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Abstract:

This study analyzed the transportation issues at the University of Bahrain Sakhir campus, where a bus system with an unorganized and fixed number of buses allocated each semester was in place. Data was collected through a survey, on-site observations, and student schedules to estimate the number of buses needed. The study was limited to students who require to move between buildings for academic purposes and not those who choose to ride buses for other reasons. An algorithm was designed to calculate the optimal number of buses for each time slot, and for each day. This solution could improve transportation efficiency, lower costs, enhance students' mobility experience, and decrease CO_2 emissions. A series of recommendations were provided to university officials including the need for further research to examine creating new routes and implementing express buses.

Keywords: Bus scheduling, transportation, demand, optimization, graph-based algorithm.

1. Introduction

University of Bahrain (UoB) has multiple campuses situated throughout the Kingdom of Bahrain. The largest and primary campus is located in Sakhir, with currently almost 25,000 students. Additionally, the university has two other campuses: one in Isa Town, which is home to the College of Engineering, and the other in Manama, which houses the College of Health Sciences.

The Sakhir campus of UoB spans over 104,000 square meters and comprises seven colleges and many other facilities such as the Zain E-learning Center, Khunji Hall, Health Center, and University Library. Figure 1 showcases an aerial view of the Sakhir campus. Given the multidisciplinary nature of many programs, students are required to attend courses in different buildings, necessitating seamless internal mobility. This is particularly crucial due to the campus's considerable size, the intense heat prevalent during the academic year, and the limited time between lectures, making the use of walking pathways impractical. To address this issue, the university has implemented a bus transportation system to facilitate student movement around the campus.

Figure 1. Aerial View of UoB Sakhir Campus.

Numerous bus stops are strategically located across the campus, serving the various colleges, including the College of Information Technology and its building code is S40, College of Science (S41), College of Law (S39), Deanship of Admission and Registration (S38), College of Applied Studies (S20), Bahrain Teachers College (S22), and College of Business Administrations (S1B). To optimize the transportation service, certain bus stops, namely S39 and S38, and S20 and S22, which are positioned opposite each other, have been consolidated into a single station. As a result, there are now five distinct bus stations: S1B, S20-22, S38-39, S40, and S41. As shown in Figure 2, the official route for the bus is as follows: it starts at S1B and proceeds to S20-22, followed by S38-39, S41, and finally, S40. This route constitutes one-half of the cycle, where the bus makes a stop at each station. Subsequently, the bus returns from S40 to S38-39, then to S20-22, and finally arrives back at the starting point, S1B.

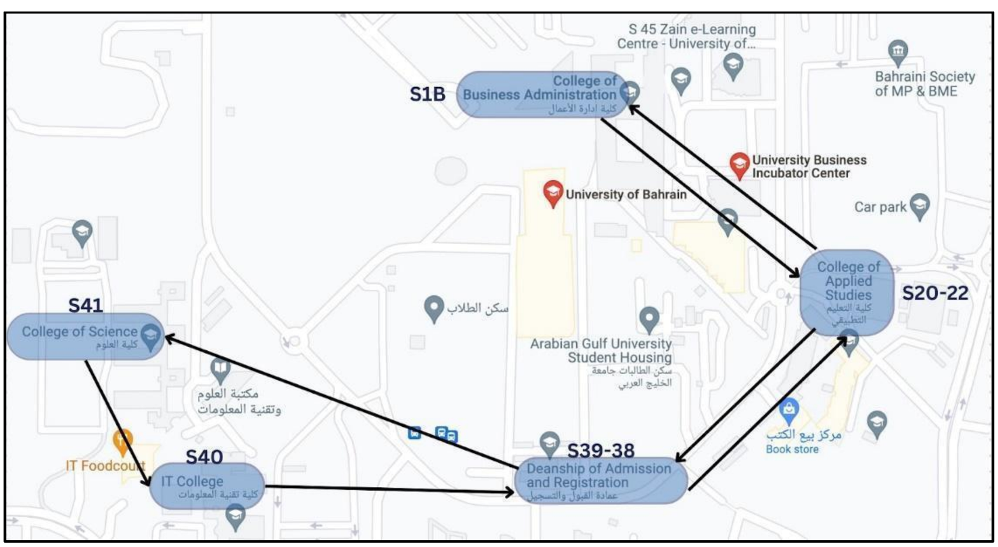

Figure 2. Graphical Representation of Current Bus Route.

The buses do not follow a fixed schedule, and there are no direct routes available between different colleges. For instance, a student boarding a bus at station S41 would need to stop at all stations on the campus before reaching S1B. During peak morning hours, this often results in delays for students, while in the afternoons when the number of students is lower, the buses continue to operate their designated routes, even when they have almost empty seats. Moreover, the number of buses allocated for each semester is determined based on the transportation directory's prior experience, careful observations, and estimations. For instance, in the most recent second semester of the 2022-2023 academic year, the transportation directory has provided 25 buses, although uncertainty remains as to whether this number exceeds or falls short of the actual demand.

It is worth noting that a scientific approach is not employed to resolve this issue, and the number of buses is subject to modification depending on the contract that is signed between the university directory and the transportation company. Based on this observation, it can be concluded that the distribution of buses across the various stations throughout the day does not correspond accurately with the actual demand for the service as well as it results in less efficient use of resources and increased operational costs for the transportation system.

It is important to consider several constraints when addressing this issue. Firstly, the number of students varies each semester, which affects the demand for transportation services. Secondly, the bus capacity, which is currently fixed at 25 seats. Finally, the time slots between lectures are limited between 10 to 15 minutes, which places a constraint on the amount of time available for students to move between different colleges or facilities. These constraints must be taken into account when producing an optimal solution that is efficient, cost-effective, and able to accommodate the needs of all students, ensuring a smooth movement of students between different buildings, while using the minimum number of buses possible.

2. Literature Review

Optimization of bus networks has been a focus of transportation research for many years. The aim of optimizing transportation is to increase the bus system's efficiency, reliability, and cost-effectiveness. Moreover, the impact of CO_2 emissions resulting from transportation has become a significant concern in these optimization efforts. Reducing CO_2 emissions and promoting environmental sustainability have become integral objectives in optimizing bus networks. In their comprehensive study on the sustainable transportation system in India and lessons to be learned from other developing nations, Mohapatra et al. [1] examined the impact of CO_2 emissions. They discussed the significance of reducing CO_2 emissions in the transportation sector to achieve sustainability goals. The authors emphasized the need for implementing effective strategies and policies to mitigate CO_2 emissions and promote cleaner and more efficient transportation systems.

In recent years, researchers have investigated numerous approaches for optimizing bus networks by employing various mathematical models and algorithms. Ren et al. [2] investigate the issue of optimizing school bus stop location and route in consideration of walking accessibility and mixed load. The authors claim that a well-designed school bus system may greatly reduce road congestion, enhance safety, and improve student movement efficiency. The authors suggest a two-stage algorithm that optimizes both school bus stop site and routing while taking walking accessibility and mixed load into account. The algorithm's initial step identifies the optimal sites for school bus stops based on walking accessibility and proximity to the number of students. The second stage of the algorithm optimizes the school bus route based on mixed load and travel time.

Evidently, addressing the issue of optimizing routing for mixed loads has been an endless debate, prompting more contributions targeted at resolving it. Therefore, a mixed integer linear programming (MILP) approach is used in the work done by Campbell et al. [3] to resolve the routing issue for mixed load school buses. The issue is formulated as a linear program with additional integer restrictions using the MILP method, a mathematical optimization approach. An objective function that must be minimized, decision variables, and a set of requirements must all be defined. Beginning with a binary decision variable representation of the assignment of students to buses and route selection, the method models the issue at hand. Accordingly, in order to guarantee that every student is allocated to a bus while taking into consideration their eligibility criteria, restrictions are created. To make sure that the number of allocated pupils does not exceed the seating capacity of each bus, capacity restrictions are implemented. Subsequently, once the issue is defined as a MILP, the best solution can be discovered using specialist solvers or optimization software tools. These solvers search the solution space and find the optimal set of routes and student assignments that meet all constraints and minimize the objective function by utilizing complex algorithms like branch-and-bound or cutting plane approaches.

Furthermore, contributions have been made by Park et al. [4] to improve the school bus routing problem (SBRP) considering mixed load. The study provides a new mixed load improvement algorithm that may be used on a variety of single load plans to allow a bus to serve students from several schools. Computational experiments demonstrate the success of the suggested approach in addition to the effective use of various real-world SBRPs. Moreover, the research provides a quantitative analysis of the effects of permitting mixed load. Finally, the study provides a new set of SBRP benchmark instances of the problem. On the benchmark problem cases, the suggested approach outperforms the proposed existing techniques in the literature.

To compare mixed and non-mixed load school bus routes, Ellegood et al. [5] constructed a continuous approximation model and applied it on a school district in Missouri. Results showcase that mixed load routes are more advantageous when distance between schools is not too great and student density at stops are low. The authors suggest a hybrid policy of mixed and non-mixed routes as a more optimal approach to school bus routing.

On the other hand, Ma et al. [6] examined an integrated optimization strategy for customized bus routes and schedules that takes hold control into account. The strategy intends to reduce passenger waiting time and travel time, as well as the negative impact of controlling bus operations. The authors created a mathematical model that accounts for a variety of characteristics, including passenger demand, travel time, headway, and holding control. To overcome the optimization challenge, they also presented a heuristic approach. The algorithm is divided into two stages: the first creates possible routes and schedules, and the second performs a local search to refine the solutions. The technique was also tested in a case study in Beijing, China, and the findings showed that the suggested approach may increase bus operations efficiency and minimize passenger waiting time. Moreover, Shi et al. [7] provided an approach for evaluating bus routes using multi-source bus data. The model constructs an indicator system for evaluating bus route optimization using a target hierarchy classification approach. The authors consider thirteen different indicators that have a major influence on bus route adjustments where it covers a broad range of specifications relating to bus operation, passenger flow, and travel characteristics both before and after bus route optimization. The authors tested the model with data from several sources, including GPS, smart cards, and a bus dispatching system. Moreover, significant contributions have been made by leveraging the utilization of two-commodity network flow model, this research proposes an exact solution for solving the Capacitated Vehicle Routing Problem (CVRP). Preprocessing, initial solution construction, and solution enhancement are the three steps of the method.

Techniques such as dominance rules and problem size reduction are used in the preprocessing step to improve the algorithm's efficiency. To develop workable solutions, the first solution creation step employs approaches such as the Clarke and Wright savings algorithm and insertion heuristics. Finally, the solution improvement step refines the initial solutions towards optimality using techniques such as local search and tabu search. Several advantages are provided by the algorithm based on the two-commodity network flow formulation. It increases computing performance by utilizing problem frameworks, allowing optimal solutions to be found in appropriate time periods. Furthermore, the technique is scalable, making it appropriate for large-scale CVRP instances [8].

Genetic algorithms (GA) are a widely used metaheuristic approach to tackling different routing problems. A bus route optimization process built based on Geographical Information Systems (GIS) was presented in [9], which considers bus station and demand optimization, and trip demand at each stop, then creates potential shortest path sets. In the final stage, a GA was implemented to discover the optimal shortest path set. This framework was applied to Wuhan, China and results showed that involving trip demand as a factor increased the transportation network optimization. A GA framework was also employed by Nnene et al. [10], along with agent-based modeling in place of traditional travel demand models to simulate accurate demand, in a heuristic approach to design an optimal transportation network. The solution regarded the impact of users through total travel time and operators through total operational cost on the efficiency of the network. A graph was used to represent each generated feasible network, then the network pool is used in the GA to produce the optimal one. The findings showcased that balancing the user and operator factors while using a combination of direct and indirect routes leads to a more efficient network. Similarly, Shrivastava et al. [11] presented a method for designing an effective feeder route network. The authors initially performed a study on feeder route network design and uncovered a gap in previous studies that did not take into account the connections between various aspects such as passenger demand, travel time, and network connectivity. Consequently, the authors proposed designing an optimal feeder route network using a combined GA and specialized repair heuristic. The GA is applied to develop a collection of possible feeder route networks, which are then repaired and optimized using the specialized repair heuristic.

An Alternating Objective Genetic Algorithm (AOGA) was employed by Arbex [12] to solve the complex transit network and design frequency setting problem (TNDFSP). The proposed process focuses on the first two of five phases of a bus transit network design: route design and frequencies setting (operators' cost) and results in a better-efficient set of Pareto optimal solutions in comparison to previous results.

One notable distinction between scheduling campus shuttles and general public transit lies in the impact of class schedules. This irregularity is evident in the high student demand during specific times, which differs from the typical peak demand patterns observed in urban transit scenarios. Existing literature reveals that students primarily attend classes around 10 a.m., 11 a.m., 12 p.m., and 2 p.m., while the overall number of students tends to be lower on Fridays [12] [13]. The campus transportation system stands out in several ways due to its unique characteristics. One notable distinction lies in the timing of the system, which is heavily influenced by the schedule of lectures and classes. Additionally, the limited space available within each bus further contributes to the distinctive nature of the campus transportation system.

Existing studies have employed the clustering technique to identify homogeneous time periods, where they consolidated these periods into multiple 1-hour or 30-minute intervals. Regrettably, the influence of class schedules was overlooked in these studies [14] and [15], neglecting an important factor in the analysis.

In conclusion, enhancing efficiency, reliability, and cost-effectiveness while addressing the environmental impact of CO_2 emissions is critical. Strategies to reduce CO_2 emissions and promote greener transportation systems should be undertaken. Optimizing mixed-load bus routing and assessing the benefits of mixed-load routes can lead to more efficient school bus systems. Using multi-source data for route evaluation and advanced optimization techniques are critical for creating effective bus network designs.

It is also necessary to consider the unique features of campus transportation systems, such as class schedules and limited bus capacity. Researchers may contribute considerably to the improvement of bus network optimization by following these guidelines and avoiding the stated restrictions, resulting in greater efficiency, less environmental impact, and superior transportation systems.

The primary objective of this study is to address the issue of short intervals between lectures and ensure the provision of an appropriate number of buses during unaggregated time periods. By considering unaggregated time intervals, rather than aggregating them into larger periods, the study aims to better align transportation services with the class schedules and improve overall efficiency.

3. Methodology

3.1. Data Collection

Similar to Shi et al.'s [7] approach of collecting data from multiple sources, our study utilized three methods to collect data: a survey, on-site observations, and students' schedules. The survey was distributed online and received 418 responses from UoB Sakhir campus students. On-site observation was used to collect data on the exact route duration for each direct path between two bus stations. Lastly, the UoB Information Technology Center provided schedules of 21,964 students summarized in an excel sheet with 207,177 records. This data was analyzed to determine the number of students in need of internal transportation at each time slot throughout an academic week and to estimate the number of buses needed.

A. Survey: Gathering Information on Bus Usage and Issues

To gather direct information from the students about their bus usage, usage factors, and issues, a survey was designed and distributed online. The survey was conducted over several weeks and received 418 responses. The survey was limited to the Sakhir campus students to ensure that the received data remained within the scope of the problem. The survey questions were designed to collect information on important aspects regarding the scope of internal transportation. Students were asked about the frequency of bus usage to which the overwhelming majority confirmed that they utilize the buses on a weekly basis. Another question was asked about whether students face delays and at which bus station they occur most. Over 90% of the respondents stated that they experienced delays, most of which occurred at S40 and S1B stations. Lastly, the responses showcased the large impact the hot weather had on the decision to depend on transportation for movement between buildings on the campus.

B. On-Site Observation

On-site data was collected via observation across several days and several times throughout a single day to increase the accuracy of the data. Data about the exact route duration for each direct path between each pair of bus stations as well as the duration of the entire bus route which starts from station S1B, circulates throughout the bus route, and ends at the same station was gathered. Furthermore, the level of usage of buses, their numbers, and the number of students waiting at different stations were collected. It was noticed that for a large portion of the time, buses were either undersupplying or oversupplying student demand which showcases the necessity behind formulating a scientific method to estimate the demand for buses. In addition, the measured traveling duration between each pair of buildings was found to be ill-suited and might cause student delays in the 10 to 15-minute time frame between lectures if buses are not properly scheduled. Table 1 displays the measured traveling times between each building pair. The measurement was done using student's car and respecting the driving limited speed in campus.

Table 1. Traveling durations in minutes between different buildings

	S_{1B}	S_{20}	S_{39}	S_{40}	S_{41}
S_{1B}	0	1.04	1.32	2.51	3.18
S_{20}	0.58	0	0.38	1.51	2.15
S_{39}	1.32	0.5	0	1	1.22
S_{40}	3.39	2.38	1.27	0	1.58
S_{41}	3.29	2.38	1.51	1.05	0

C. Student Schedules

The UoB Information Technology Center in collaboration with the Registration Department provided the students' schedules for the second semester of the 2022/2023 academic year. Each record was stripped of any personal identifiers by hashing the student ID to ensure privacy and contained the day, building, start time, and end time of each registered lecture. The days are represented by code [U, M, T, W, H] where U represents Sunday, M is Monday and so on. An example of a student schedule is shown in Figure 3. Note that a working week in Bahrain starts on Sunday and ends on Thursday.

Hash_Student_ID	Day	FROM_TIME	TO_TIME	BUILD_CODE
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	U	11:00AM	12:15PM	S20B
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	H	11:00AM	12:15PM	S20B
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	M	2:30PM	3:45PM	S50
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	W	2:30PM	3:45PM	S50
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	T	3:30PM	6:00PM	S41
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	U	1:00PM	1:50PM	S48
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	T	1:00PM	1:50PM	S48
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	H	1:00PM	1:50PM	S48
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	T	2:00PM	2:50PM	S48
0x00B2858CFFF70B7852110F2360412A84950A33BB5AB862A2916B1BB43911D21D	U	2:00PM	3:40PM	S41

Figure 3. A single student's schedule records.

The data was analyzed to estimate the number of students traveling between each pair of bus stations in every time slot on every academic day and to calculate the number of buses needed to transport them. A python program was written to count the number of students that need to move from one building to another based on the location of the buildings where their lectures took place. The data was first filtered by day, then grouped by student hash id, and later sorted by time which resulted in a chronological view of each student's schedule for each day. The time slots considered in this method were based on the TO_TIME provided from the student records. After, the number of students in need of transportation in a single time slot was counted by pinpointing if there were changes in building codes in consecutive rows for each unique hashed id. An additional condition was added to check the time difference between the consecutive rows to ensure only students who had consecutive lectures were considered. This count of students was used to estimate the maximum number of buses needed to deliver students to their classes on time for which another python program was written. This process was repeated for each time slot during the day, ensuring that the estimated number of buses needed was accurate for the entire day.

3.2. Data Visualization

Directed graphs can be used to visualize the resulting data from the previously mentioned python program where nodes represent the 5 distinct bus stations, the arcs signify the direction of the bus route, and the weights are the numbers of riders who need to move between respective buildings. The graphs were generated to provide a clear representation of the data obtained from the analysis of the student schedule information. An example of such a graph is shown in Figure 4.

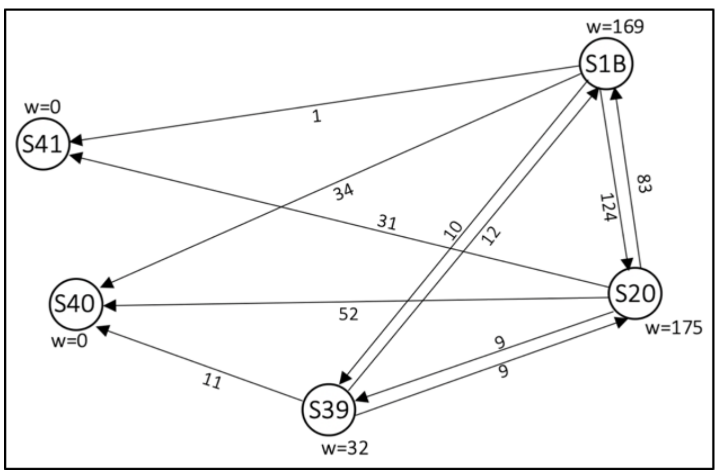

Figure 4. Directed graph representing the movement of students between buildings on Sunday at 10:45:00 AM.

The visualization of the data obtained from the student schedule analysis was an essential component in presenting the transportation needs of the UoB Sakhir campus students to stakeholders. Figure 4 illustrates the demand status on Sunday at 10:45 AM. The figure provides a clear visual representation of the student traffic patterns at each bus station. By examining this graph, we can identify the number of waiting students (w) and optimize the use of resources accordingly.

3.3. Algorithm to determine the number of needed buses.

Figures 5 and 6 illustrate the algorithm that was written to acquire the accurate number of buses that meet the student demand. The used variables and symbols are summarized in Table 2.

The first algorithm calculates the number of needed buses for each time slot. First, the algorithm iterates over the 5 stations, starting from S1B till S40, to simulate the first part of the bus route (Algorithm 1: lines 4 to 12). Later, the total number of students waiting at each station is calculated, along with the number of students who will be dropped off at each station. The remaining number of students on the buses is calculated and compared with the maximum remaining amount in each iteration. Afterward, another loop (Algorithm 1: lines 13 to 18) is created that represents the rest of the bus route from S39 back to S1B. The same calculations are performed as in the previous loop. The greatest remainder is then divided by the bus seat capacity of 25 to find the number of needed buses (Algorithm 1: line 19).

In the following stage, the student schedule records were taken as input for Algorithm 2, then lines 3 and 4 cleaned the raw data. The time slots in each day were iterated over to count the number of students waiting at each bus station (source) as well as to identify where each student was headed (destination). This is done after a series of conditions have been checked, including whether the time difference between two lectures does not exceed 15 minutes. A 5×5 matrix is generated at each iteration, with the rows and columns defined as stations ordered in the same sequence taken by the bus route, and the values representing the count of students heading from and to each building pair. Afterward, each matrix is used as input in the first algorithm, BusesPerTimeSlot.

In the end, once the largest number of buses for a certain time slot is returned in the Bus-Count algorithm (Algorithm 2: line 16), it is compared with the largest amount from previous time slots to determine which is greater. The final output is an array of size 5, where each value represents the maximum number of buses required per day (Algorithm 2: line 20).

Table 2. Algorithm notations.

Symbol	**Description**
n	The total number of records in the student schedule dataset.
SID	Student ID
D	Day
FT	From Time which represents the start time of a lecture.
TT	To Time which represents an end time of a lecture.
BC	Building Code
A	nx5 matrix where the 5 columns are: SID, D, FT, TT, BC.
B	Array of size 5 to store the number of needed buses per day.
BO	Array [S1B, S20, S39, S41, S40] that stores the order of the stations in the bus route.
BPC	5x5 matrix to store the count of students at each station in each time slot.
waiting	the number of students waiting at a station at a given timeslot.
remainder	the number of remaining students in a bus.
tsMaxRem	the greatest number of remaining students in a bus.
dropOff	the number of students that are dropped off at a certain station.

```
Algorithm 1: BusesPerTimeSlot(BPC[0...4,0…4])
    Input: BPC
    Output: Return number of buses per timeslot
    remainder ← 0, tsMaxRem ← 0, maxBus ← 0, dropOff ← 0
    for i ← 0 to 4 do
        waiting ← 0
        for j ← 0 to 4 do
            waiting ← waiting + row BPC[i][j]
        for j ← 0 to i do
            dropOff ← dropOff + BPC[i][j]
        remainder ← remainder – dropoff + waiting
        if remainder > tsMaxRem
            tsMaxRem ← remainder
    for i ← 2 to 0 do
        for j ← i to 4
            dropOff ← dropOff + BPC[i][j]
        remainder ← remainder – dropoff
        if remainder > tsMaxRem
            tsMaxRem ←remainder
    bus ←⌈tsMaxRem/25⌉
    if bus > maxBus
        maxBus ← bus
    return maxBus
```

Figure 5. BusesPerTimeSlot Algorithm to generate the buses needed for each time slot.

```
Algorithm 2: Bus-Count (A [0...n-1,0…4])
    Input: A
    Output: Maximum number of buses needed per day
    GROUP rows of A by D column then by SID
    SORT rows of A by TT
    for day ← 0 to 4 do
        B[day] ← 0
        for each unique time slot t in TT do
            b ← 0 //b is the number of buses needed for day
            for i ← 0 to n-2 do //loop through the rows
                if A[i][TT] = t
                    if A[i][SID] = A[i+1][SID] AND A[i][BC] ≠ A[i+1][ BC]
                        if A[i][FT] - A[i+1][TT] = 15min
                            i1 ← index of A[i][BC] in BO
                            i2 ← index of A[i+1][BC] in BO
                            BPC [i1][i2] ← BPC[i1][i2] + 1
                r ← BusesPerTimeSlot(BPC)
                if r > b
                    b ←r
        B[day] ← b
    return B
```

Figure 6. Bus-Count Algorithm to produce daily needed buses.

4. Findings and Discussion

The first algorithm, BusesPerTimeSlot, produced the maximum number of buses needed at each time slot for each working day by calculating the largest demand in a single edge and dividing the amount by the number of seats in each bus: 25. In reality, the number of buses generated is subject to slight increase due to additional students who choose to ride the bus for recreational purposes such as attending seminars and workshops, participating in university-led activities, and socializing with their university peers. On the other hand, there is a possibility of a decrease as well in the case of student absence for diverse reasons such as exams, medical issues etc.

Originally, an exact count of buses was generated for all 58 unique timeslots throughout the academic week. The timeslots with zero demand for all days were removed resulting in 32 timeslots. As shown in Table 3, for each day, there is a variance in the number of buses needed at each time slot. For example, on Sundays and Thursdays, 10 buses are required at 10:45 AM and 10 or 11 buses at 13:45 PM, while on Mondays and Wednesdays, the maximum of 8 buses is only allocated to 10:45 AM. The rest of the timeslots need fewer buses or, in many cases, none. Thus, the greatest number of buses is easily extracted as demonstrated in Table 4. Sunday and Thursday need the most buses at 10 and 11, respectively. The least number of buses for a single day was 3 buses on Tuesday, while the remaining days, Monday and Wednesday, need each 8 buses at most. Since the results for each day do not vary in amount, aside from Tuesday, the quota of buses needed for students who require transportation in an entire academic week could be considered 11 at most.

Table 3. Number of needed buses for the slot times 8:50 am to 20:50 pm

Time Slot	U	M	T	W	H
8:50:00	1	0	1	0	1
9:15:00	4	6	0	6	4
9:50:00	3	0	2	0	3
10:45:00	10	8	0	8	10
10:50:00	8	2	3	1	8
11:40:00	1	0	0	0	1
11:50:00	4	1	3	0	4
12:15:00	7	4	0	4	7
12:40:00	0	1	0	0	0
12:50:00	3	2	3	2	3
13:40:00	0	1	0	0	0
13:45:00	10	2	0	2	11
13:50:00	6	1	3	1	6
14:15:00	0	7	0	7	0
14:40:00	0	1	0	1	0
14:50:00	2	0	2	1	2
15:15:00	5	1	0	1	5
15:30:00	1	1	0	1	0
15:40:00	0	0	0	0	1
15:45:00	0	7	0	7	0
15:50:00	2	2	2	1	2

16:30:00	0	1	0	0	0
16:40:00	1	0	1	0	1
16:45:00	2	1	0	1	2
16:50:00	1	0	1	0	1
17:15:00	0	4	0	4	0
17:30:00	0	1	0	1	0
17:50:00	0	0	0	1	1
18:00:00	0	1	0	0	0
18:45:00	1	1	0	1	0
20:50:00	0	0	1	0	0

Table 4. The maximum number of buses needed per day.

Day	Number of Buses
U	10
M	8
T	3
W	8
H	11

In comparison with the 25 buses that are currently used, the findings showcase that the UoB Sakhir campus requires, at most, 56% fewer buses in an academic week. Furthermore, the results provide the optimal number of vehicles needed for each timeslot, thereby reducing the total amount of buses employed in a term and decreasing unnecessary resource utilization throughout the day. In addition, minimizing vehicle utilization leads to a great decrease in CO_2 emissions. Hence, creating a more efficient internal transportation system. It is important to note that solution results represent only students who need to attend successive lectures in different buildings in a 15-minute timeframe.

In future terms, it is recommended that UoB officials commission a fixed number of buses for an entire week, the number would be the largest of all the daily needed buses. Alternatively, a dynamic contract could be written: each day would have a different number of buses based on the provided results. To combat the issue of non-essential riders, an extra two or three buses could be provided for each day. For further improvement of the transportation network, a line of communication must be opened between the departments concerned with student registration and internal transportation as both factor into the network's efficiency. Considering that student bus seat demand fluctuates throughout a single day, the registration department, in collaboration with the transportation office, could possibly examine the distribution of student courses across different buildings at certain times, which would additionally decrease the overall need for internal transportation. A possible solution that can lead to a better distribution, is if many students from the same college take service courses (program requirements, non-major electives), then the instructor could move to the college instead of relocating all the students to a different building. Moreover, as the student body oscillates with each term, and students' schedules change accordingly, the registration department must provide new data input each term to the transportation department to acquire accurate results.

5. Conclusion and Future Work

In conclusion, this research has investigated the student bus usage patterns and analyzed the current transportation issues on the University of Bahrain Sakhir campus. The findings revealed that the buses are not being utilized in an optimal manner, as they often travel around the university campus despite the absence of students at some stations, or the presence of varying numbers of students at other stations. This practice leads to inefficiencies as the bus continues to circle along the stations without knowing the number of students it may encounter.

To address this transportation issue, data analysis and movement patterns were visualized to develop an algorithm for optimizing the number of buses required by students. The algorithm calculated the exact number of buses needed for each unique time slot during the academic week on each day, resulting in a different number of daily needed buses. This approach has the potential to improve internal mobility efficiency by employing the optimal number of buses and decreasing congestion. Subsequently, many other advantages will arise such as lowering operational costs, enhancing students' mobility experience, and decreasing CO_2 emissions.

Therefore, the university administrators and the transportation department could benefit from the findings of this research by inputting the students' schedules for each semester to the algorithm, so that it can precisely provide the university with an optimal amount of the required buses for each semester. If the bus amount is not satisfactory in terms of cost, both the registration and transportation offices could repeatedly cooperate to refine the student schedules until a suitable number of buses is reached.

However, some limitations were found regarding data collection and analysis. The collected data records account only for students who need to move between buildings for lectures registered in their schedules and not students who may choose to utilize the internal transportation for other purposes as it falls out of the research scope. Moreover, while the suggested solution increases the overall efficiency of the university's transportation, it still utilizes the same bus route. Therefore, future research should explore the possibility of creating new routes. To further improve the solution, an express bus, that takes a station-to-station direct path, could be implemented in the case of high demand for certain pairs of stations. For example, there is generally a high demand at the S1B, S40, and S41 stations.

6. References

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