Optimization of Electric Bus Scheduling Using Genetic Algorithm: A Case Study in Public Transport of UNNES Campus Area

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***Abstract*— The transportation service system requires improvements to evolve into a smart and more efficient system. Passengers waiting at bus stops can create long queues, causing a lack of available shuttle bus capacity when arriving at the bus stop. This work proposes a genetic algorithm model to reduce the time passengers spend waiting and schedule shuttle buses to stops with high capacity. The Genetic Algorithm works by searching for the optimal value to result in optimal waiting time by providing calling shuttle bus. After the method reaches the optimal solution, the simulation result will provide a minimum waiting time. In case studies of simulated design at either campus in Central Java, Indonesia. This method provides a simulated system shuttle bus on scheduling to raise a challenge in waiting time efficiency and passenger accumulation at campus transportation. The case studies of the application on passenger waiting time showcase the model's ability to improve transportation services in the unscheduled campus area. This system was designed to ensure that it was effective in addressing the transportation challenges faced by students and staff. Use the full potential of bus transportation in the campus area to ensure continuity between stops and city transportation. Therefore, this approach reduces waiting times and schedules to overcome challenges posed by passenger accumulation for structured campus transportation services.**

Keywords*— *Shuttle Bus; Genetic Algorithm; Campus Area; Minimize Waiting Time; Scheduling; Optimization.

I. INTRODUCTION

Several large cities have initiated to enhance and utilize advanced technology in computing and communication, as well as big data analysis, to improve operational efficiency and service [1]. A smart city needs to ensure that its transportation system has broad and effective coverage, allowing services and schedules to be dynamically modified in real-time. Consequently, this ensures that the smart transportation system enables passengers to reach their destinations punctually [1], [2], especially within the campus area. School Bus Scheduling (SBS) is part of the vehicle route planning (VRP) problem designed to optimize the use of school buses[3]. Developing intelligent transportation through specialized technology requires a thorough evaluation of transportation infrastructure facilities utilizing state-of-the-art engineering equipment[4]. These could include sophisticated photo and video surveillance capable of identifying material objects with high precision, laser scanning, as well as intelligent support systems and decision-making mechanisms that seek solutions through digital data processing from various sources[5]. Through the development of widespread mobile technology and cellular networks, real-time vehicle tracking has become achievable for efficient traffic management. The implementation of intelligent vehicle systems helps mitigate long waiting times for shuttle bus [6]. In the present time, drivers rely on Global Positioning System (GPS) based navigation systems to travel on roads more efficiently[7], [8]. Vehicle navigators can take the form of specialized devices installed on dashboards or applications on smartphones and other mobile devices[9].

In this study, the issues addressed include passenger congestion at stops and long waiting times at stops within the campus area. This case study takes place at one of the state universities in Central Java, specifically at Universitas Negeri Semarang (Unnes) which studied the shuttle bus system and bus stops on campus with operating hours from 6 AM to 6 PM. To address this challenge, smart transportation needs to provide an optimal number of vehicles to accommodate passenger volume and minimize waiting times. To support this goal, coordination systems between stops and public vehicles are necessary, including schedule adjustments during peak student hours. By utilizing genetic algorithms as a supporting recommendation system, similar public vehicles can be summoned at stops with high passenger capacity within the campus area.

The paper is structured as follows: Section 2 provides the literature review and Section 3 explains the methodology employed to reduce waiting times and develop a scheduling system using genetic algorithms. Section 4 offers a discussion of the findings, including recommendations for future studies, and Section 5 provides conclusion of the paper.

II. LITERATURE REVIEW

As explained in the introduction, smart cities require technologies that improve operational and service quality. This research considers several issues that are further classified into different categories: minimizing passenger waiting time and fleet deployment recommendation systems in surge trends. Consequently, in this part, the research reviews the literature relevant to the topic of this paper: improving service by

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recommending fleet deployment at specific times to reduce passenger waiting time at bus stops. Using genetic algorithms to solve the problem.

A. Bus runs and shuttle bus planning optimization

Each day, a designated bus is assigned a schedule for its run. As depicted in Figure 1, there are multiple shuttle bus runs throughout the course of a typical day's traffic, with certain shuttle buses operating from 6 AM to 6 PM and others solely during the morning and afternoon rush hours.

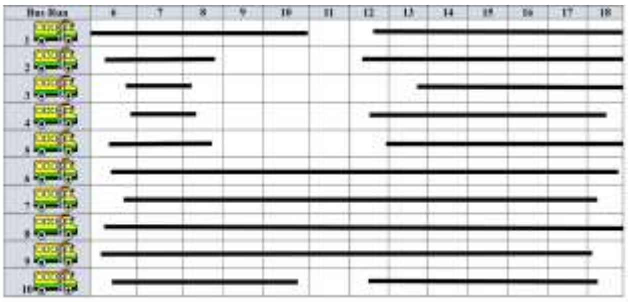


Figure 1**:** This chart displays the bus runs during typical traffic hours (6 a.m. to 6 p.m.). Each row represents a numbered bus route. (1, 2, 3, etc.). The vertical axis displays the numbered bus run, while the horizontal axis shows the time of day.

A bus shuttle line is a design transportation route with several stops that allow passengers to travel between distinct locations. For the purpose of this paper, a school bus refers to a bus route exclusively available for pupils and funded by the local government. Meanwhile, a bus trip pertains to a single journey from one end stop to the other on a specific bus route.

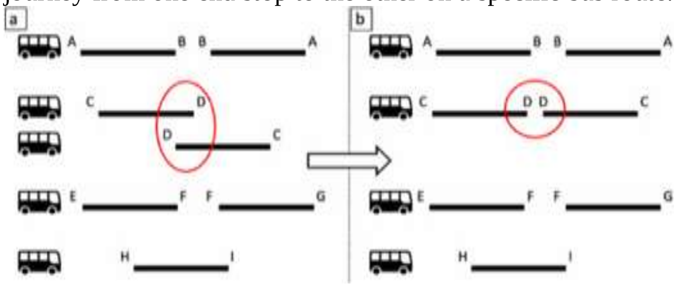


Figure 2: Figures 2a and 2b illustrate the impact of departure time adjustments on bus requirements. In location D, two bus trips overlap, requiring two bus runs (Fig. 2a). Illustrated in Fig. 2b, adjusting the departure times covers both trips within a bus line.

In Figure 2 bus schedule and driver assignments are optimized based on cost and preferences using shuttle bus planning software. When it comes to planning bus routes, key factors taken into account encompass the seamless connection of different routes, the appropriate vehicle type, the appropriate duration for which a specific vehicle should operate, providing information on the duration of each stop (dwell time), and the duration between two trips (layover time). The optimization procedure strives to minimize idle time and unnecessary kilometres, meaning periods when the vehicle isn't actively serving a bus line.

The other research discusses [10] Utilizing a similar heuristic optimization method (Hybrid Bee Colony Optimization) to solve a two-level model in transit network design. The transit system uses a two-level approach to determine routes and frequencies while minimizing passenger transfers and travel time. At the upper level, an objective function is combined to calculate the best routes for each transit line. At the lower level, a simulation is run to determine passenger route choices based on the transit routes from the top level. This simulation follows a transit operating model with capacity barriers and aims to minimize total travel time for transit users. Developed schedules with uniform time intervals while incorporating additional objectives to coordinate passenger transfers[11], [12]. However, this model cannot respond directly to real-time changes in travel conditions and does not account for changes in travel time during real-time operations. Several other models[13] in the effort to optimize schedules have focused on maintaining uniform travel delivery times throughout the day. For instance, aimed to achieve an even workload for all buses when they reached full capacity by determining travel delivery times that were not too far from the desired even time differences.

Different fields of work recognize scheduling issues through distinct lenses, notably stochastic optimization. This approach combines travel time factors and passenger request fluctuations when establishing daily travel delivery schedules in the tactical planning phase (as reported by Xuan) [14]. However, implementing these stochastic models in real-time operations is not possible using computational methods, so control methods that estimate the optimal delivery policies are usually used instead [15].

Based on the provided information, the work that most closely resembles ours was produced by [16] which discusses the problem of scheduling freight trains with similar objectives this research aims to minimize the complete waiting time for departure equivalent to minimizing space usage and maximizing turnover.

B. *Increase in passengers*

By modifying departing times, resources that are saved can be redirected towards reinvestments in the local transport system. This could lead to an expansion of the shuttle bus services available. Additional studies have indicated that the Mohring effect exerts a greater influence on buses during off-peak travel times, as opposed to rail and subway systems, which are more affected during peak hours[17].

The correlation between fluctuations in passenger quantities and the availability of shuttle buses can be explained using the concept of elasticities. Elasticity is a way to measure how changes in one variable impact demand, such as the relationship change in the percentage of public supply. transportation and the corresponding percentage change in the number of passengers. The formula for supply elasticity is as follows:

$$\varepsilon_s = \frac{\%\Delta N}{\%\Delta S} \qquad (1)$$

In this context: ε_s Represents the supply elasticity. $\%\Delta N$ means the percentile change in the number of boarding passengers. $\%\Delta S$ means the percentage change in public transport supply. For example, if the supply elasticity is 0.4, it means that a 10% increase in public transport supply will result in a 4% rise in the number of passengers.

Passenger waiting times within a transit system are influenced by several factors, including passenger types (planned or unplanned, commuters or non-commuters), service types (schedule-based or frequency-based, high or low frequency), and time of day (peak or off-peak periods)[2], [18].

In a recent Swedish case study, it was determined that augmenting the frequency of rural public transport during off-peak hours led to a noteworthy surge in passenger numbers. Interestingly, this surge was predominantly observed during peak hours. The study found that an increase in the availability of public transport had a greater impact on demand for transportation services, as the long-term supply elasticities were greater than 1 [2] [19].

III. METHODOLOGY

In this research, a genetic algorithm was employed as the primary approach. The collection of data was conducted by obtaining various measurements from the correlated devices. This research conducted an in-depth exploration of various aspects relevant to the existing issue. The analysis results were based on the data associated with these aspects. Details regarding the steps taken in this research methodology can be found in Figure 3.

This research was conducted in several stages, beginning with a literature review within the local campus environment. Then, a problem-solving system was designed for the campus area, followed by implementation using MATLAB to achieve optimal results.

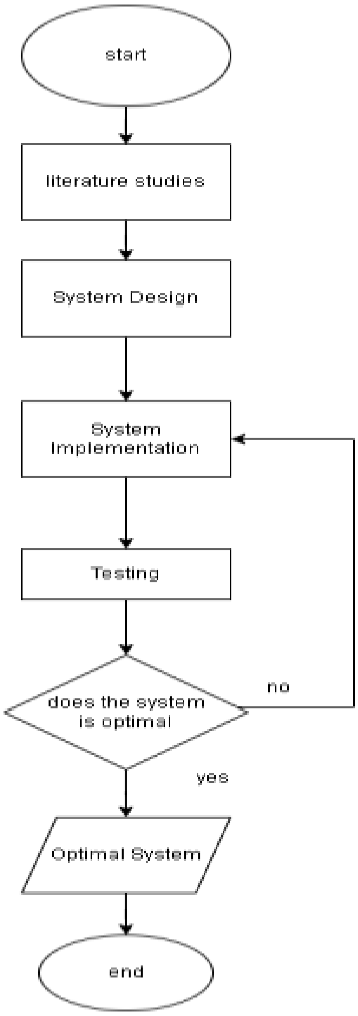


Figure 3: Research Methodology

A. Data collection and preprocessing

This section will delve into the importance of data in research and the necessary steps for its preparation. Moreover, provides a comprehensive explanation of the process involved in making the data usable. A visual representation of the data preparation schema is depicted in Figure 4, with further elucidation provided in the subsequent sections.

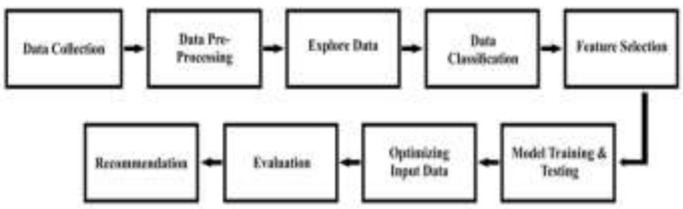


Figure 4: The schema for Data Preprocessing

Each bus was equipped with GPS devices that tracked their location at specific intervals. Additionally, the buses were connected to both 4G and Wi-Fi networks to consign the data in real-time. However, as a backup in case of network issues, the data was also stored in a memory unit on the bus. It's worth noting that the GPS devices only collected data at scheduled times as the buses were primarily at the terminus during other times [20], [21].

Figure 5: A Sample of Map Mapping of Shuttle Bus in Campus Area

This transportation system has several important characteristics. Firstly, the maximum speed achievable by this smart transportation is around 19 km/h. Although not as fast as other public transportation options, this speed is adequate for facilitating mobility within the campus. Furthermore, this transportation has a passenger capacity of 13 individuals. This capacity may be sufficient to accommodate most transportation needs within the campus during peak hours.

The travel duration within the campus area using this smart transportation is approximately 15 minutes. Within this timeframe, the transportation can cover a total distance of 3.42 km. The total overall travel time, including waiting and journey time, is approximately 19 minutes. Additionally, this smart transportation system has stops at each faculty within the campus. The total number of stops available is 14. The presence of these stops greatly facilitates the accessibility for campus users to board and alight from the transportation comfortably and efficiently.

Overall, the smart transportation system in the campus area significantly contributes to supporting mobility and connectivity within the campus environment. It provides a relatively fast, efficient, and easily accessible service for campus users.

B. Problem description

The considered issue involves the scheduling of smart transportation within the campus area, which entails the unstructured departure schedules of these smart vehicles. The availability of these intelligent vehicles relies on both the driver's condition and the state of the campus, which can lead to delays for passengers waiting at bus stops if scheduling is not monitored properly. This may result in long queues. The proposed plan involves monitoring smart vehicle scheduling in real-time at every bus stop within the campus area. This will allow for the calculation of the minimum total waiting time for passengers based on trends at specific times. Additionally, the plan will present a fleet that caters to the increasing number of passengers during peak times.

To determine the optimal timing to send vehicles during each time period, a model is necessary for managing electric vehicles. Within this framework, there are several key assumptions that govern the movement of electric vehicles within the campus area:

(1) All shuttle buses only operate within the campus area.

(2) Passenger arrivals at bus stops are random as their timing cannot be regulated in transportation services.

(3) In campus services, the vehicles called will come more frequently to accommodate all passengers based on their needs.

(4) When buses stop at bus stops, the time it takes for passengers to get on greatly influences delays, while disembarking passengers runs more quickly.

(5) Every shuttle bus has one bus driver to operate. Bus drivers cannot work more than working hours.

From the description above, the decisions to be taken are as follows:

1. Determine a certain time period by adding the number of fleets on smart vehicles and scheduling in real-time
2. Determining which bus stops often reach the highest passenger capacity is a top priority in improving service quality.

C. Objective Function

Our research is centred on high-frequency services that aim to ensure consistent service. For instance, a previous study [2] explored the approach of decreasing the total waiting time for passengers by reducing the squared difference between arrival times. Similarly, our study strives to minimize the time that passengers spend waiting at bus stops. This can be achieved by minimizing the total time that passengers arrive and depart from the stop.

The notation used in this research is as follows.

Time Delay

$$W_{tn} = \sum_{i=1}^{n} (P_{turun\ i} + P_{halte\ i})\ x\ W_{pn} \tag{2}$$

Arrival time at the next stop

$$W_{dt} = \sum_{i=1}^{n} \frac{S}{V_{20,25}} + W_{tni} \tag{3}$$

TABLE 1
NOTATION FORMULA

n	=	number of stops that electric vehicles pass
P_{turun}	=	number of passengers getting off at bus stop-i
P_{halte}	=	number of passengers getting on at bus stop-i
W_{pn}	=	the time each passenger gets on/off
S	=	distance between the i-stop and the next stop
$V_{20,25}$	=	speed of electric vehicles is between 20 and 25

W_{tn}	=	time delay at stop-i
W_{dt}	=	arrival time at the next stop

D. Design system

From the provided framework, it can be explained that his research pertains to the communication between bus stops and smart vehicles within a campus area as in Figure 6. It involves inputs and outputs that integrate bus stops with smart vehicles. Inputs generated from both bus stops and smart vehicles are initially received by a central entity. Under the given conditions, the central entity processes these inputs using a genetic algorithm, and the results are then displayed back to the bus stops and smart vehicles.

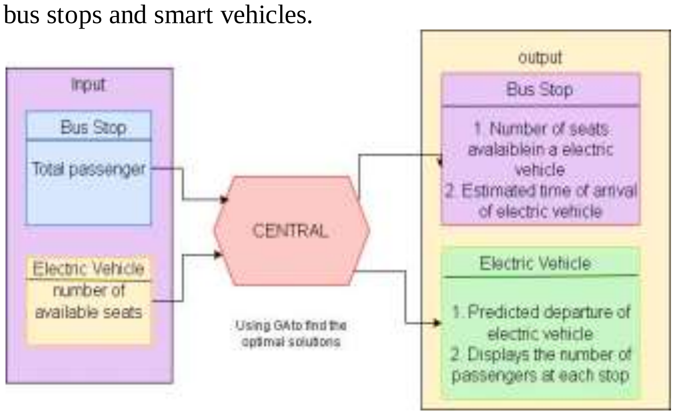
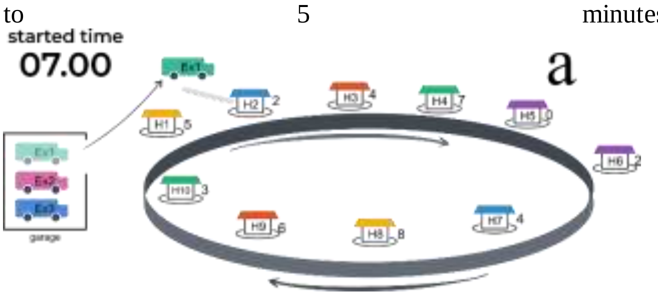
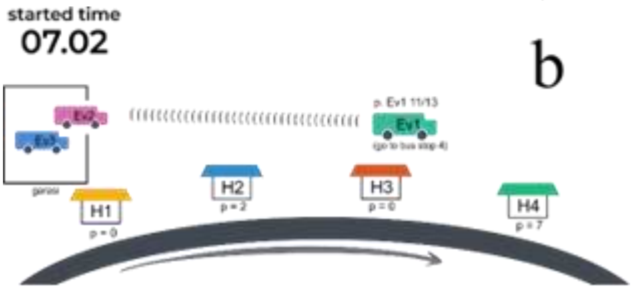


Figure 6: Research Framework

In the research illustration (Figures 7a and 7b), it is explained that certain time periods will result in an increase in passenger volume at bus stops and intelligent electric vehicles. Following the trend of passenger density in the campus environment, where there is a busy time from 6.30 to 8.30 in the morning, traffic flow becomes less conducive. Thus, this research provides an appropriate solution by implementing a recommendation system at bus stops experiencing passenger congestion during specific times, by calling or summoning intelligent electric vehicles to those stops. This system minimizes passenger waiting times, with the electric vehicles generally arriving on a scheduled basis every 10 minutes. However, due to high passenger density during specific hours, the system will recommend summoning smart vehicles every 4 to 5 minutes.





.
Figure 7: (A) Electric Vehicle 1 (EV1) exits the garage and searching for nearest stop, and each bus stop send data on pasengers ariving to the bus. (B) Then, if Electric Vehicle exceeds the passenger capacity (13), Electric Vehicle will recommend the next Electric Vehicle (Ev2) to go to the bus stop. Because in the Bus Stop 2 (H2) there were 2 passengers arriving, the next Vehicle Electric went stop in Bus Stop 2 first.

E. Genetic Algorithm

Genetic Algorithm is a search algorithm that imitate natural selection and evolution in biology. It seeks the best solution through individual selection, crossover, mutation, and evolution. Its strengths include intelligence, parallel operations, general working ability, and the ability to achieve global optima without prior information. However, it has a weak local search ability. Nevertheless, it excels in comprehending and executing the entire search process [22], [23], [24], [25].

A study on urban transportation has identified a two-step decision-making process involving route design and bus assignment. The main goals of this process are to meet passenger needs and improve service quality. The results of the analysis show that both the local search algorithm and the simple tabu search algorithm provide significantly better solutions than the ones currently in place. However, when using different algorithms, it is possible to reduce waiting times by assigning more weight to them. Despite this improvement, waiting times are still longer than travel times. Reducing waiting times leads to longer travel times.[25].

The Genetic Algorithm method utilized can optimize passenger wait times by increasing the shuttle speed variable and reducing the boarding/alighting time for each passenger through mutation processes. Consequently, it can yield an improvement in the shuttle speed variable and a reduction in passenger boarding/alighting time, generating optimal new genes.

(a). Single-Objective Optimization

During the first phase, the process begins with an initial population which includes individuals or chromosomes. Each individual is portrayed as a set of genes that represents potential solutions. Moving on to the next phase, each individual in the population is assessed based on how well they satisfy the optimization objective. Choosing individuals with higher fitness values gives them a better chance of being chosen. In the Crossover phase, the chosen pair of individuals will merge their genetics. The production of offspring involves the exchange of chromosome fragments between two individuals, leading to a stochastic process in which certain genes in an individual's chromosomes undergo mutations. This process plays a crucial role in maintaining genetic diversity within populations. Additionally, the selection of the fittest individuals for reproduction contributes to the preservation of diversity. Following the optimization process, the best solution is chosen as the final outcome, representing the individual with the highest level of fitness among all candidates in the final population[26], [27], [28].

TABLE 2
GENETIC ALGORITHM. STEPS OF THE PROPOSED ALGORITHM

Genetic Algorithm. Steps of the proposed algorithm

Input: Number of passengers
Output: Display the number of passengers at each stop

```
Initial Population
P= fittest chromosomes
for each parameter do
    Evaluation
    Selection
    Crossover
    Mutation
    Survivor selection
End
return the super best solution
```

GA is utilized to reduce passenger waiting time at bus stops. The algorithm selects the best solution for each parameter through selection and mutation, resulting in an optimal outcome.

F. Analysis method

To conduct research on the shuttle bus, we observe and study local campuses and cities that support it. In order to gather the necessary data, we follow several stages as outlined below.

1. Data collected

Data is collected via an app that calculates vehicle speed, travel time, distance between stops, and passenger capacity.

2. Recapitulating Data

The survey data is collected and filtered based on relevant groups for this research.

3. Processing Data

Processing data involves adjusting the acquired data with the chosen analysis method. If the obtained data is incomplete, it is necessary to retest and collect additional data to ensure it can be adequately analyzed.

G. System Programming

The system program is implemented using Matlab, aligning with the designed flowchart. This software enables the creation of efficient algorithms to manage and optimize the smart transportation system, ensuring seamless coordination between stops and vehicles to enhance passenger experience within the campus. The code is available at https://github.com/farrelekaputra/CodeShuttleGA.

IV. RESULTS AND DISCUSSION

A. *Case Study*

Our case study revolves around a regional campus area located in Central Java, featuring a 14-stop shuttle bus system that runs from 6:00 AM to 6:00 PM. The route spans 4 kilometres in length, with an estimated travel time ranging from 15 to 20 minutes. The shuttle maintains speeds between 15 and 25 kilometres per hour.

The local campus area was chosen as a case study because it has a shuttle bus system with a high frequency of service. The operator of the system is interested in improving the regularity of service, which is also the objective of our proposed dispatch control method. The shuttle bus system in this area has enough shuttles to meet the demand, and the number of passengers waiting for a shuttle is low. The time it takes for a shuttle to stop is primarily determined by the number of passengers boarding or alighting. The average time to load or unload an additional passenger is 60 seconds.

The local campus area was chosen because it has high-frequency routes that monitor in terms of service regularity. The bus operator's objective aligns with the delivery control method we propose to enhance service regularity. The planned service offering is sufficient, and the number of waiting passengers is very low. Moreover, the stopping time depends primarily on passenger boarding and alighting (the average observed time for an additional passenger is 60 seconds).

The topology of the shuttle bus routes within the campus area is presented in Figure 5. The shuttle bus routes serve as feeder services connecting various faculties or buildings around the campus, as well as public facilities, linking them to the nearest bus stop, commonly referred to as Bus Rapid Transit (BRT). The primary service area encompasses environments with high-capacity articulation due to the high demand from students at specific times of the day, with a seating capacity of 13 passengers. As depicted, the scheduled intervals (targets) vary between peak and off-peak hours. It is important to note that from 06:30 to 09:00, there will be a high frequency, and assume passenger arrivals are evenly distributed at each bus stop, as passengers cannot coordinate their arrival times with the bus schedule.

TABLE 3
SCHEDULE HEADWAYS

Scheduled headways of electric vehicle lines at different times of the day in minutes.	
Period	**Target Headway (minutes)**
06:00-06:30	-
06:30-08:30	4
08:30-15:00	8
15:00-17:00	4

B. *Passenger Waiting Time Efficiency at Bus Stops*

From the survey conducted at the local university, the following results were obtained:

TABLE 4
BUS SHUTTLE BEFORE OPTIMIZATION

Before Optimization	
Max Speed	19km/h
Passenger Capacity	13 passengers
Travel Duration	15minute
Total Distance Traveled	3,42km
Total Travel Time	19minute

After optimization, the campus shuttle bus results in the table below:

TABLE 5
BUS SHUTTLE AFTER OPTIMIZATION

After Optimization	
Max Speed	35km/h
Passenger Capacity	13 passengers
Travel Duration	7minute
Total Distance Traveled	3,42km
Total Travel Time	10minute

Previously, the transportation system relied on manual methods without any updates. However, with this research, the transportation system has been improved through the implementation of genetic algorithm methods, which have proven effective in reducing passenger waiting times.
Based on the data in Table 4 before optimization, the total travel time from start to finish was 19 minutes, with the journey itself lasting 15 minutes and a total waiting time of 4 minutes. The maximum speed of the bus was 19 km/h, with a maximum passenger capacity of 13 people. Although the travel distance was only 3.42 km, the relatively long travel time indicated potential for improving the efficiency of the transportation system on campus.

After optimization in Table 5, there was a significant improvement in the performance of the transportation system. The total travel time was reduced to just 10 minutes, with a shorter journey duration of only 7 minutes and a waiting time reduced to 3 minutes. The maximum speed of the bus increased to 35 km/h, but the passenger capacity remained the same at 13 people. Despite the unchanged travel distance, the increase in speed and the reduction in travel and waiting times indicate that the optimization has successfully improved the overall efficiency of the transportation system.

From the data, it can be concluded that the survey results indicate that optimizing the transportation system using genetic algorithm methods has resulted in a significant improvement in travel and waiting times for passengers on campus. This research offers a method like this to enhance campus services and further develop the transportation system in the campus area.

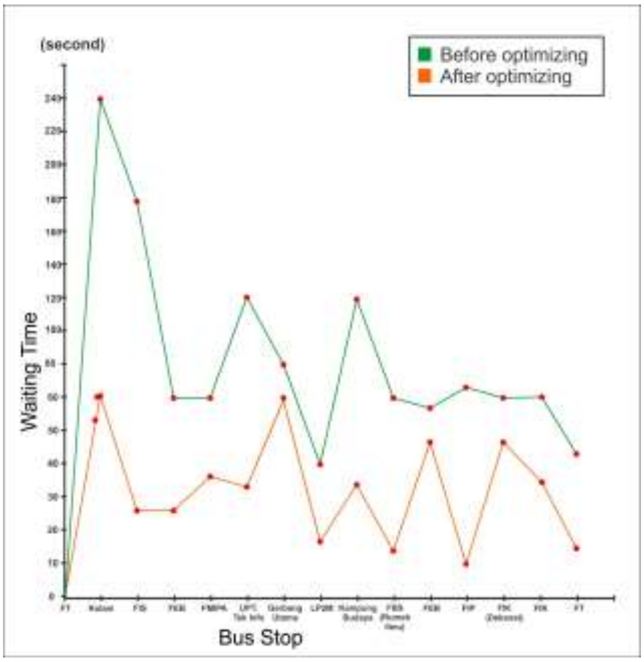


Figure 8: Result Optimization

This research aims to address the issue of passenger congestion at each bus stop by implementing a shuttle scheduling method. This approach utilizes a Genetic Algorithm (GA) to optimize passenger waiting times by utilizing data on the number of passengers at each stop and transferring this information to the relevant shuttle. Furthermore, through the inter-shuttle scheduling system, when the first shuttle reaches maximum capacity, the system will call the next shuttle to pick up passengers at that stop. This process repeats until all passengers at the stop have been transported.

With the implementation of this scheduling system, coordination between shuttles can be well-maintained, thus avoiding passenger congestion. Another positive impact of this system is the significant increase in average bus speed by approximately ±107%, reaching a speed of 27km/h. This is highly significant in improving transportation efficiency in the campus area. Additionally, this approach also leads to a reduction in passenger waiting times at stops by approximately ±80%, ensuring passenger comfort, safety, and security.

The application of these various strategies has brought about significant positive changes in the efficiency and quality of transportation services in the campus area.

C. *Monitoring Shuttle Scheduling System*

The outcomes of this research are capable of suggesting that the next shuttle bus should arrive at bus stops with excess passenger capacity. This scheduling system is closely tied to the efficiency of passenger waiting times. Within this

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recommendation system, the quality of service can be improved and scheduled effectively, enhancing overall service quality.

- If Shuttle 1's passengers exceed its capacity

```
— Announcement for Shuttle 1 ---
The next stop is bus stop 1.
There are 16 passengers at bus stop 1.
Apologies, the shuttle is full. 3 passengers can wait for the shuttle 2.
```

The output indicates that when the number of passengers in Shuttle 1 reaches its capacity (13), the next shuttle will be activated.

- If three stops have been passed without reaching capacity

```
— Announcement for Shuttle 1 ---
The next stop is bus stop 1.
There are 16 passengers at bus stop 1.
Apologies, the shuttle is full. 3 passengers can wait for the shuttle 2.
```

The above output describes a scenario where if Shuttle 1 arrives at the third stop without reaching its maximum capacity, the next shuttle (Shuttle 2) will start from the first stop.

- Genetic Algorithm (GA)

```
Best individual: [ 2  5 13]
```

The program demonstrates an initial approach to implementing a genetic algorithm in Python. Its objective is to identify bus stops based on the highest number of passengers.

D. *Program Implementation in MATLAB.*

- When the shuttle reaches its passenger capacity

```
The next stop is bus stop 4.
Apologies, Shuttle 1 is already full.
The nearest stop after this is: halt 3, which is 200m away.
Shuttle 1 will depart after
00:00:03
```

The outlined scenario indicates that if the number of passengers at a bus stop surpasses the shuttle's capacity, the overflow (e.g., 3 passengers) will be accommodated by the subsequent shuttle.)

- Scenario when the first shuttle operates for 3 minutes and is still not at capacity

```
— Announcement for Shuttle 2 ---
Shuttle 2 is leaving the garage.
There are 13 passengers waiting at bus stop 1.
The next stop is bus stop 1.
Currently, there are 13 passengers at bus stop 1.
Apologies, Shuttle 2 is already full.
1 passenger can wait for the Shuttle 3.
The next closest stop is: halt 2, located 240m away.
Shuttle 2 will depart shortly.
```

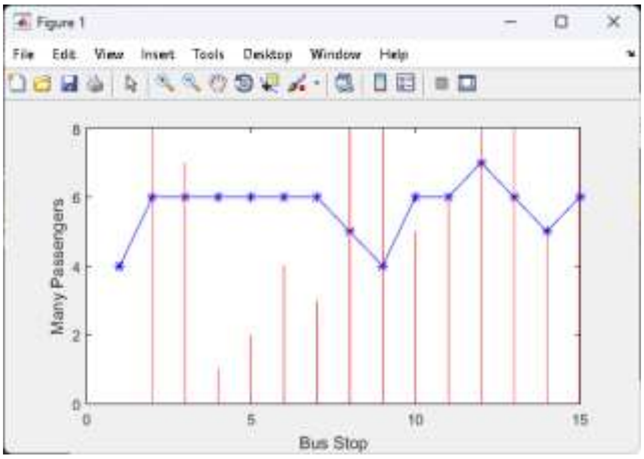
In the situation described, if the program has been running for 3 minutes and the shuttle still hasn't reached its passenger capacity, the following shuttle will depart.

- Alternative Method

```
— Announcement for Shuttle 1 ---
There are 12 passengers waiting at bus stop 2.
The next stop is bus stop 3.
The current number of passengers on the shuttle is: 13.
The stop after this will be: halt 3, which is 200m away.
Shuttle 1 will depart shortly.
```

According to this method's output, the GA will suggest the bus stop with the most passengers, directing the shuttle immediately to that particular stop.

- Genetic Algorithm Graphic Output in MATLAB



In this graphic representation, the number of passengers at each stop is denoted by a blue line. Concurrently, the red line signifies the fitness value at every stop.

E. *Future Studies*

The results of this research have provided clear findings, there is still considerable potential for future development. Subsequent studies may explore combining Genetic Algorithms with other algorithms to schedule and make decisions regarding locating stops with the highest passenger density, as well as implementing a more adaptive system considering future conditions.

V. CONCLUSION

Based on the results obtained from this research, it provides convenience in transportation within the campus area. Smart electric vehicles will coordinate with stops that have excessive passenger capacity, and the scheduling system will immediately dispatch the appropriate smart electric vehicle to accommodate the number of passengers to prevent overcrowding. This system aims to minimize the waiting time for passengers at stops and provide good and scheduled service quality. The implementation of a genetic algorithm is intended to provide an optimal scheduling system for shuttles, where the analogy of passengers at each stop represents the population and the fitness value is the passenger capacity of each shuttle. This is then combined with a scheduling system between stops, which can serve as a solution to passenger congestion at stops, resulting in an approximate 80% reduction in time efficiency. Several factors influencing this optimization include the addition of shuttle speed and coordination system among shuttles.

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