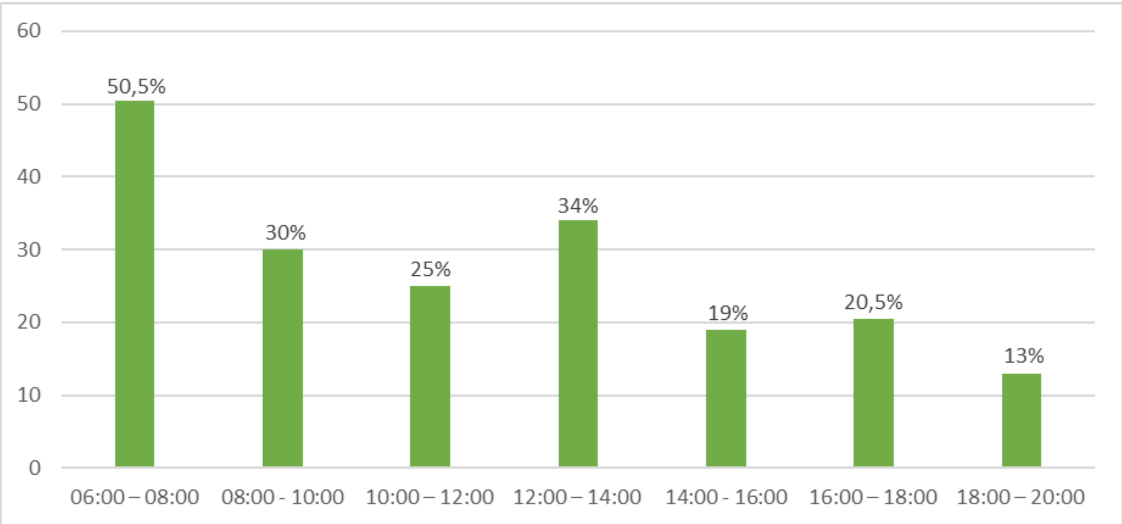


Fig. 6. Bus demands of a day.

4. Survey results

4.1. Current residence

Understanding these housing patterns is crucial when designing and developing public transportation services like electric buses. The data reveals that 58% of students reside in boarding houses, making this the most common form of housing. The remaining students are distributed across private residences (19%), university dormitories (14%), and relatives' houses (9%), as given in Fig 7. Since most students live in boarding houses, developing an electric bus system is essential. Students staying in private residences (19%) and university dormitories (14%) also are opportunities for the development of electric bus systems.

Those living in dormitories and private housing may benefit from well-planned bus schedules aligned with academic timetables. Consequently, enhancing bus routes that connect these student-dense zones with universities would encourage greater use of electric buses, mitigating traffic congestion and reducing environmental impact. Improving route coverage, ensuring timely schedules, and promoting safety will be essential to incentivize students to switch from motorbikes to public transport. Also, affordable pricing and group travel incentives could appeal to students with limited budgets.

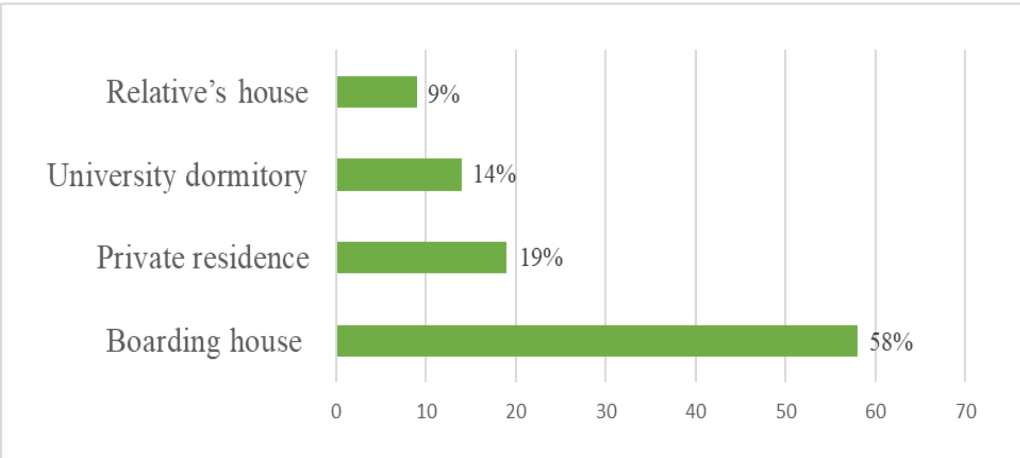


Fig. 7. Current residence.

4.2. Area of residence

The distribution of students across various districts, with an overwhelming concentration in Ninh Kieu (84%), is given in Fig 8. This concentration highlights the strategic importance of designing bus routes that cater primarily to Ninh Kieu, as it holds the majority of potential users. In contrast, other districts such as Cai Rang (10.5%), Binh Thuy (3.5%), Phong Dien (1.5%), and O Mon (0.5%) represent a minor proportion of the student population. Given these percentages, focusing resources on developing a comprehensive and efficient electric bus system in Ninh Kieu District would likely yield the highest utilization rates.

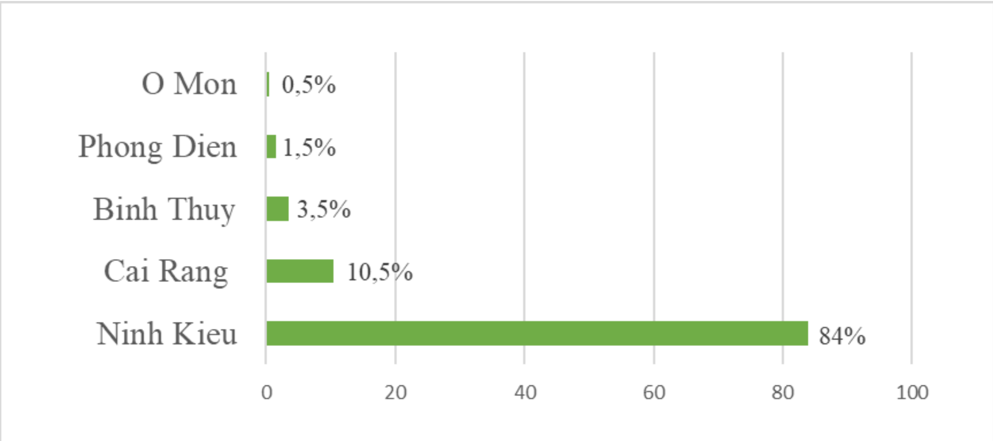


Fig. 8. Area of residence.

4.3. Type of public transport that should be equipped

Fig. 10 provides insight into the preferred mode of public transportation as per survey respondents. A significant 83.5% of respondents favor electric buses, underscoring a strong preference for sustainable and environmentally friendly transportation options. Other options like bicycles (7%), no installation required (5.5%), and conventional diesel-powered buses (4%) are far less favored. Besides, the electric bus system aligns with global trends towards minimizing the environmental impact of public transportation. By investing in electric buses, not only would the city address environmental concerns, but it would also align with the desires of the surveyed students.

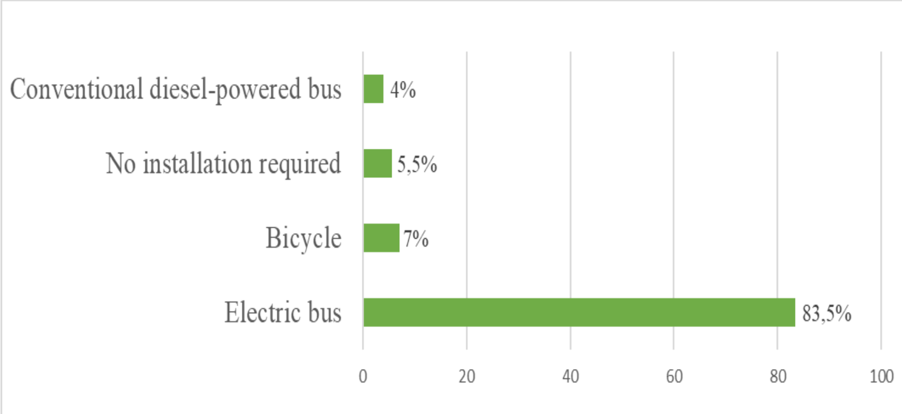


Fig. 10. Type of public transport that should be equipped

4.4. Frequency of bus usage per week

The figure for the traditional bus shows that the current usage of traditional buses among students is relatively low, as given in Fig 11. A majority, 64.2%, report using the bus fewer than 5 times per week, indicating limited reliance on traditional bus services for daily commuting. These figures suggest that traditional buses may not be fully included in the students' regular transportation routines.

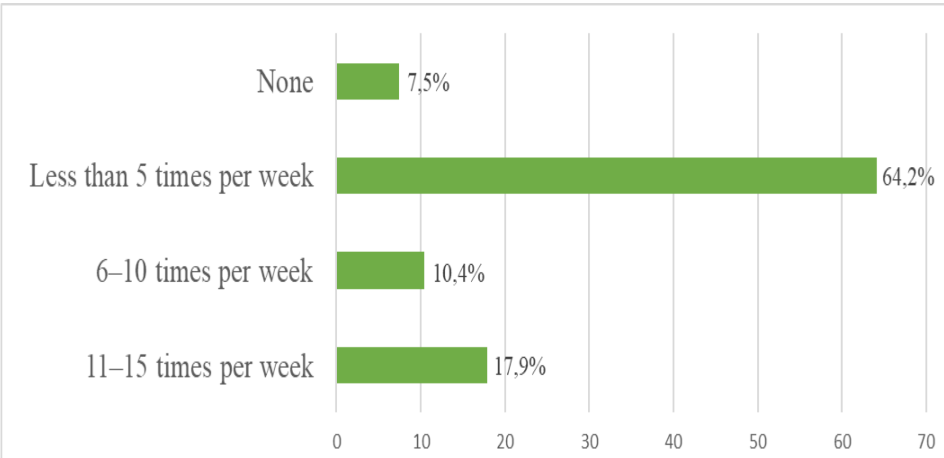


Fig. 11. Frequency of traditional bus usage per week

4.5. Electric bus

Fig. 12 presents projected usage patterns if electric buses were introduced as a public transportation option. The data for electric buses indicates a notable shift in usage frequency.

While 46.4% of students still anticipate using electric buses fewer than 5 times per week, this is a considerable decrease compared to the 64.2% for traditional buses. Additionally, there is a substantial increase in moderate usage frequencies: 37.5% of students would use electric buses 6-10 times per week, compared to only 10.4% for traditional buses.

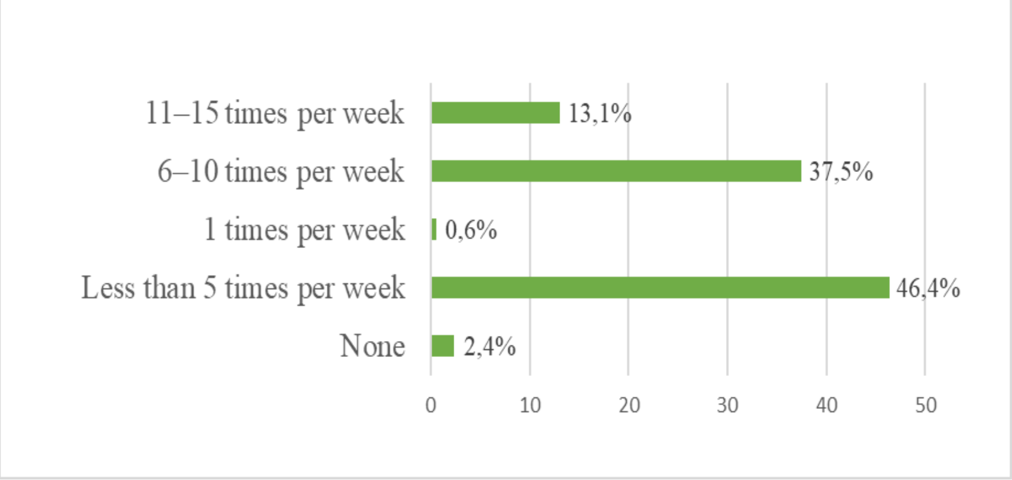


Fig. 12. Frequency of electric bus usage per week

The findings suggest that integrating electric buses could increase student public transport engagement. A significant rise in the 6-10 trips per week category (from 10.4% with traditional buses to 37.5% with electric buses) indicates that electric buses could become part of students' regular commuting habits. This shift highlights the potential of electric buses to enhance the public transportation network's appeal, contributing to reduced carbon emissions.

5. Model formulation: Simulation-based optimization

The bus route problem is solved using several assumptions, including known demand levels during specific time windows, linear travel costs, and bus capacity constraints. The simulation-based optimization model is formulated for the problem, which aims to maximize the number of passengers served while minimizing total travel distance and emissions. between locations in the network Constraints included ensuring that no bus route exceeds vehicle capacity, avoiding breakdowns during travel, and ensuring each route begins and ends at specified stations.

Sets and indices

i, j:	Index of stops *i*,*j*	(i = 1...J)
k:	Index of bus routes *k*	(k = 1…K)
h:	Index of customer *h*	(h = 1...H)

Parameters

cnl_k:	Fixed costs	(VND/bus)
ce_k:	Electric bus costs	(VND)
da_{ij}:	Travel distance between stops	(km)
dis_{hi}:	Travel distance from customer *h* to stop *i*	(km)
ta_{ij}:	Travel time between stops	(minutes)
s_j:	Service time at stop *j*	(minutes)
s_{ij}, e_{ij}:	Time windows at stop *j*	(minutes)
st:	Starting service time	(minutes)
t:	Unit time to get on and get off the bus	(minutes)
bo_j, al_j:	Customer demand to get on/off the bus at stop *j*	(person)
v:	Bus speed	(km/minutes)
Q:	Bus load	(seats)

Decision variables

X_{ijk}:	1, a route exists from station *i* to station *j*; 0, otherwise	
T_{hi}:	1, customer *h* is assigned to station *i*; 0, otherwise	
W_i:	1, station *i* is selected to open; 0, otherwise	
F_{ik}:	Number of customers to get on bus route *k* at stop *i*	(person)
Sl_{ik}:	Number of customers to get off route *k* at stop *i*	(person)

Y_{ik}: Arrival time at stop *i* of bus route *k* (minutes)

U_i: Order in which each bus stop *i* is visited on a route

Objective function

The objective function (Z) aims to minimization of the total travel distance.

$$\text{Min } Z = \sum_{i,j}^{I} \sum_{k=1}^{K} \left(X_{ijk} \times ce_k \times da_{ij} \right) + cnl_k$$

Constraints

$$T_{hi} \le W_i \qquad \forall i, h \in J, H \qquad (C1)$$

$$\sum_{h=1}^{H} T_{hi} \ge W_i \qquad \forall i \in J \qquad (C2)$$

$$\sum_{i=1}^{I} T_{hi} = 1 \qquad \forall h \in H \qquad (C3)$$

$$\sum_{i=1}^{I} W_i = 20 \qquad (C4)$$

$$X_{ijk} = 0 \qquad \forall i, j, k \in I, K, i = j \qquad (C4)$$

$$\sum_{i=1}^{1} \sum_{j=2}^{I-1} X_{ijk} = 1 \qquad \forall k \in K \qquad (C5)$$

$$\sum_{i=2}^{J-1} \sum_{j=1}^{J} X_{ijk} = 1 \qquad \forall k \in K \qquad (C6)$$

$$W_i \le \sum_{j=2}^{J} X_{ijk} \times M \qquad \forall k \in K, \forall i \in (J-1), i != j \qquad (C7)$$

$$W_i \times M \le \sum_{j=2}^{J} X_{ijk} \qquad \forall k \in K, \forall i \in (J-1), i != j \qquad (C8)$$

$$\sum_{k=1}^{K} X_{ijk} = 0 \qquad \forall i, j \in J, i = j \qquad (C9)$$

$$X_{ijk} + X_{jik} \le 1 \qquad \forall i, j, k \in J, K, i! = j \qquad (C10)$$

$$\sum_{i=1}^{J-1} X_{ijk} - \sum_{i=2}^{J} X_{jik} = 0 \qquad \forall k \in K, j \in \{2,..J-1\}, i! = j \qquad (C11)$$

$$\sum_{i=1}^{J-1} \sum_{j=47} \sum_{k=1}^{K} X_{ijk} = 2 \qquad (C12)$$

$$X_{ijk} = 1 \rightarrow Y_{jk} = st + \left[\left(\frac{da_{ij}}{v} \right) \times 60 \right] \qquad \forall i, j, k \in J, K, j! = \{1, J\}, i = 1 \qquad (C13)$$

$$Y_{jk} = Y_{ik} + s_i + \left[\left(\frac{da_{ij}}{v} \right) \times 60 \right] \qquad \forall i, j, k \in J, K, i! = \{1, J\}, j! = 1 \qquad (C14)$$

$$Y_{jk} \le ei_j \times X_{ijk} \qquad \forall j, k \in J, K, j! = 1 \qquad (C15)$$

$$X_{ijk} \times da_{ij} \ge X_{ijk} \times 1 \qquad \forall i, j, k \in J, K, j! = i \qquad (C16)$$

$$F_{jk} \le \sum_{i!=j}^{J-1} X_{ijk} \times M \qquad \forall j, k \in J, K, j! = \{1, ...J-1\} \qquad (C17)$$

$$\sum_{k=1}^{K} F_{jk} \le \left(bo_j - al_j \right) \times W_j \qquad \forall j, k \in J, K, j! = \{1, ...J-1\} \qquad (C18)$$

$$Y_{jk} \le \sum_{i!=j}^{J} X_{ijk} \times M \qquad \forall j, k \in J, K, j! = 1 \qquad (C19)$$

$$Sl_{1k} = Q \qquad \forall j, k \in J, K, j! = 1 \qquad (C20)$$

$$Sl_{jk} \ge \left(Sl_{ik} - F_{jk} \right) - M \times (1 - X_{ijk}) \qquad \forall k, j \in J, K, j! = i, j! = 1, i! = J \qquad (C21)$$

$$Sl_{jk} - F_{jk} \le Q \qquad \forall j, k \in J, K, j = \left(2...J-1 \right) \qquad (C22)$$

$$U_{ik} - U_{jk} + \left(N \times X_{ijk} \right) \le N - 1 \qquad \forall i, j, k \in J, K, j! = 1 \qquad (C23)$$

$$1 \le U_i \le N - 1 \qquad \forall i \in I \qquad (C24)$$

$$Y_{jk} \leq \sum_{i=1}^{J} X_{ijk} \times M \qquad \forall i, j, k \in J, K, j! = 1 \qquad (C25)$$

Constraints C1 and C2 determine that each customer is assigned to a stop. Constraint C3 guarantees that each customer is assigned to only one stop. Constraint C4 ensures the number of stops. Constraint C5 determines no further routes from stop *i*. Constraint C6 determines that each route originates from the starting stop. Constraint C7 ensures that each route must end by returning to the final stop. Constraints C8 and C9 ensure a route *k* from stop *i* to stop *j* when station *i* is opened. Constraint C10 guarantees vehicles must not depart from and arrive at the same location.

Constraint C11 guarantees that vehicles cannot return to the previous stop on the same route. Constraint C12 ensures consecutive points. Constraint C13 guarantees routes to stop at the Can Tho University twice. Constraint C14 ensures the starting time of service at the initial stop. Constraint C15 ensures the start time of service at station *j* for route *k*. Constraint C16 determines the earliest and latest service start times at open stop *j*. Constraint C17 ensures travel distance between stops. Constraints C18 and C19 guarantee that customer demand to get on the bus at stops is met. Constraint C20 ensures the start time of service at open stop *j*.

Constraint C21 guarantees that the number of customers getting on the bus at the starting stop corresponds to the vehicle's capacity. Constraint C22 determines the number of customers that can board when customer demand is at open stops. Constraint C23 guarantees that the number of customers on route *k* from stop *i* to stop *j* does not exceed the vehicle's capacity. C24 is the sub-tour elimination constraint. Constraint C25 guarantees service time at stop *j*.

Bus systems simulation model:

The modeling of the electric bus system is illustrated in Fig 13. The bus route model begins when the electric bus leaves the station. The bus travels to the first bus stop and proceeds to determine the number of passengers waiting at each stop. If passengers are available to board at each stop, the model checks whether the response is “Yes” or “No” If “Yes” the bus stops to pick up passengers at the stop. If “No” the bus stops at the station to drop off passengers. Following this, the bus moves on to the subsequent stops. The sequence continues until the bus reaches the final station, marking the end of the route.

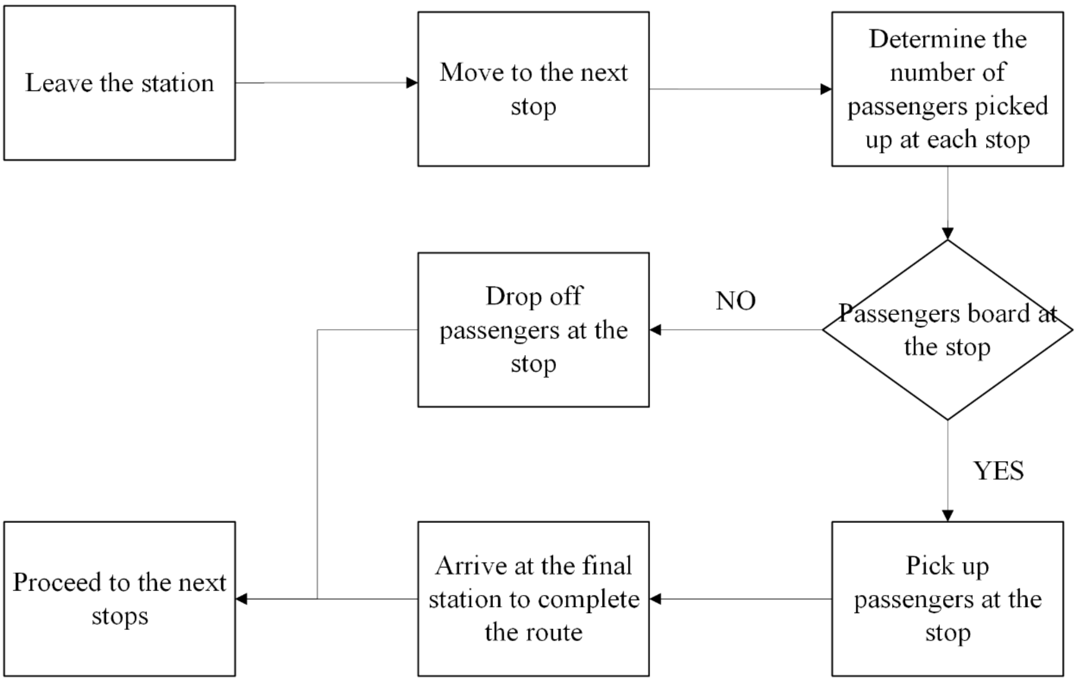
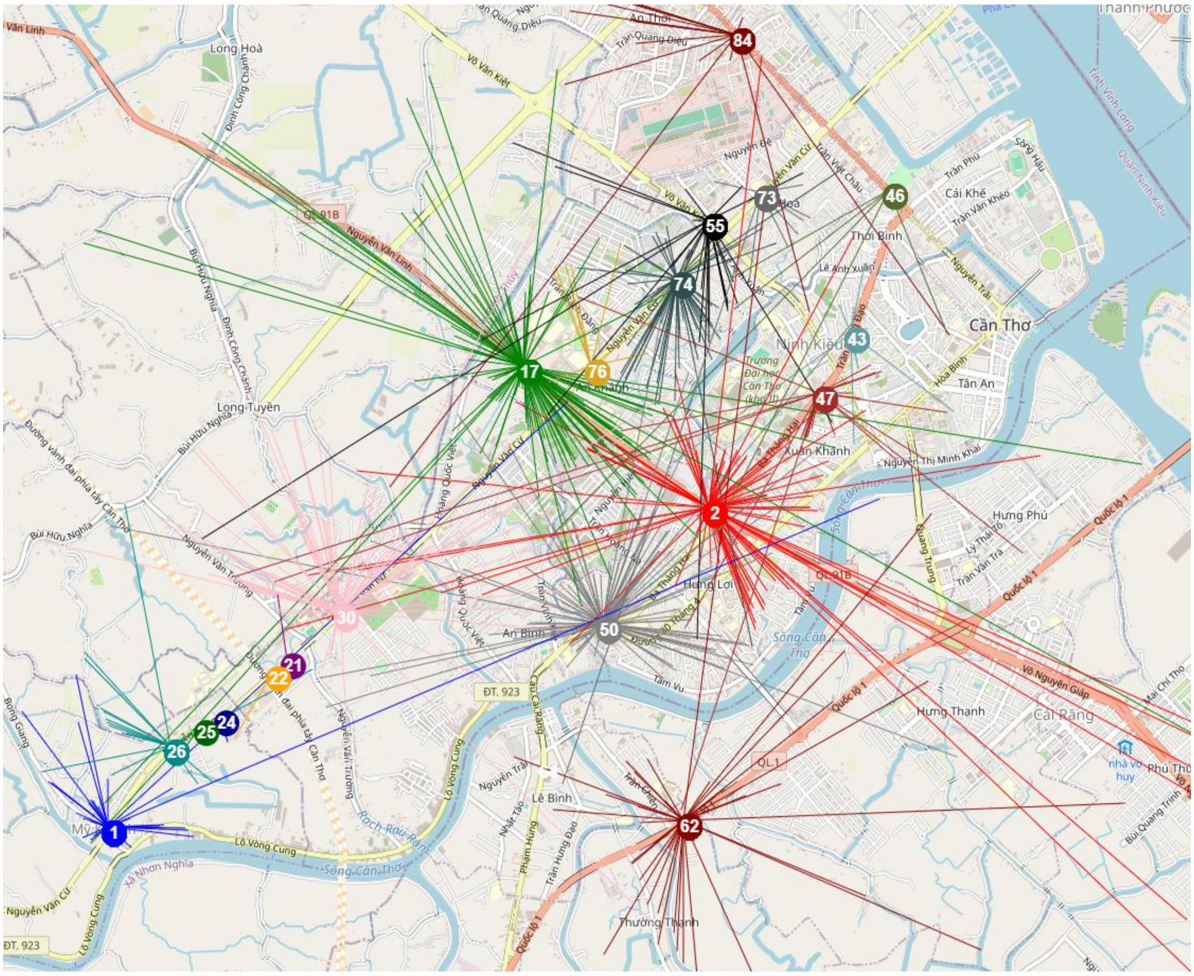
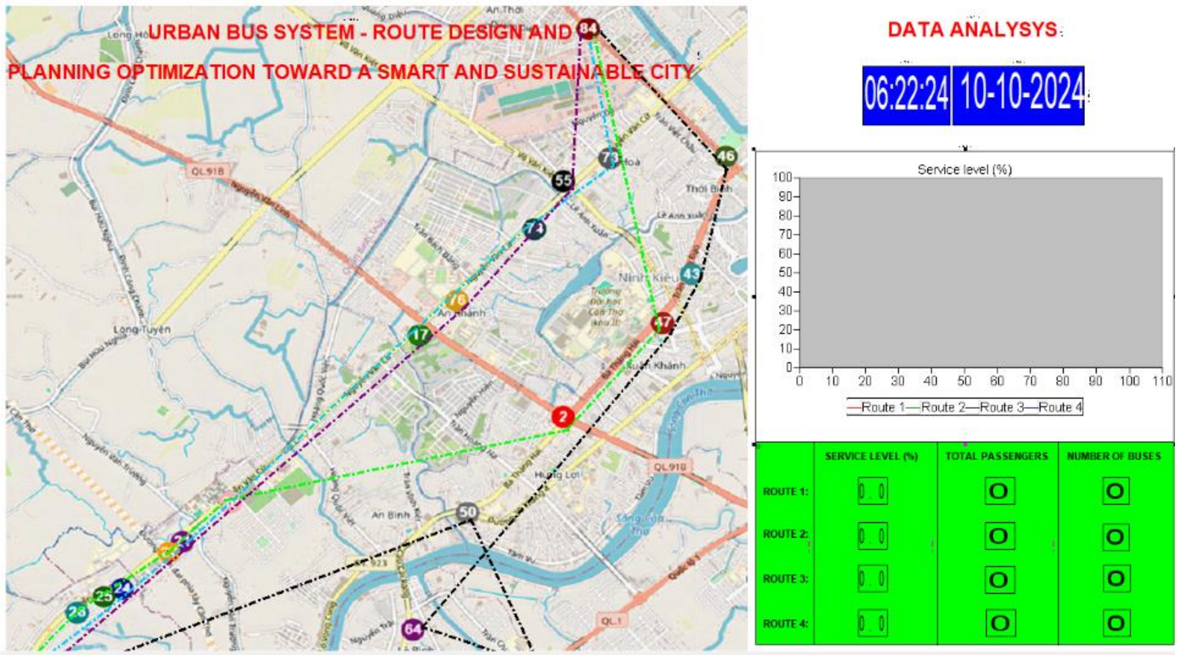


Fig. 13. Bus system simulation model.

The dynamic model simulates the real-time interactions between buses, stops, and students to evaluate the system's performance under various scenarios, as illustrated in Fig 14. Key elements include the arrival and departure times at each stop, the boarding and alighting processes, and the bus headway between consecutive buses. The model provides a visual and interactive representation of the electric bus system in Can Tho, allowing observe the real-time movement of bus routes and stops.



a. Electric bus system serves for the six universities in Ninh Kieu and Cai Rang district.



b. Dynamic model interface by Arena simulation software.

Fig. 14. Bus system simulation model.

6. Results and Discussions

6.1. Scenarios analyses

Table 1. Scenarios description.

Scenario 1 (S1): 1 bus for each route.	
- Route 1: 70%	- Route 3: 59%
- Route 2: 60%	- Route 4: 63%
Scenario 2 (S4): 2 buses on routes 1,3; and 3 buses on the remaining routes.	
- Route 1: 97%	- Route 3: 90%
- Route 2: 80%	- Route 4: 82%
Scenario 3 (S7): 3 buses for each route.	
- Route 1: 99%	- Route 3: 99%
- Route 2: 90%	- Route 4: 92%

Table 2. Scenario analyses.

a. Parameter estimation.

		Scenario 1	Scenario 2	Scenario 3
Fleet size (bus)		4	10	12
Fixed cost (1 mil VND)	***Bus***	1,600	4,000	4,800
Daily calculation				
Travel information	***Travel times/day***	48	120	144
	Travel distance/day (km)	723	1,887	2,169
Variable cost (1 mil VND)	***Driver salary/day***	2.4	6	7.2
	Electricity cost/day	4	10.4	11.9
	Maintenance cost/day	1.6	4	4.8

b. CO2 emissions calculation.

Yearly calculation	Scenario 1	Scenario 2	Scenario 3
Expected number of customers using electric buses (1 mil)	0.8	**1.1**	1.2
Variable cost (1 mil VND)	2	**5.1**	6
CO_2 emissions (ton CO_2) for transport of 1.2 mil customers:			
- If using motorcycles	1,076		
- if using electric buses + motorcycles	507	**413**	368
- CO_2 savings	52%	**62%**	66%

The resulting model comprises a set of Pareto scenarios along the Pareto frontier, as shown in Fig 15. Each Pareto scenario corresponds to a specific scenario. There are 7 scenarios, labeled from S1 to S7. These scenarios allow decision-makers to understand the relationship between total costs and the corresponding CO_2 emissions. Its shape clearly shows that the general trend of higher costs results in correspondingly lower emissions reductions, demonstrating a trade-off relationship between investment and environmental impact.

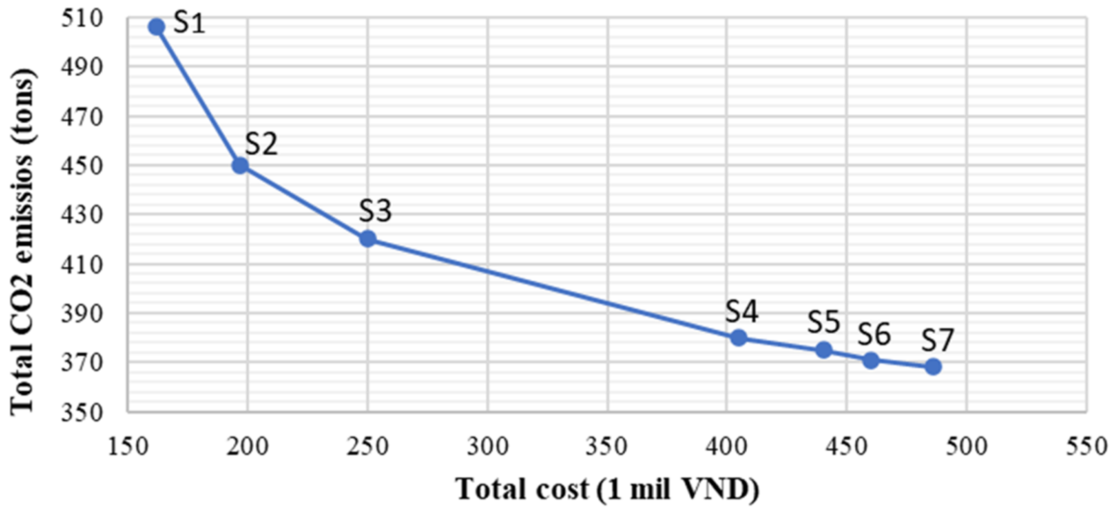


Fig. 15. Trade-offs between the total cost and CO2 emissions.

According to the Pareto frontier, scenarios located on the left side of the frontier tend to lower total costs. In Scenario 1, CO_2 emissions reach the highest level, approximately 507 tons, with a lower associated cost; however, subsequent scenarios (S2 to S7) demonstrate a progressive decrease in emissions as costs increase. Notably, the steep slope between S1 and S2 indicates that initial investments result in significant emission reductions.

Conversely, scenarios on the right side of the frontier prioritize minimizing CO_2 emissions, albeit with decreased cost-effectiveness. For example, Scenario 7 achieves a 66% reduction in environmental impact compared to emissions generated by motorcycle use; however, this scenario leads to an increase of 3 times in total costs. In the optimal Scenario S4, deploying 12 electric buses attains a service level of 88% with an associated cost of approximately 413 million VND, achieving a 62% reduction in CO_2 emissions relative to the current motorcycle use. Integrating electric buses presents substantial potential for reducing air pollution, with projected CO_2 reductions of 663 tons annually. This approach achieves a favorable balance between cost and environmental benefits, making it a viable option for practical application.

6.2. Four optimized bus routes

Following scenario 4, the proposed electric bus system design includes 18 main bus stops and 4 optimized routes. Each route was designed to minimize emissions while ensuring coverage of key university locations.

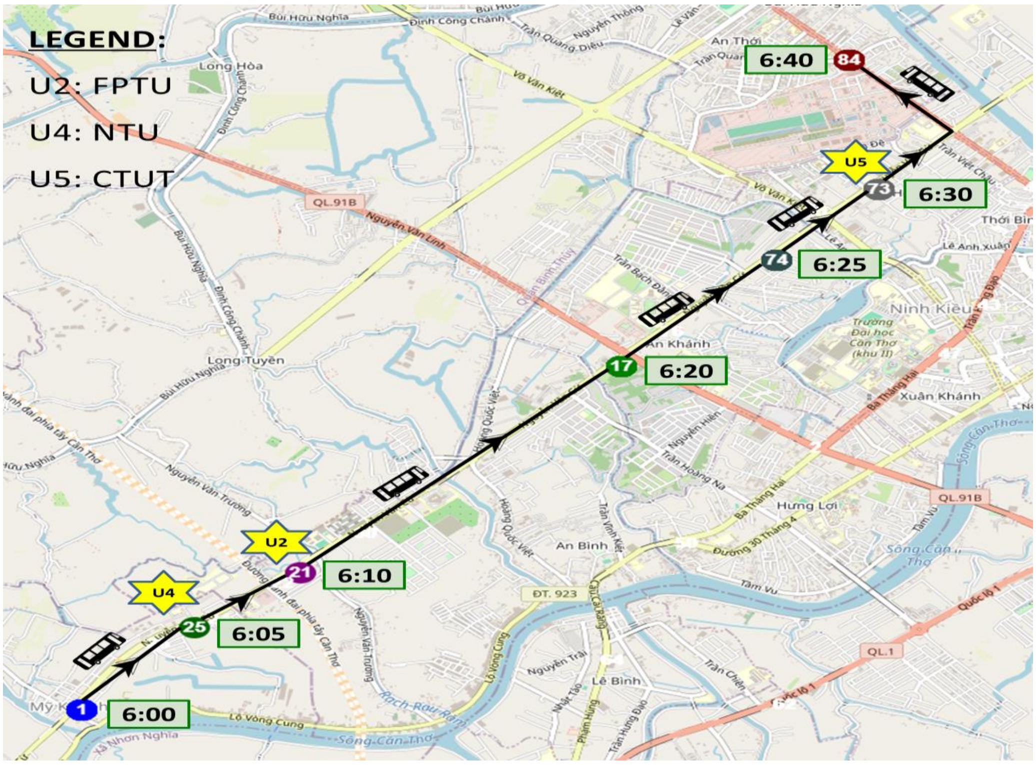


Fig. 16. Route 1.

Route 1 covers 7 stops, including 3 university stops, with a total travel distance of 11.579 km. The route operates at a service level of 97% and generates 6.95 kg CO_2 emissions per trip. Two buses are allocated to this route per service cycle, operating between 6:00 and 6:55, with a 15-minute interval between departures. The route follows the path: Nguyen Van Cu → NCTU → FPTU → Nguyen Van Linh → CTUT → CMT8.

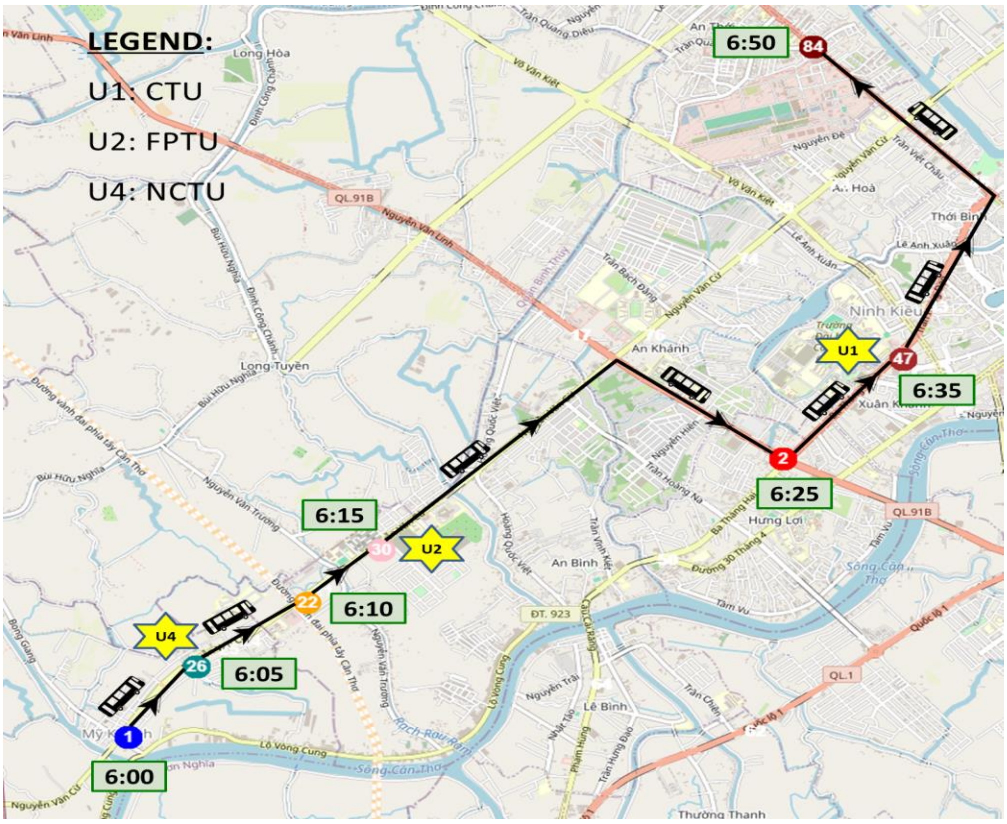


Fig. 17. Route 2.

Route 2 covers 7 stops, including 3 university stops, with a total travel distance of 15.208 km. The route operates at a service level of 80% and generates 9.12 kg CO_2 emissions per trip. Three buses are allocated to this route per service cycle, operating between 6:00 and 7:20, with a 15-minute interval between departures. The route follows the path: Nguyen Van Cu → NCTU → Nguyen Van Cu → FPTU → Nguyen Van Linh → CTU → CMT8.

Route 3 covers 5 stops, including 3 university stops, with a total travel distance of 11.89 km. The route operates at a service level of 90% and generates 7.13 kg CO_2 emissions per trip. Two buses are allocated to this route per service cycle, operating between 6:00 and 6:55, with a 15-minute interval between departures. The route follows the path: Nguyen Van Cu → NCTU → CTUMP → CTUT → CMT8.

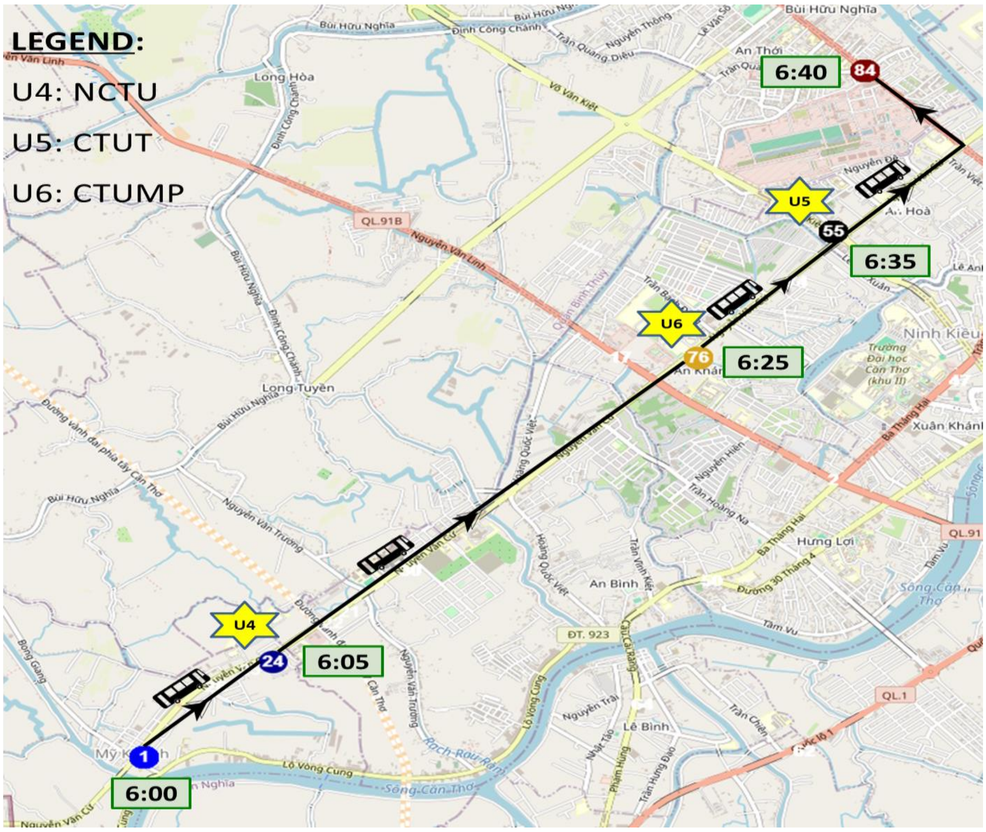


Fig. 18. Route 3.

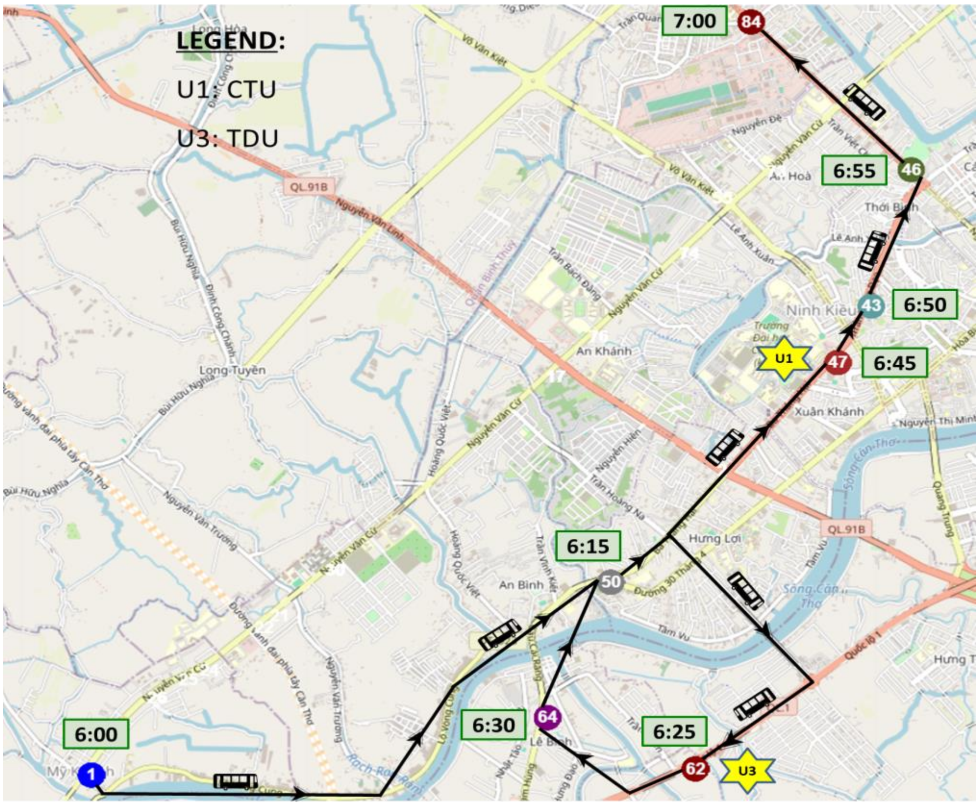


Fig. 19. Route 4.

Route 4 covers 8 stops, including 2 university stops, with a total travel distance of 21.56 km. The route operates at a service level of 82% and generates 12.94 kg CO_2 emissions per trip. Three buses are allocated to this route per service cycle, operating between 6:00 and 7:30, with a 15-minute interval between departures. The route follows the path: Nguyen Van Cu → 3-2 Street → TDU → Pham Hung → CTU → 3-2 Street → CMT8.

7. Conclusion

This research demonstrates the feasibility and benefits of transitioning to an electric bus system in Can Tho. The system can serve a larger population by optimizing bus routes while promoting environmental sustainability. The electric bus network not only meets the city's goal of becoming a smart city but also provides students with a safer and more efficient transportation option.

8. Recommendations

Regular data collection and route adjustments: To ensure the electric bus system remains efficient and meets evolving passenger demands, it is recommended that transportation agencies conduct surveys each semester or annually. This data should include passenger numbers, peak travel times, and route feedback, allowing for necessary adjustments to bus schedules and routes to accommodate changing needs. For instance, new residential or university buildings may require adjustments to existing routes or the addition of new stops.

Public awareness campaigns: Increasing public awareness of the environmental and health benefits of electric buses is crucial for maximizing ridership. It is recommended that campaigns be conducted at universities, on social media platforms, and in public spaces to educate students and the general public about how electric buses contribute to reducing air pollution, noise, and traffic congestion. Partnering with universities to integrate environmental education into student orientation sessions could further promote eco-friendly transportation choices.

Student discounts and incentives: Since students are a primary target group for the proposed electric bus system, policymakers should collaborate with universities to offer discounted or even free bus fares. Implementing a system where student ID cards are linked to transportation fares can encourage greater student participation and reliance on public transportation. This initiative could also be tied to eco-friendly programs, offering rewards or incentives for frequent use of electric buses.

Infrastructure development: To ensure the smooth operation of the electric bus system, the city should prioritize the development of essential infrastructure, such as charging stations and parking facilities for buses. Strategically placing these stations near universities, major bus stops, and public areas will help avoid operational delays. Furthermore, integrating the electric bus network with existing transportation systems, such as bike-sharing programs or walking paths, can enhance accessibility and reduce initial investment costs.

Expanding the electric bus network: Once the initial phase of the electric bus system is implemented and proven effective, the network should be expanded to cover a larger area of the city. The long-term goal should be to ensure that 100% of the population lives within a 500-meter walking distance from the nearest bus stop. This expansion will help reduce the use of private vehicles and further lower the city's carbon footprint.

Government support and policy initiatives: To facilitate the transition to a fully electric bus system, the government must provide financial support and policy incentives. These could include subsidies for electric bus operators, tax incentives for manufacturers, and grants for infrastructure development. Additionally, policies that promote green transportation, such as setting emission reduction targets and encouraging the private sector to invest in sustainable mobility scenarios, will be vital in achieving the city's smart city goals.

Appendix

A1. Parameters

Fixed cost/bus (1 mil VND)	400	Driver salary/times (VND)	50,000
Variable cost (1 mil VND)	1.9	Electricity cost (VND/km)	5,500
CO_2 emissions (kg CO_2/km):		Maintenance cost/times (VND)	33,000
- If using motorcycles	0.114	Number of operating days per year	250
- If using electric buses	0.6	Number of boarding house	716
Number of people	84%	Number of customers per boarding house	8
Number of operating days/year	250		

A2. The formula to calculate cost is the following:

+ *Investment cost:*

$$\text{Investment cost} = \text{Number of bus} \times \text{Fixed cost per bus}$$

+ *Variable cost:*

$$\text{Variable cost} = (\text{Driver salary} + \text{Electricity cost} + \text{Maintenance cost}) \times \text{Number of operating days per year}$$

$$\text{Driver salary} = \text{driver salary per times} \times \text{times per day}$$

$$\text{Electricity cost} = \text{electricity cost per km} \times \text{travel distance}$$

$$\text{Maintenance cost} = \text{maintenance cost} \times \text{times per day}$$

A3. The formula to calculate CO_2 emission is the following:

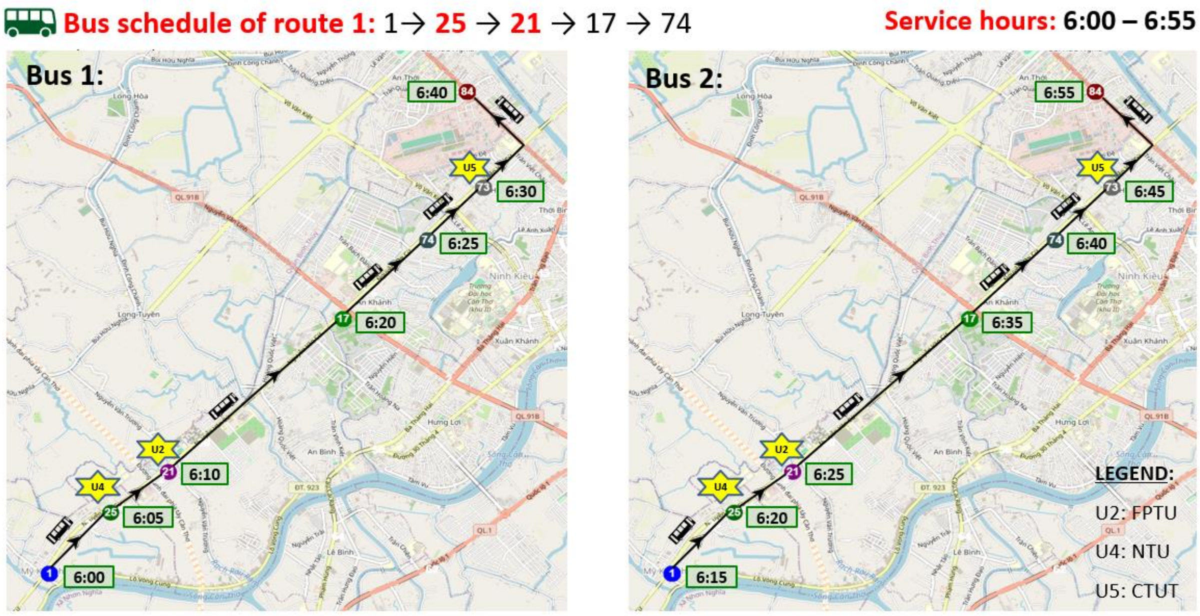
+ If using electric buses:

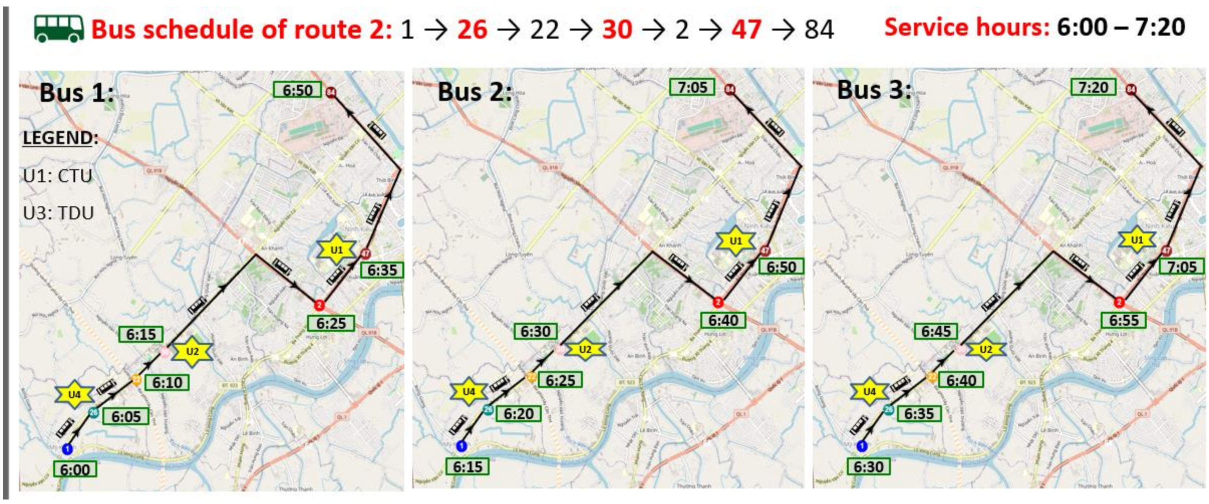
$$CO_2 \text{ emissions} = \text{Travel distance} \times \text{Emission factor} \times \text{Number of operating days per year}$$

+ If using motorcycles:

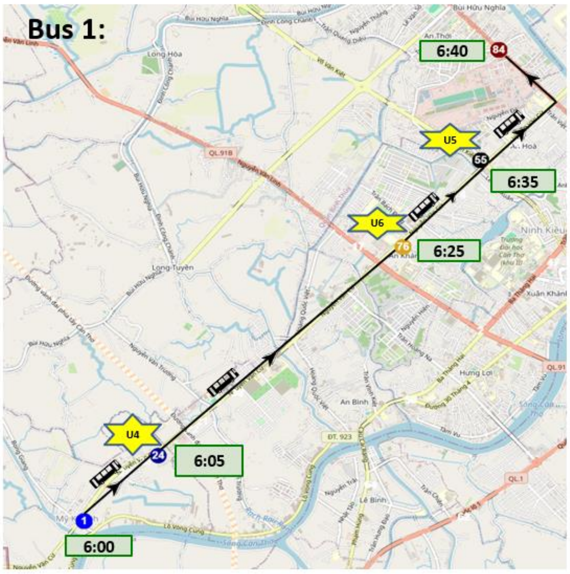
$$CO_2 \text{ emissions} = \text{Travel distance} \times \text{Emission factor} \times \text{Number of customers} \times \text{Number of operating days per year}$$

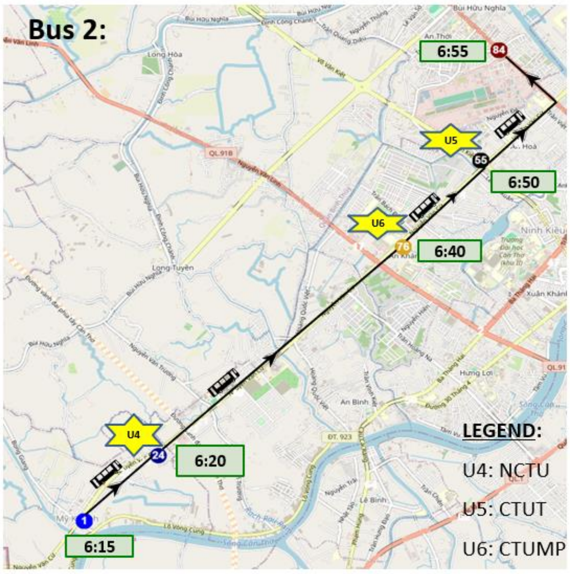
A4. Bus schedule:





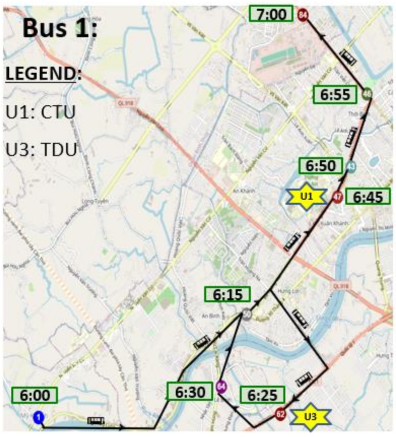
Bus schedule of route 3: 1→ **24** → **76** → **55** → 84 **Service hours:** 6:00 – 6:55

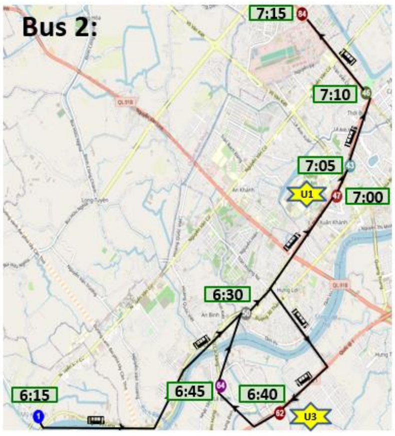


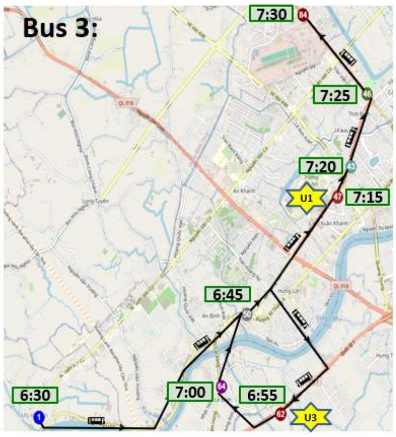


Bus schedule of route 4: 1→ 50 → **62** → 64 → **47** → 43 → 46 → 84

Service hours: 6:00 – 7:30







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