Department of Electrical and Computer Engineering

North South University

Junior Design Project

An Efficient In-Campus Shuttle Bus Operation Model

Course: CSE 299

Section: 1

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Group: 3

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ABSTRACT

Universities around the world have large-sized premises. Some are so big that students need to rely on in-campus bus services to reach one department building to another. Now, where there is a matter of bus service, efficient routing and steps to ensure on-time arrival are bound to come up. And a regular model that's based on the distance of one building to another is not nearly enough for such scenarios. In this project, we aim to come up with a model that will not only meet the requirements of such bus services but also excel in fulfilling the limitations that the existing projects have left out to improve on. Some examples of those limitations are handling peak hours better, considering special cases where the bus needs to take a different route than usual, and considering different time frames, such as learning weeks and exam weeks. Our proposed models aim to achieve all these limitations and specific needs of such services by making it easier for the students and staff to move from one building to another, ensuring on-time arrival, and precisely predicting peak hours and managing them accordingly. The model also focuses on lowering trip counts, managing exceptional cases, and minimizing waiting time.

CHAPTER 1: INTRODUCTION

Simple shuttle services stick to a straightforward model. Those have a fixed arrival time and a specified starting time. Such an approach not only fails to address on-time arrival issues but also makes it stressful for the users. Our model will circumvent such types of problems and offer something that will minimize all hassles. But to thoroughly understand what the model will end up functioning like, it is crucial to know each key term. And this chapter aims to shed light on them.

1.1 Why Efficient

Making any efficient means to accomplish a given task in such a way that it maximizes output while minimizing output. However, in our model, efficiency refers to the overall operation of the bus service. That is, in the context of the title, an efficient in-campus shuttle bus operation model refers to a model that excels in providing transportation services in a manner that maximizes the benefits while minimizing the cost.

1.2 What's An In-Campus Shuttle Bus Operation

In-campus shuttle bus operation refers to a system of transportation that is designed to provide transportation services confined within the premise of the campus. The primary goal of such services is to provide a safe, reliable, and efficient transportation medium that will make it easier for the students and staff to reach from one key building to another. Generally, a simple in-campus shuttle bus operation service is designed to transport passengers on a fixed route, often with multiple stoppages.

1.3 What Does "Model" Stand For

At the core, the model refers to a functional system that understands, analyzes, and predicts the behavior of a real-world problem. [1] When it comes to our project, a model refers to a system that will optimize the in-campus shuttle bus operation and improve the efficiency of simple available models.

1.4 Aim and Objectives

The main aim of this project is to come up with a generic and user-friendly model that is suitable for all large-scale universities. And when it comes to objectives, the model will address and fix most of the issues present in a simple in-campus shuttle bus operation model, optimize it, and offer something that will be much more efficient. In short, it primarily focuses on improving the transportation system within a campus, eventually enhancing the quality of the campus's transportation service.

CHAPTER 2: BACKGROUND STUDY

Before diving into the project, we decided to do some background study. Through that, we were able to gather information on previous projects that surrounded the same idea, which allowed us to get a deeper insight into what such a model actually demands. This chapter will summarize all the research papers we have gone through and highlight their key findings.

2.1 Relevant Study

This segment will summarize the research papers we have taken a look at before starting the project.

2.1.1 Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis: A Case Study [2]

This case study goes through the utilization of smart technology and machine learning algorithms to improve transport management. The focus of the study is on predicting travel time, gas emissions, and fuel costs for a university shuttle bus system. To come up with a better system, the paper went through Artificial Neutral Network (ANN) and Support Vector Machin (SVM) algorithms on the project. The researchers compared the performance of both algorithms and used a recommender system to suggest suitable routes for the system.

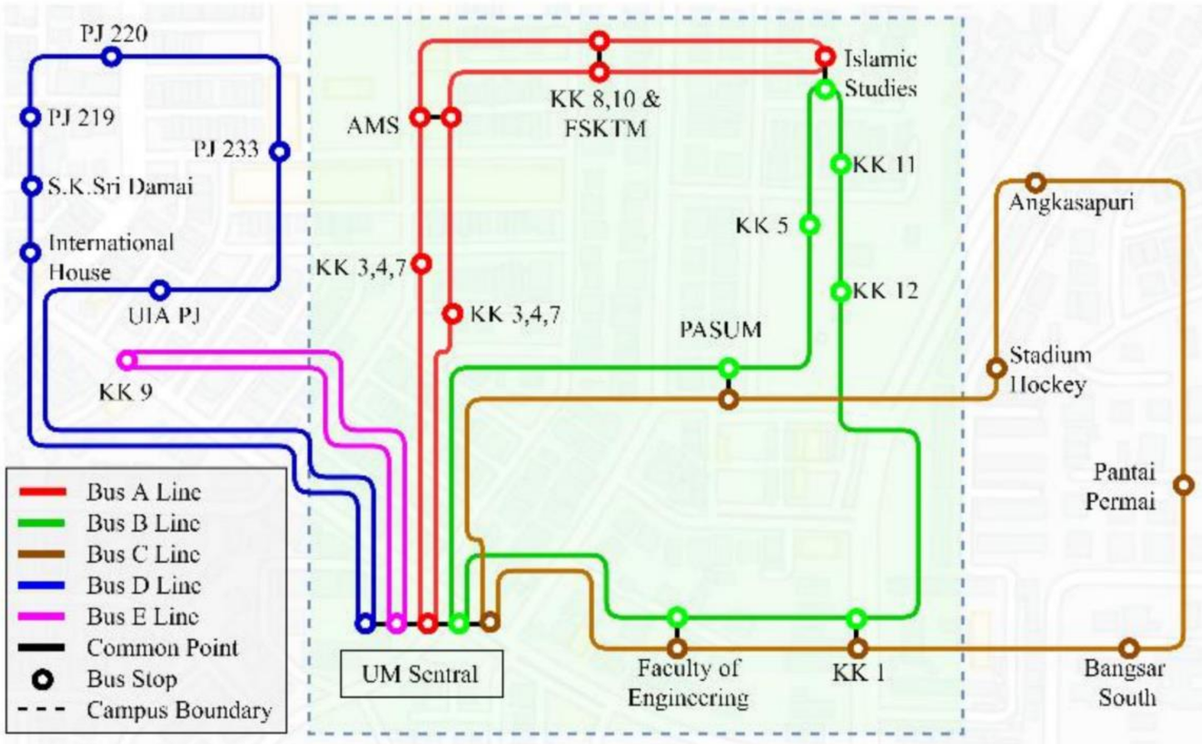

Figure 1: Visual Representation of the working bus routes

After evaluating the performance of the ANN, SVM, and recommendation system, the paper went on to discuss how the use of models allowed the project to reach its main goals. The suggested end model significantly reduced gas emissions, fuel consumption, and travel time. Among the main highlights, the recommendation system enhanced the quality of service, which has been backed up by key research findings.

Bus Routes	Peak Hour (Sec)			Non-Peak Hour (Sec)		
	Before	With ANN	With SVM	Before	With ANN	With SVM
A	1572.15	1616.37	1797.15	1144.50	1164.33	1299.50
B	1350.45	1362.23	1470.45	1078.43	1043.15	1140.22
C	2606.11	2570.39	2759.11	1620.33	1675.18	1670.45
D	1960.22	1975.22	1990.14	1276.29	1306.24	1389
E	1031.10	1058.12	981.19	785.29	813.57	765.12

Table 1: Comparison of travel time with before, ANN, and SVM

The paper also compared the data obtained with the root means score error (RMSE) formula. Through that, the study shed light on the performance evaluation of the overall prediction accuracy.

Bus Routes	RMSE (Sec)			
	ANN		SVM	
	Peak Hour	Non-Peak	Peak Hour	Non-Peak
A	112.5	77.5	22.1	9.91
B	60.0	30.9	5.8	17.6
C	76.5	25.0	17.8	27.43
D	14.9	56.3	7.5	14.98
E	24.9	10.0	13.5	14.14

Table 2: Comparison of the prediction accuracy

Overall, the results of the study showcase that the ANN model performs better than the SVM model. And with the recommendation system, the model was capable of bringing more improvements to the table. The study ends with offering suggestions for future work. Mostly, the suggestions were the limitations of the study, which included the consideration of extreme peak hours, exams and break times, special cases, and traffic congestion.

2.1.2 Optimizing University Campus Shuttle Bus Congestion Focusing on System Effectiveness and Reliability: A Combined Modeling-Based-Routing Approach [3]

The paper addresses the problem of increased vehicle queuing within university campuses. This causes inconvenience to staff and students. In order to reduce congestion and improve system reliability, a model-based routing and optimization approach is proposed. A bi-objective goal programming optimization model is developed to select the best alternative routes for the university shuttle bus service during peak hours. As a case for the model implementation, the shuttle bus service network of Qatar University is used. A Monte Carlo simulation is performed to verify the daily bus capacity. A sensitivity analysis is performed to identify the most sensitive bus stops. The selected routes meet the daily demand of the stations, and the proposed alternative routes could improve the system efficiency by 75%.

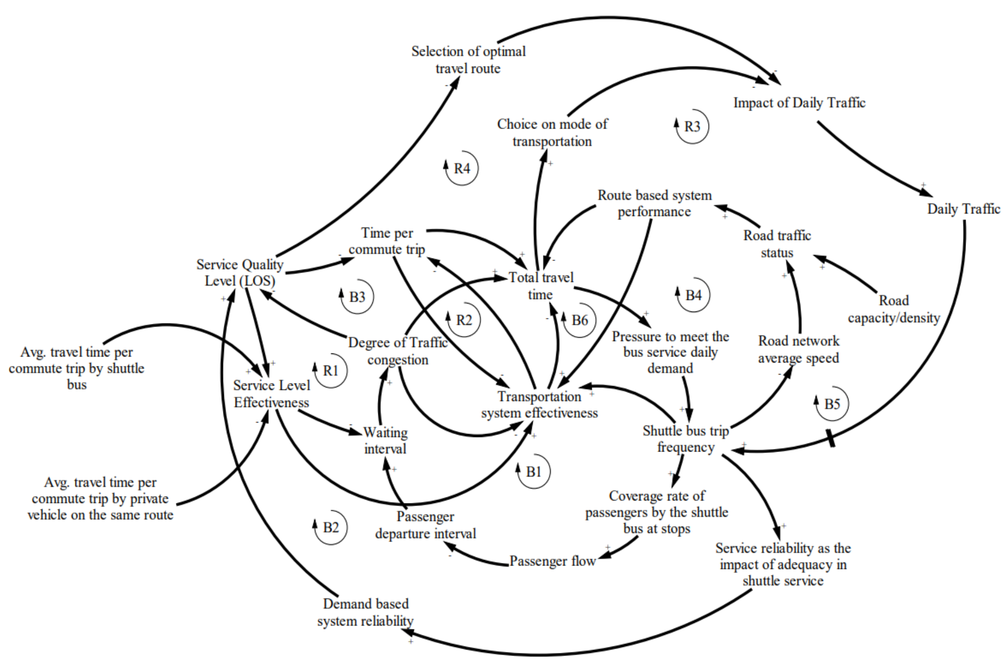

Figure 2: Conceptual model for the effectiveness of shuttle bus service with congestion dynamics

The paper concludes by discussing how to improve the effectiveness and reliability of shuttle bus transportation systems within university campuses using systems thinking and optimization models. The study used Qatar University as a case study. Alternative routes were proposed to reduce traffic congestion and improve system performance. The best routes with the least travel time and distance were identified using the proposed objective programming model. The sensitivity analysis identified the most sensitive stations and the study found the best-performing route for the bus services. The authors provided recommendations to improve the shuttle bus service level based on the study results. These recommendations included adopting short-term measures to enhance the quality of service, efficiency, and reliability.

2.1.3 Campus Bus Network Design and Evaluation Based on Route Property [4]

With a focus on minimizing costs for both passengers and operators, this paper discusses the design and evaluation of a campus bus network at Tsinghua University. The paper proposes a sequential approach to planning the campus bus system, including designing the route network, optimizing headway, and evaluating the system. A non-fixed schedule is introduced to account for the variability in passenger demand, and an improved genetic algorithm is proposed to optimize the route network. A comprehensive evaluation system is developed using VISSIM to simulate the campus bus system. The proposed approach shows an improvement of 18.7% and 10.1%, respectively, compared to the current bus network and the one without consideration of the route characteristics, and the sequential approach shows an improvement in efficiency compared to the alternative method.

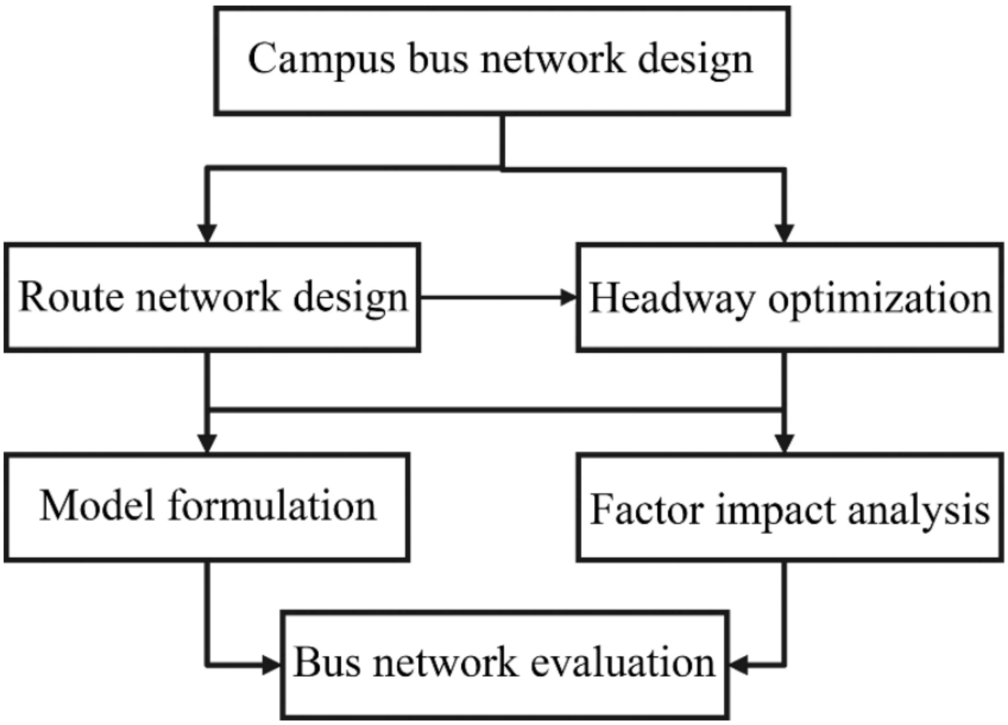

Figure 3: Framework for the campus bus network design

This paper presents a systematic sequential approach, including route network design, headway optimization, and system evaluation, for the design of a campus bus system at Tsinghua University. A genetic algorithm is used for the optimization of the bus routes under the consideration of the route characteristics and passenger demand fluctuations. Headway optimization also considers the identity ratio of passengers. An Analytic Hierarchy Process (AHP) evaluation system is developed to objectively evaluate bus route service level. The proposed approach can be applied to the design of bus routes with existing metro and BRT lines and shows a 54.7% improvement over alternative methods. The incorporation of real-time data to more accurately describe passenger demand can be a focus of future research.

2.2 Explanation of Key Terms

2.2.1 What is ANN?

Artificial Neural Networks (ANNs) use interconnected groups of artificial neurons. [5]. They utilize the groups to process information through a connectionist approach, which refers to the interaction between a large number of units in a network that is responsible for the emergence of higher-level information processing. [6]

2.2.2 What is SVM?

Known to be among the most popular Supervised Learning algorithms, Support Vector Machine (SVM) is used for classification problems as well as regression problems. [7] Here classification problem demands a result that's in an anticipated class label from a particular input data example. [8] On the other hand, the regression problem demands an output that offers a continuous numerical value. [9]

2.2.3 What is a bi-objective goal programming optimization model?

Bi-objective programming is a type of multiobjective optimization model that attempts to optimize two conflicting objectives simultaneously. [10] Multiobjective optimization is a branch of multiobjective decision analysis. It extends linear programming to handle multiple metrics. [11]

2.2.4 What is A Monte Carlo simulation?

Monte Carlo simulation, at the core, is a probabilistic numerical technique that is used to approximate the result of a particular process that is uncertain in nature. [12]

It is an approach to simulate events that can not be modeled implicitly. It is typically used when there are random variables in the processes. [13]

2.2.5 What is VISSIM Technology?

VISSIM, as a company, develops software, integrates systems, and delivers turnkey projects for the Offshore Wind, Offshore Power, and Maritime Surveillance industries. The company provides solutions to optimize the logistics of building and operating wind farms and improve sea safety. VISSIM, however, is a visual block diagramming program for simulating dynamic systems and model-based design of embedded systems using its own visual language. [14]

2.2.6 What is Analytic Hierarchy Process?

The Analytic Hierarchy Process (AHP) is a decision-making method for organizing complex decisions and then analyzing them using math and psychology. [15]

CHAPTER 3: METHODOLOGY

3.1 Overview

This chapter aims to introduce the steps, procedures, and techniques used to target the problem of In-Campus Shuttle bus operation. It introduces the overall system workflow through a system diagram and the introduction to the system model in detail that we will be working on. It further aims to describe the types and categories of data that we will be working with.

Here, through **Figure: 4**, we present a procedure diagram of the flow of our methodology, providing a clear understanding of the sequential steps taken in our approach.

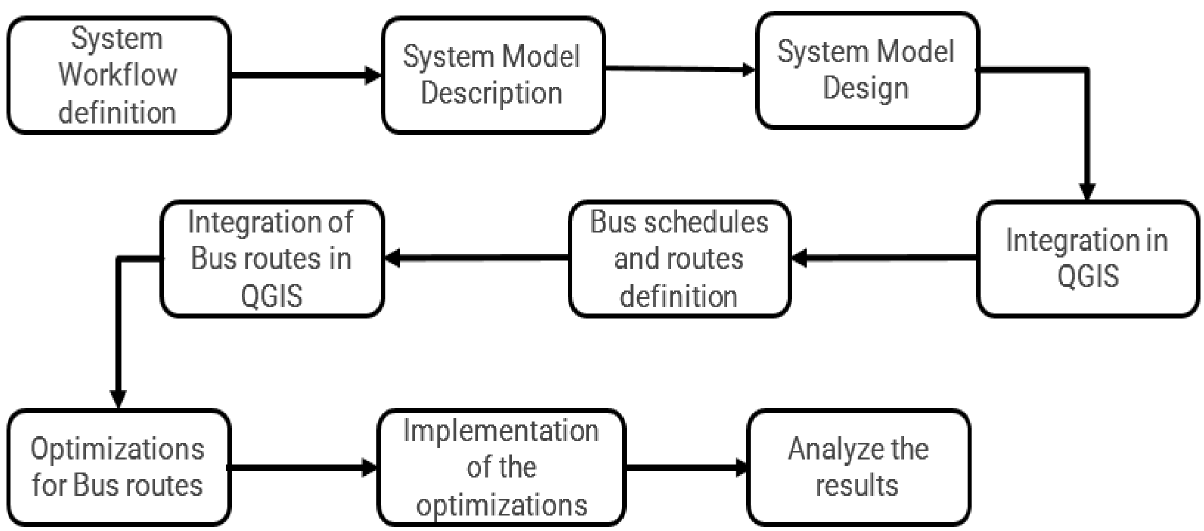

Figure 4: Methodology Workflow

3.2 System Workflow and Information Stream

3.2.1 System Diagram

The system diagram in **Figure 5** represents how our system would work and the types of information that will be transferred between them.

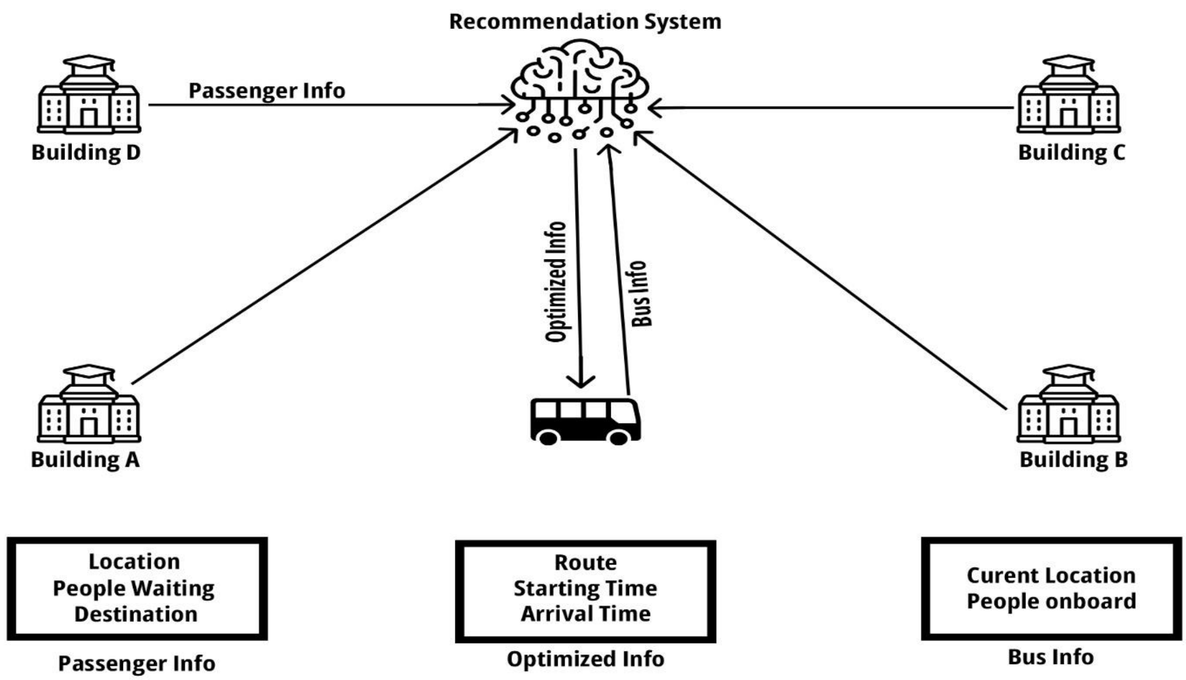

Figure 5: System Diagram for an Efficient Model of In-Campus Shuttle Bus Operation

There are mainly two actors who are involved in our system: the Bus drivers (here, in this case, represented by Buses) and the passengers. A fixed number of buses will function inside the campus during specific times on different routes, with three to four stops along those routes. The passengers, in this case, may include students, teachers, campus officials, and people touring inside the campus. The passengers will be able to request a ride from one building inside the campus to another building.

The bus drivers will be able to provide the best service with an optimized solution proposed by the system.

3.2.2 Information Stream

The types of information that will be transferred in our model can be divided into three categories based on the actors and system:

1. **Passenger Information:** When a passenger requests a ride from a location, some data will be fed into our system. These include the location in the form of longitude and latitude, the number of passengers waiting in that location, and the destination in the form of longitude and latitude. Although the first and third information is a must for the system, the number of passengers waiting to avail of the ride is more important when the optimization is done for peak and non-peak hours.
2. **Bus Information:** The bus information will generally include its ID, course/route, speed of the bus, its current location, and the number of people on board.
3. **Recommendation System Information:** The recommendation system will be fed with passenger and bus information. Based on that information, it will propose an optimized route, starting time, and arrival time for both the bus and the passengers.

3.3 System Model

3.3.1 Model Description

The model we are trying to build will test the efficiency of In–Campus Shuttle Bus operation on large-scale campuses. Since there are few large-scale Universities in Bangladesh and not all use shuttle bus services, we tried to test the efficiency on a custom University premise. We tried to create a virtual map surrounding North South University and built the University Campus surrounding it. We took the area in and around North South University and designated different buildings to be different departmental, administrative, and other facilities of North South University. There are 21 buildings; among them, 16 are departmental buildings, and others comprise the canteen, library, auditorium, and playground.

There are 6 bus terminals and a total of 6 buses in our model. These terminals will work as both pickup and dropoff points. Each bus terminal is assigned at a location closest to a cluster of buildings within 30 secs of walking distance. Whenever someone requests a ride, they will walk to their nearest terminal and wait for the bus to arrive. The bus will drop them off at the bus terminal closest to their destination.

While analyzing the shuttle bus operation, we considered the shuttle bus operation for the whole academic year. We took into account the learning weeks, exam weeks, and emergency cases.

3.3.2 Custom Map Based on the Model

Our first step in creating the custom map was to implement the initial design frame of the map based on the model. We used Geojson to serve this purpose as it is much easier to represent the geospatial data of our model in this format. It is also compatible with different mapping APIs and Libraries. [16] We created outlines of our buildings and pathways as a form of map elements as geojson features in the website.

Our next step was to make the map interactive through the use of Mapping libraries of Python. The libraries that we used are Folium, Pandas, and ipywidgets. Folium was used to create an HTML map file for the custom map. Pandas will be used to convert the geospatial data into suitable data frames and ipywidgets for the UI. A snapshot of a part of our custom map is shown in **Figure 6**.

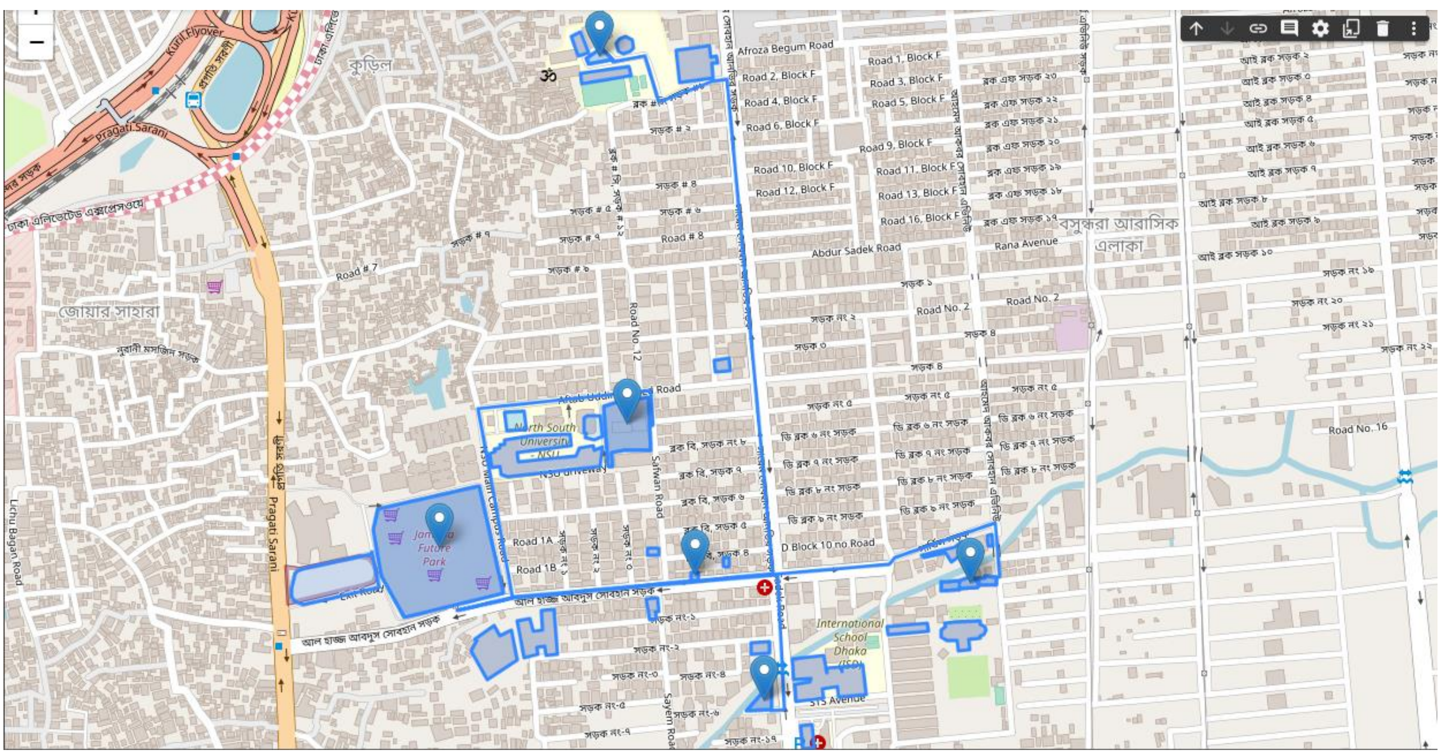

Figure 6: Screenshot of the custom map created for this project

3.3.3 Integration in QGIS

For enhancing the map and for applying our logic for optimizations, we opted to use QGIS software. It is an open-source mapping utility that provides functions like mapping, visualization, and data analysis. The map design which we created earlier was integrated into QGIS through an OSM (Open Street Map) base map with proper layering.

Figure 7 shows an enhanced version of our map in QGIS:

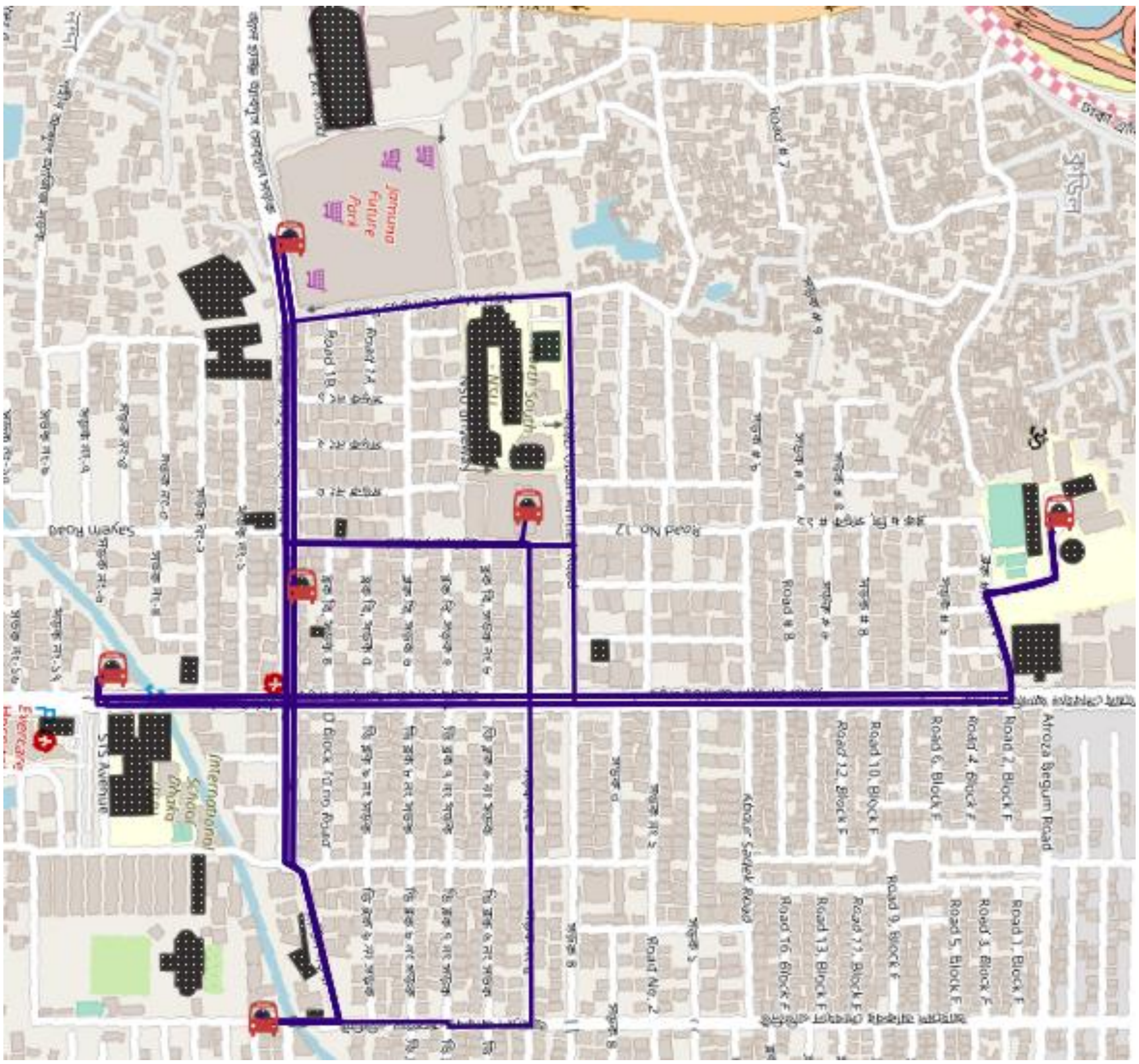

Figure 7: Enhanced Custom Map in QGIS

We also created a quick reference map at this stage to use as a guide to identify terminals and buildings. **Figure 8** shows the reference map of our system model.

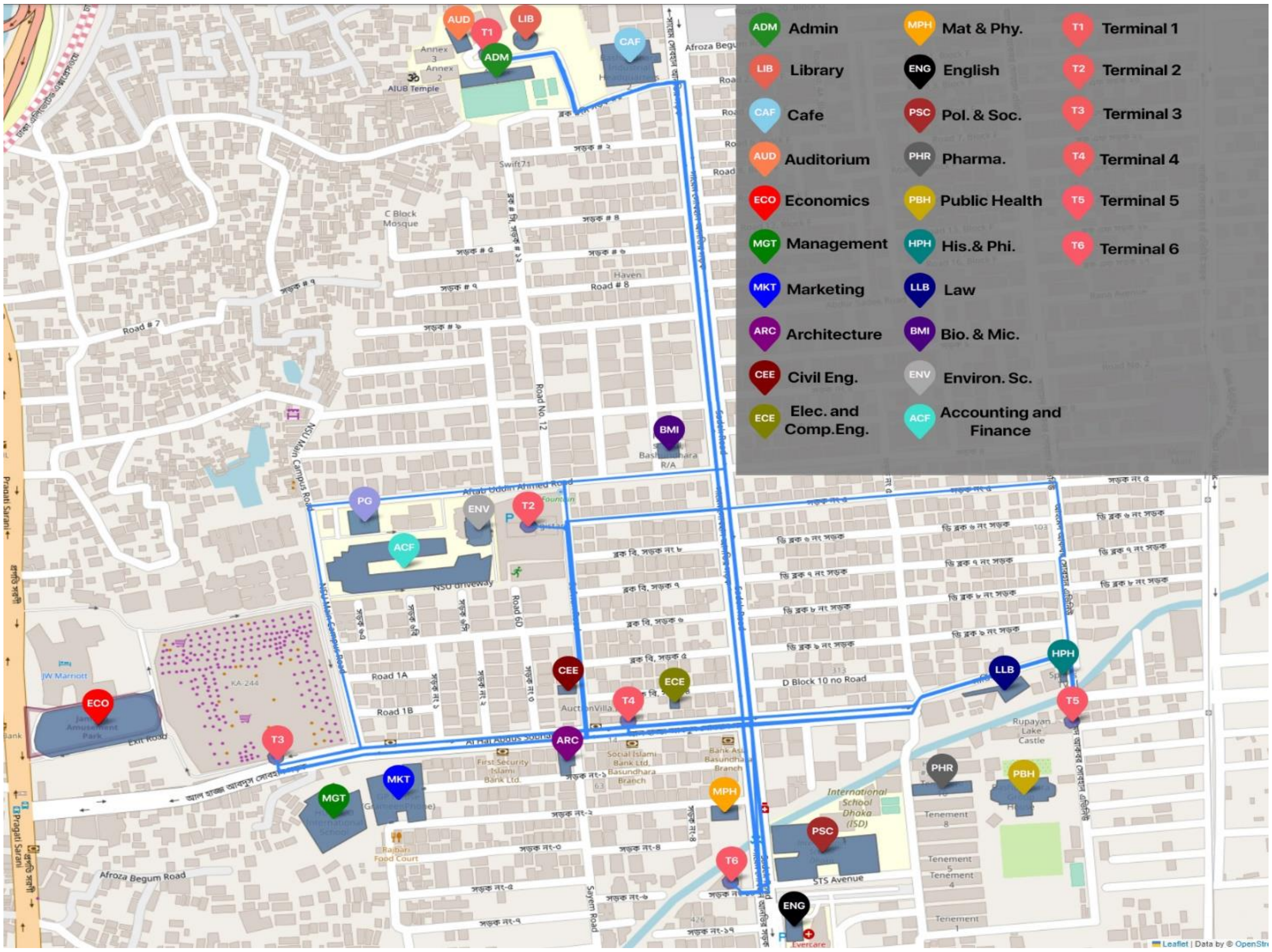

Figure 8: Reference Map of custom NSU campus

3.4 Route Design and Bus Schedules

3.4.1 Route Design

This section describes the routes that we have designed for our system model. It also includes a detailed description of each route and the considerations considered while designing the routes.

Route 1: T1 - T2

This route resides between Terminal 1 and Terminal 2. It houses an auditorium, library, admin building, cafeteria, and gallery. It also houses the environmental department, microbiology department, and accounting department.

Considerations: This route is particularly long and would not have any rush hours on regular days. Rush hours might occur while an event is happening, which needs optimization.

Route 2: T2 - T3 - T4

This route covers terminals: Terminal 2, Terminal 3, and Terminal 4. With the addition of the environmental department, microbiology department, accounting department, and gallery, this route houses the Electrical and Computer Science departments (CEE & ECE), Architectural department, and Economics and Marketing Department.

Considerations: The departments mentioned have the most number of students. Hence, this route was kept short to make it easier for the teachers and students to commute easily.

Route 3: T4 - T5 - T6

This route also covers terminals: Terminal 4, Terminal 5, and Terminal 6. With the addition of the ECE, CEE, and Architectural departments, this route houses Social Sciences, Politics, History, and Public Health departments. It also houses the Mathematics, Physics, and English Departments.

Considerations: The departments mentioned above have comparatively less amount of students than Route 2. So the route is longer than Route 2.

Figure 9 shows all the routes on the map:

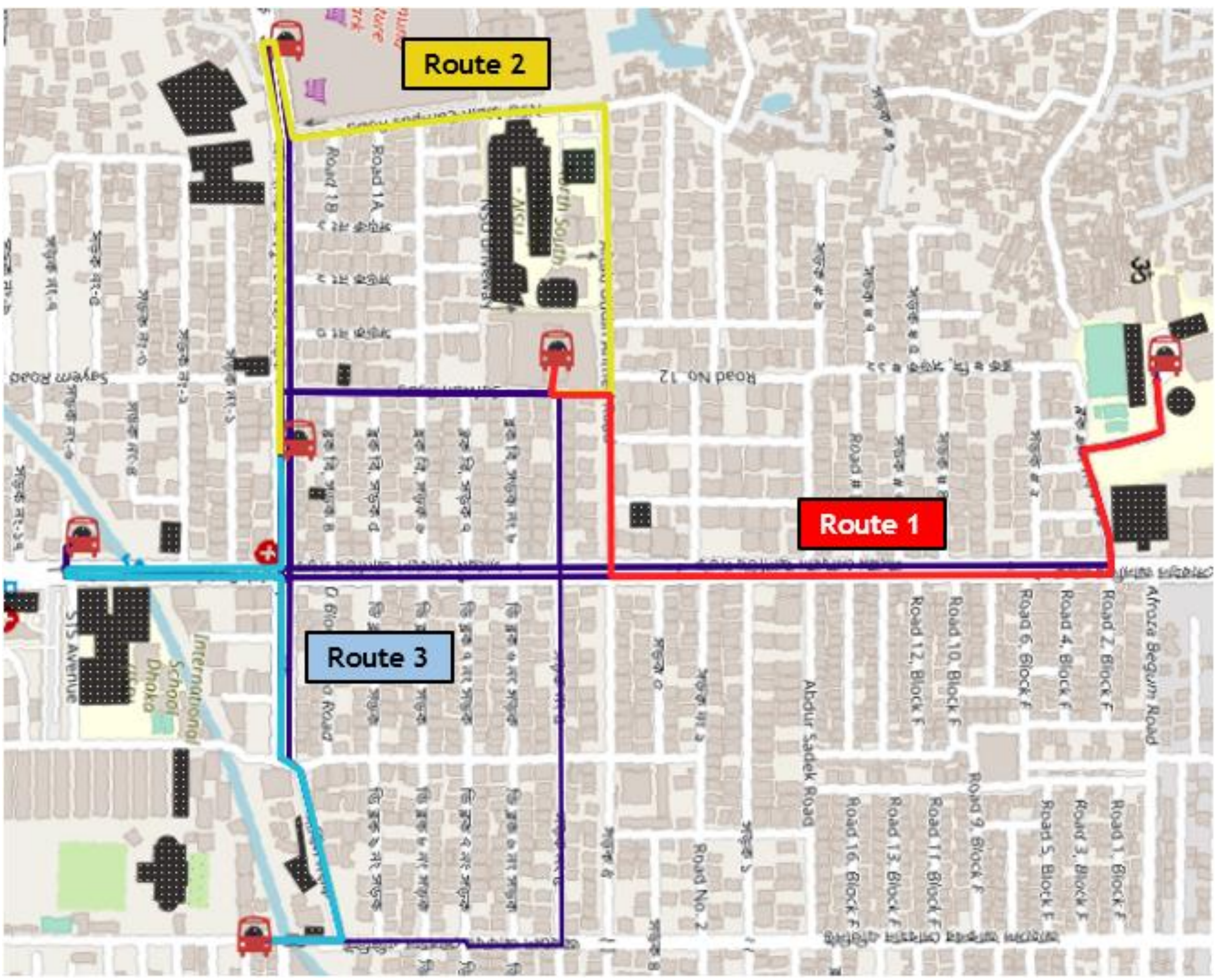

Figure 9: Routes of the System Model

3.4.2 Bus Schedules

Four buses in our system model will operate in the prescribed three routes. These are:

- BUS A1, A2: Route 1 - Between Terminals 1 & 2.
- BUS C: Route 2 - Between Terminals 2, 3 & 4.
- BUS D: Route 3 - Between Terminals 4, 5 & 6.

All four buses will make five rounds each, each lasting 10 minutes. Each bus will be able to carry 40 passengers at most. The bus schedule was made per the undergraduate class schedule. The different Bus schedules are given below:

Route 1		
Start Time	**Route**	**End Time**
07:40 AM	T1 → T2	07:50 AM
11:20 AM	T2 → T1	11:30 AM
02:50 PM	T1 → T2	03:00 PM
04:10 PM	T2 → T1	04:20 PM
06:30 PM	T1 → T2	06:40 PM

Table 3: Bus Operation Schedule for BUS A1

Route 1		
Start Time	**Route**	**End Time**
07:50 AM	T2 → T1	08:00 AM
11:20 AM	T1 → T2	11:30 AM
02:50 PM	T2 → T1	03:00 PM
04:10 PM	T1 → T2	04:20 PM
06:30 PM	T2→ T1	06:40 PM

Table 4: Bus Operation Schedule for BUS A2

Route 2		
Start Time	**Route**	**End Time**
07:40 AM	T2 → T3 → T4	07:50 AM
09:00 AM	T4 → T3 → T2	09:10 AM
11:20 AM	T2 → T3 → T4	11:30 AM
01:40 PM	T4 → T3 → T2	01:50 PM
04:00 PM	T2 → T3 → T4	04:10 PM

Table 5: Bus Operation Schedule for BUS C

Route 3		
Start Time	**Route**	**End Time**
07:50 AM	T4 → T5 → T6	08:00 AM
10:10 AM	T6 → T5 → T4	10:20 AM
12:30 PM	T4 → T5 → T6	12:40 PM
02:50 PM	T6 → T5 → T4	03:00 PM
05:10 PM	T4 → T5 → T6	05:20 PM

Table 6: Bus Operation Schedule for BUS D

3.5 Triggers and Optimizations

3.5.1 Event Trigger

As described earlier, Route 1 (Terminal T1 and T2) houses an auditorium, library, admin building, cafeteria, and gallery. These areas of the campus are the places where events, seminars, and cultural programs take place. During such events, extreme passenger fluctuations between the two terminals might occur. Bus A1 and A2 can handle the waiting time of passengers since they operate on the same route at the same time, but the rush of passengers would not be possible. For that, we have proposed the following optimization in **Figure 10**:

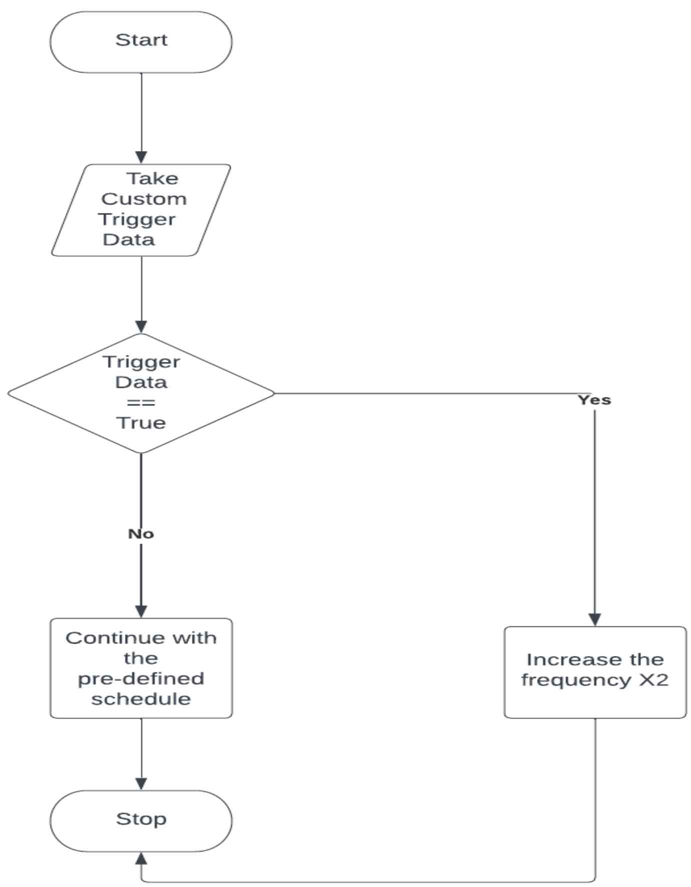

Figure 10: Admin Trigger Flow Diagram

Explanation:

We have applied this logic programmatically through an admin variable which will generate a number between 0 and 1. The generated numbers will have the following effect given a current time:

- Admin Trigger - 0 → Will follow the usual schedule of one round duration of 10 minutes
- Admin Trigger - 1 → Will extend its operating time by 20 minutes

3.5.2 Current Passenger Trigger

Routes 2 and 3 have one bus each, which operates on these routes at specified times. These buses are Bus C and Bus D. It was mentioned earlier that each bus could serve up to 40 passengers. Nevertheless, it may be the case that the number of current passengers waiting for the bus on those routes exceeds the maximum threshold. For that, we have proposed the following solution in **Figure 11** & **Figure 12**:

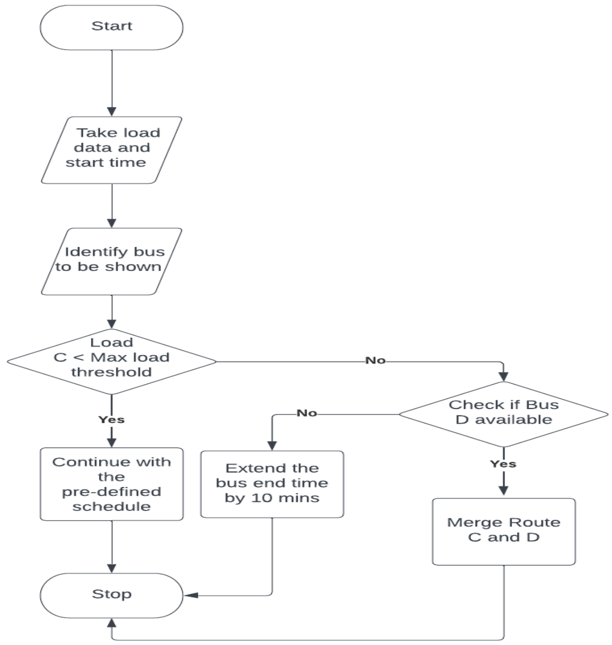

Figure 11: Passenger Optimization for Bus C

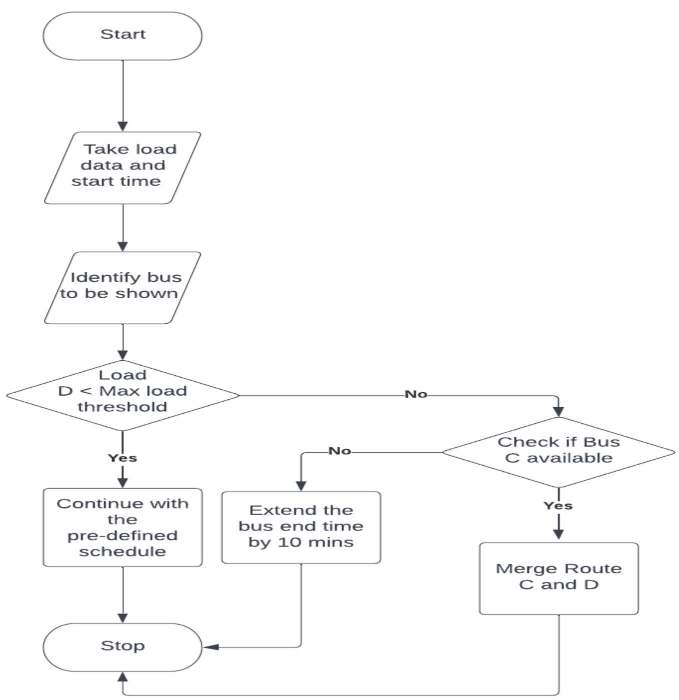

Figure 12: Passenger Optimization for Bus D

We have applied the solution programmatically, using variables that randomly generate the number of waiting passengers for each bus in their respective routes. The generated numbers will have the following effect given the current time:

- Passenger count < 40 --> Will follow the usual route for both Bus C and D.
- Passenger count > 40 --> Will merge routes; Bus C will merge with Bus D; Bus D will merge with Bus C, on the condition that the route to be merged has a free bus. If no free buses are found, then its end time will be extended by 20 minutes. That is, the bus will make two rounds.

CHAPTER 4: RESULT & DISCUSSION

4.1 Results

All of the proposed solutions were implemented in QGIS software using PyQGIS, which is an inbuilt Python library for the QGIS software. For merging the routes and extending route visibility time, QGIS inbuilt processing algorithm for merging routes and timers were used, respectively.

4.1.1 Event Trigger

<u>Random Generated Case 1: Type – Event-Triggered</u>

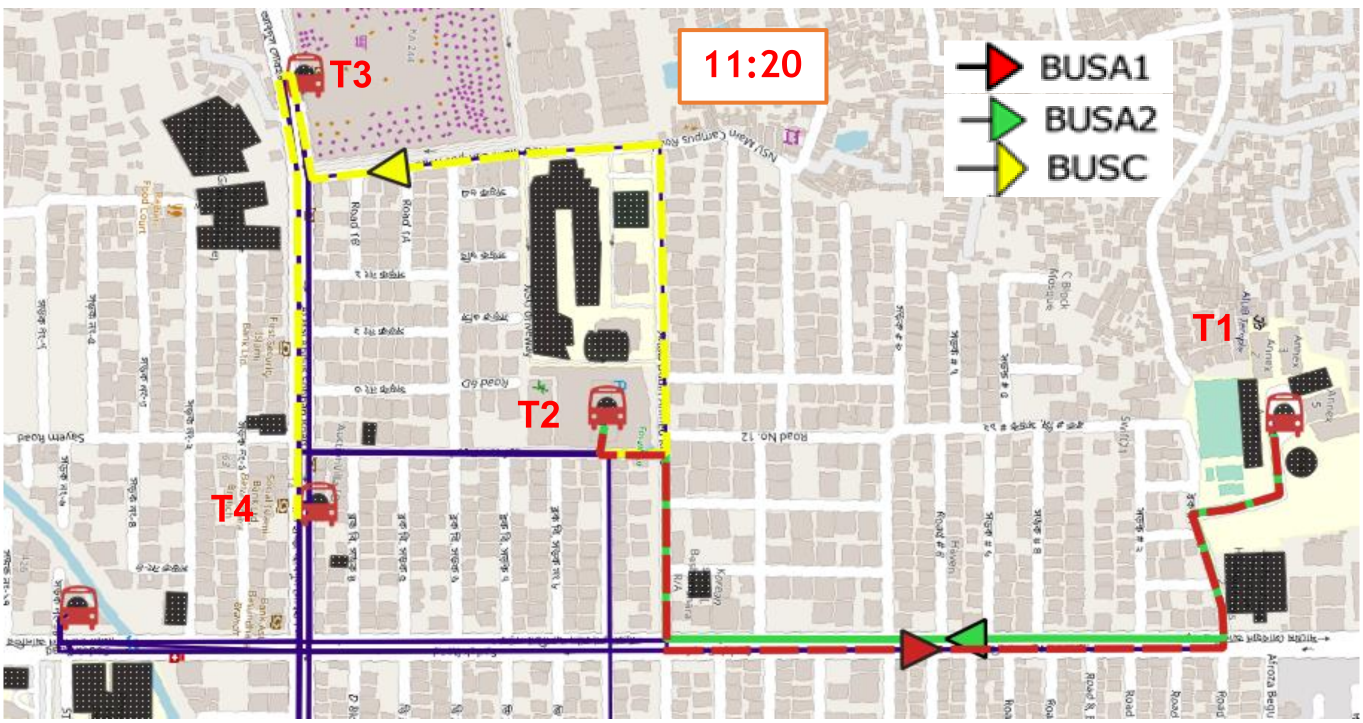

Figure 13: Generated Route for Current time : 11:20 AM, Event Trigger = 1

According to the logic represented by the flow diagram at time 11:20, all the usual routes are visible on the map as usual. Since each round's duration is 10 minutes, the operating route for Bus C will not remain visible on the map at 11:30. However, as the event trigger is on, the routes for Bus A1 and Bus A2 will still be visible, which is shown in **Figure 14**:

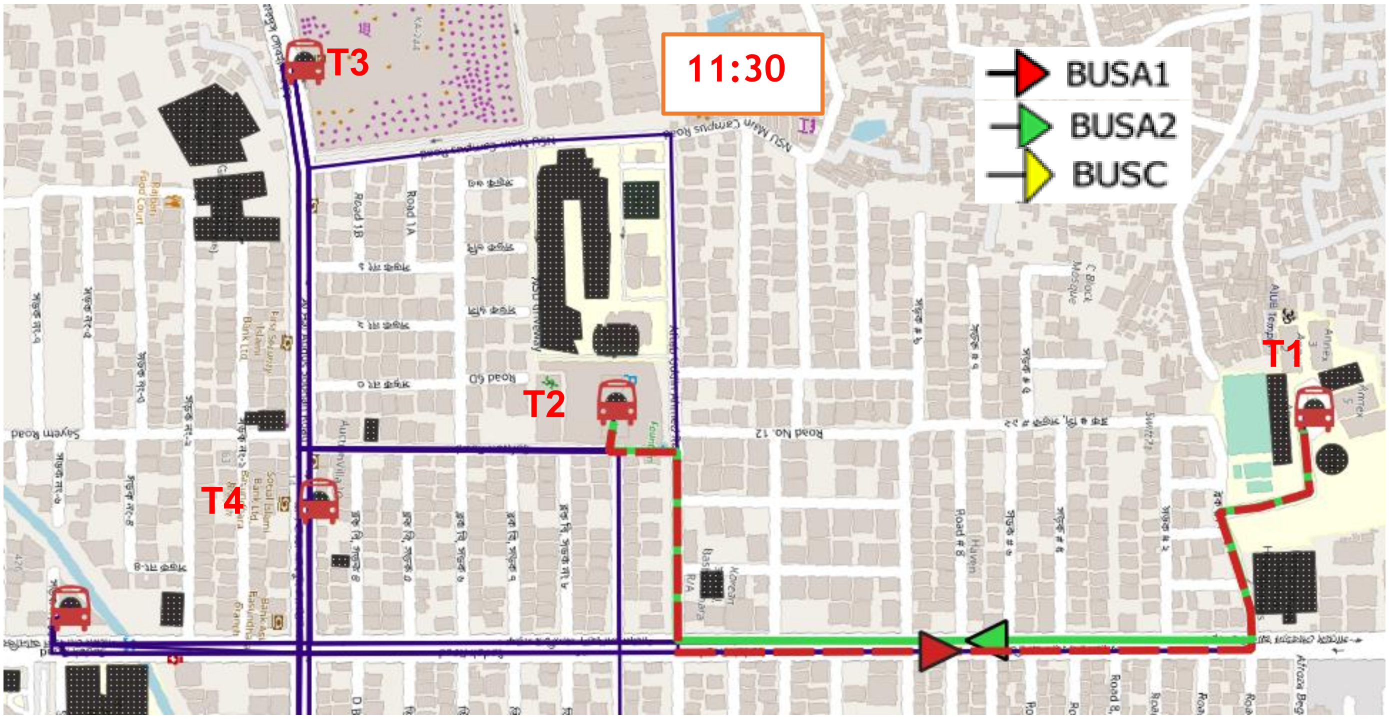

Figure 14: Generated Route at Current time: 11:30, Event Trigger - 1

4.1.2 Passenger Trigger

<u>Random Generated Case 2: Type – Usual Bus C</u>

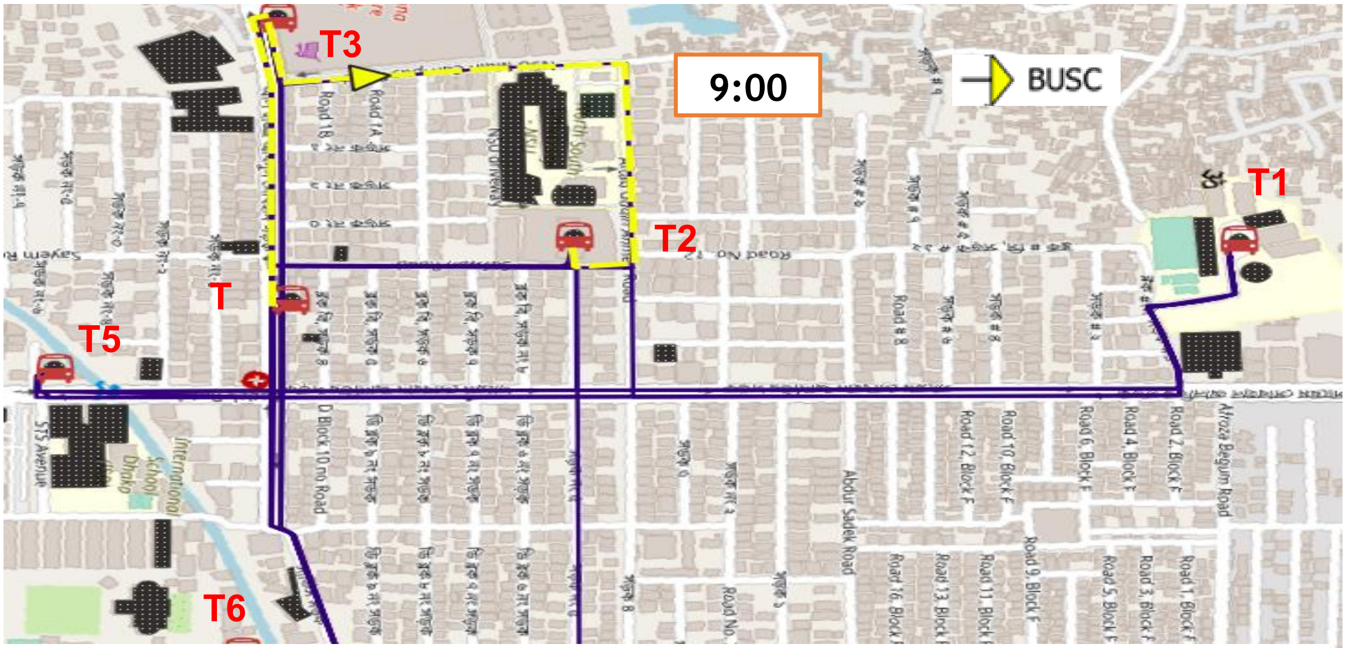

Figure 15: Generated Route for Current time : 9:00, Passenger C =35

<u>Random Generated Case 3: Type – Passenger Triggered Bus C</u>

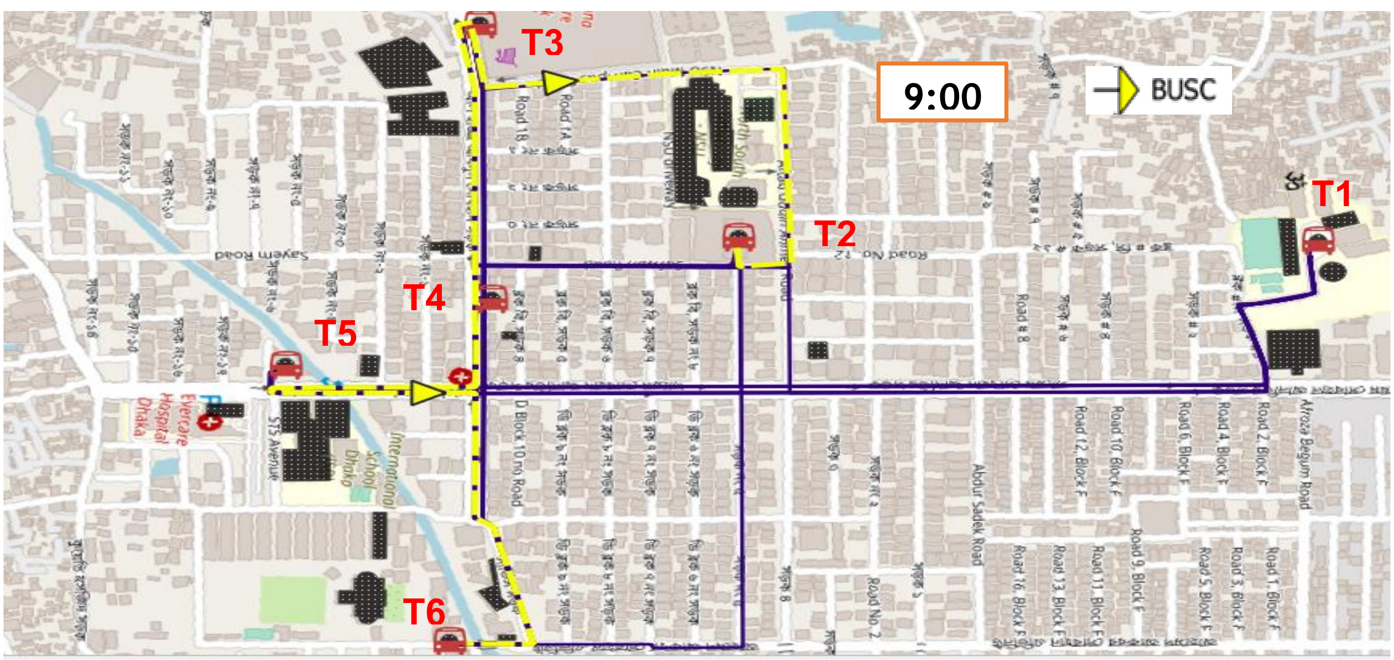

Figure 16: Generated Route for Current time = 9:00, Passenger C = 55

According to the logic represented by the flow diagram for Bus C passenger optimization, the routes were merged in **Figure 16** due to the passenger waiting count exceeding the maximum threshold, as opposed to **Figure 15,** where the passenger count was less than the threshold.

<u>Random Generated Case 4: Type – Usual Bus D</u>

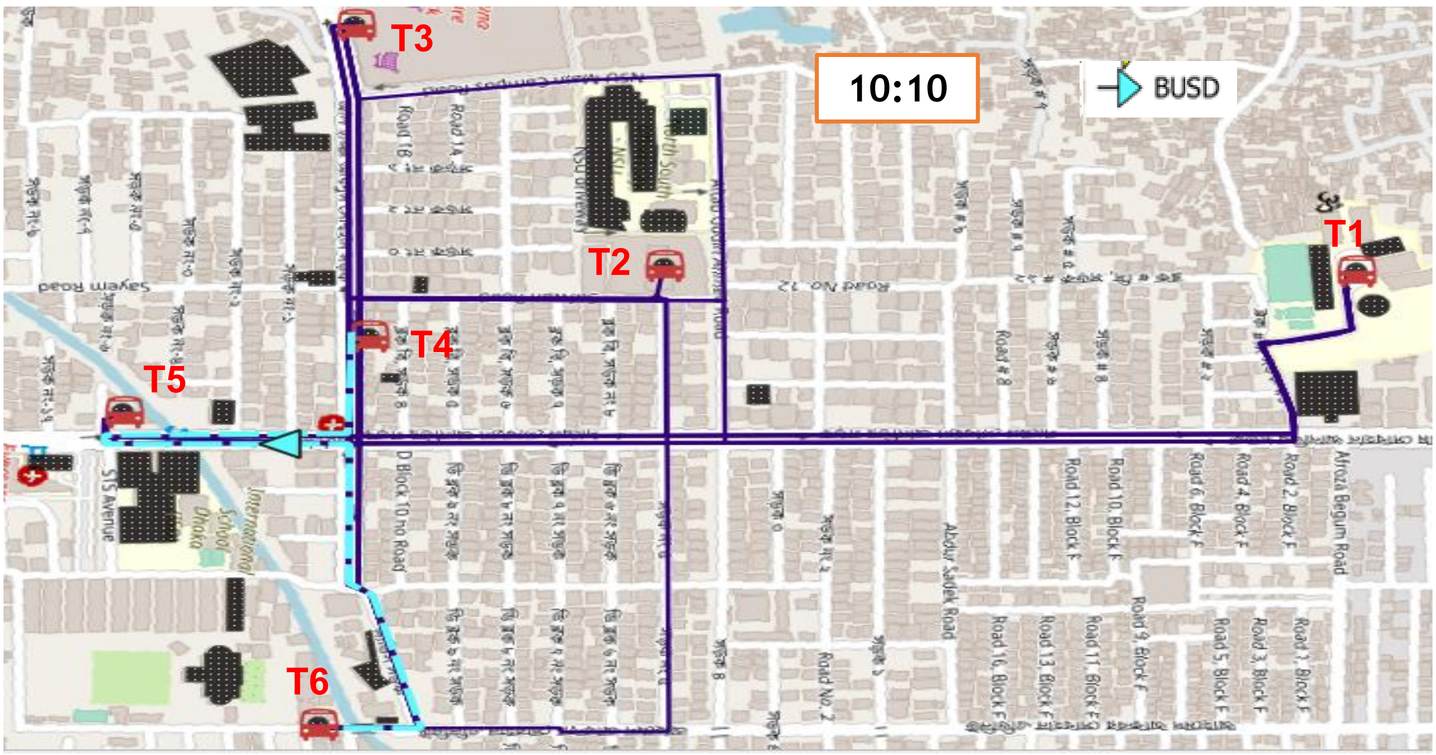

Figure 17: Generated Route for Current time = 10:10, Passenger D = 25

Random Generated Case 5: Type – Passenger Triggered Bus D

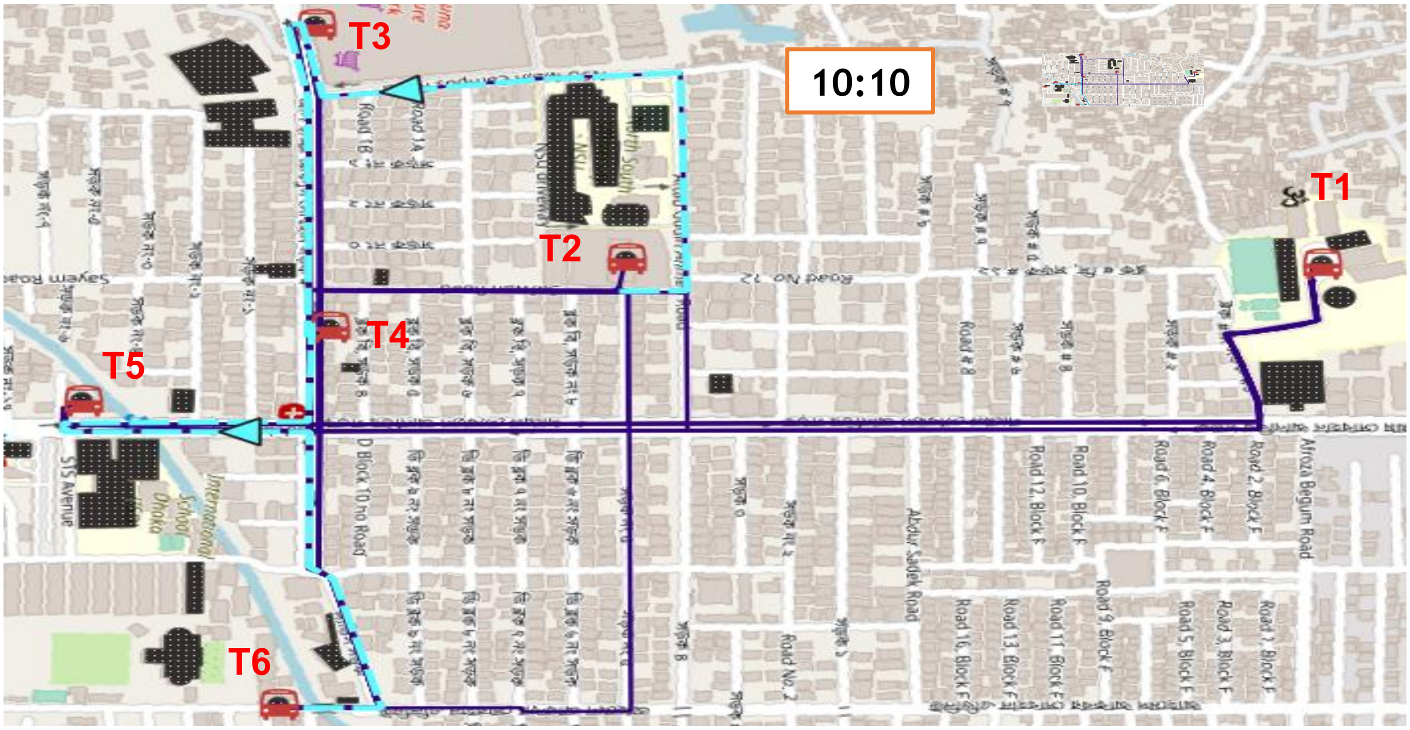

Figure 18: Generated Route for Current time = 10:10, Passenger D = 60

Figure 18 shows that the same logic was followed in the case of Bus D as well, but in this case, the route of Bus D was merged with Bus C, as the passenger threshold crosses the maximum limit, as opposed to **Figure 17.**

4.2 Discussion

This section describes the challenges we faced while implementing the said logic and the solutions we came up with to obtain the result that we did. It also highlights our initial approach to the problem while acknowledging our model's limitations and the need for improvements.

4.2.1 Event Trigger

For our model, we wanted to sync the bus schedules with the academic calendar. However, we could not find any methods of making the utilized software work according to the provided calendar.

Here, by the academic calendar, we refer to the calendar that offers all the information about the class, off days, and days with special events.

As loading up a calendar with special events was not possible within the specified time period of our project, we created a custom event trigger.

This trigger is basically a variable that can be set to 1 or 0. When the custom trigger is 1, the model will consider the day to have a special event.

Through this approach, we could create nearly the same effect as the academic calendar would have for the event to occur.

4.2.2 Merging of Routes

For the merging of routes for both Bus C and Bus D optimizations, we decided to merge Routes 2 and Route 3. We could have also merged with Route 1, but we decided not to. As said earlier, Route 1 is the longest route of our model. Merging Route 1 with any other routes will result in a longer distance.

This merging, on the one hand, will resolve the issue of passenger rush for Bus C and Bus D effectively but will increase the overall waiting time of the passengers. This is undesirable as the duration between the end of one class and the start of another is only 10 minutes.

4.2.3 Real-Time Data Handling

We wanted to use the real-time data of the shuttle bus operation as our initial data to assess the effect of different routes and timings on the overall operation of the buses, then provide adequate solutions.

We could not work with that data since our model is a custom virtual model. This made our model less inclined to analyze the effects of certain exceptional cases.

Since we could not do this, we decided to generate the triggers ourselves and create predefined routes using the Route Design Technique described in Paper 3, designing optimum routes initially to handle a small amount of the optimization early on. We also provided solutions that would be nearly similar to the solutions applied if they worked with real-time data.

4.3 Further Improvements

Since our model and our approach to the implementation of the solutions is a much simpler one, we want to acknowledge its certain lackings and propose further improvements over the model:

- Real-time data, or data collected in real-time, can be used in the future to provide the same optimizations in the model.
- Various other triggers, such as off-day triggers, off-schedule rush, emergencies etc., can be considered in the future in accordance with syncing the overall schedule with the academic calendar.
- The effects of all the triggers can be analyzed further to create the most optimum solution possible
- Various machine Learning algorithms can be used to provide a more robust model for efficient bus routing operation.
- With a robust model, we can also aim to build an app for the overall operation.

CHAPTER 5: CONCLUSION

Efficiency and optimization are two of the most important aspects of a shuttle bus operation. Without these two, the operation brings no convenience in a real-world application. The model we have worked on has considered most of the challenges a shuttle bus operation can face during implementation. However, there are still scopes for improvement. For example, we could not work with real-time location data and passenger count. These two considerations could have made the model more practical and efficient. But, at the current stage, we believe that the model is good enough for an in-campus premise. And for the future, we plan to take a deeper look into the application and tune things further to make the model efficient, cost-saving, and practical.

WORKS CITED

[1] K. Kowalski, "Explainer: What is a computer model?," Science News Explores, 8 January 2015. [Online]. Available: https://www.snexplores.org/article/explainer-what-computer-model. [Accessed 2023].

[2] R. Md. Noor, T. Nandy, R. Kolandaisamy and N. B. G. Rasyidi, "Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis: A Case Study," MDPI, 2020.

[3] A. A.Kutty, N. Al Jurf, A. F. Naser and M. Kucukvar, "Optimizing University Campus Shuttle Bus Congestion Focusing on System Effectiveness and Reliability: A Combined Modeling Based-Routing Approach," IEOM Society International, Sao Paulo, 2021.

[4] J. Ding, L. Li , y. Zhang and S. Feng, "Campus Bus Network Design and Evaluation Based on Route Property," TSINGHUA SCIENCE AND TECHNOLOGY, 2017.

[5] S. Misra and J. He, "Artificial Neural Network Model," 2020. [Online]. Available: https://www.sciencedirect.com/topics/engineering/artificial-neural-network-model. [Accessed 2023].

[6] B. MacLennan, "Connectionist Approaches," 2001. [Online]. Available: https://www.sciencedirect.com/topics/computer-science/connectionist-approach. [Accessed 2023].

[7] S. Ray, "Learn How to Use Support Vector Machines (SVM) for Data Science," Analytics Vidhya, 13 September 2017. [Online]. Available: https://www.analyticsvidhya.com/blog/2017/09/understaing-support-vector-machine-example-code. [Accessed 2023].

[8] M. Banoula, "Classification in Machine Learning: What it is & Classification Models," March 2023. [Online]. Available: https://www.simplilearn.com/tutorials/machine-learning-tutorial/classification-in-machine-learning. [Accessed 2023].

[9] S. S, "A Quick Overview of Regression Algorithms in Machine Learning," Analytics Vidhya, 10 January 2021. [Online]. Available:

https://www.analyticsvidhya.com/blog/2021/01/a-quick-overview-of-regression-algorithms-in-machine-learning/. [Accessed 2023].

[10] Wikipedia Contributors, "Multi-objective optimization," Wikipedia, the free encyclopedia, 2023. [Online]. Available: https://en.wikipedia.org/wiki/Multi-objective_optimization. [Accessed 2023].

[11] Wikipedia Contributors, "Goal programming," Wikipedia, the free encyclopedia, November 2022. [Online]. Available: https://en.wikipedia.org/wiki/Goal_programming. [Accessed 2023].

[12] R. Kwiatkowski, "Monte Carlo Simulation — a practical guide," 31 January 2022. [Online]. Available: https://towardsdatascience.com/monte-carlo-simulation-a-practical-guide-85da45597f0e. [Accessed 2023].

[13] IBM, "What is Monte Carlo simulation?," IBM, [Online]. Available: https://www.ibm.com/topics/monte-carlo-simulation. [Accessed 2023].

[14] Wikipedia Contributors, "VisSim," 2023. [Online]. Available: https://en.wikipedia.org/wiki/VisSim. [Accessed 2023].

[15] X. Meng and Z. Pian, "Analytical Hierarchy Process," 2016. [Online]. Available: https://www.sciencedirect.com/topics/engineering/analytical-hierarchy-process. [Accessed 2023].

[16] Howard Butler, Martin Daly, Allan Doyle, Sean Gillies, Tim Schaub, and Christopher Schmidt, "GeoJSON Specification," 2008 [Online] . https://web.archive.org/web/20160827120507/http://geojson.org:80/geojson-spec.html [Accessed 2023].