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Optimization of Private Bus Scheduling in UiTM Shah Alam Using Integer Linear Programming

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ABSTRACT

Bus usage among students are common in any higher learning institutions, simply because it is the cheapest transportation mode that the student could afford. In UiTM Shah Alam, there are 2 types of bus provider: one that is provided by UiTM itself and two, by a private company, appointed by UiTM. In this paper, scheduling of private bus services is presented. The problems arise in this area involved long waiting time and the unavailability of bus schedule that students can rely on. The objective of this project is on planning a schedule of the private bus service that will optimize the number of trips taken by each bus according to passenger, based on peak/off-peak hours. However, this study will only focus on zone Section 7 and Dalaman since these two zones are the mostly used by students. A reference model in scheduling of UiTM bus using integer linear programming has been applied and enhanced in this project. The variables are arranged according to the constraints in Microsoft Excel and later MATLAB Software is used to generate the results. Using optimization toolbox, the bus schedule for route Section 7 and Dalaman are generated, which optimized the number of trips taken by each bus. The schedule is arranged according to the peak hours and off-peak hours of bus service time. Result shows that the objective is achieved. However, a system that combines both private and UiTM bus is recommended to be developed in the future, as it is believed that resources such as time and money can further optimize the scheduling problem.

Keywords:
Bus scheduling; optimization; integer linear programming

1. Introduction

The quality of a local public transport depends on the apparent efficiency and consistency. However, events or instabilities inherent in the system, especially in a city setting, may cause interruptions that undesirably influence this awareness. Additionally, interruptions usually raise the operational cost, for instance, concerning extra payments for bus drivers, or penalties to be paid to the metropolis that committed the service.

Bus scheduling problem (BSP) involves the process of planning the time table of every buses at every route being used. Scheduling is the application stage of production planning, and as a continued activity in the process of production systems. Scheduling works by dividing the general production plan into the time phased weekly, daily, or hourly activities [3]. The problem of scheduling and routing buses deals with the important question of how to transport students to and from schools in the most convenient manner and most economical way [4]. In order to design the routes

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in the most efficient way, a set of potential stops and routes are determined. This is so that each pupil has at least one stop he/she can walk to and for the school buses to pick up students at allowed bus stop. The capacity of the bus must not exceed the limit [11].

In UiTM Shah Alam, there are two types of bus services available which are UiTM bus that is free of charge and private bus where you need to pay RM1 per ride. This project only focused on private buses that are managed by Prasarana Malaysia Berhad Company. An officer is responsible for preparing the vehicle scheduling every day. The private bus provides 9 buses to cover in-campus and out-campus trips. It covers 3 different routes which is routes heading to Section 2 (T750), Section 7 (T751) and in-campus trip (*Dalaman*).

As for now, the scheduling for the private bus is not fixed as the drivers do not follow the timetable that is given. This results in inconsistency of arrival time of bus at each bus stop. Based on article by Valouxis and Housos [12], a difficult combinatorial problem that must be solved for all bus companies that operate a non-fixed daily schedule is the daily bus and driver scheduling. Their schedule for the next day will change due to different load requirements on the standard route, additional services and trips that need to be performed. It means that the driver scheduling cannot be fixed due to many reasons.

2. Literature Review

There are a number of research papers in the literature that suggest alternative strategies for the bus scheduling problem. Arias-Rojas *et al*., [1], and Oughalime *et al*., [10] , conducted a study on bus scheduling around Unicampus that aims to design a competent schedule for the drivers and vehicle that will possibly cover all trip demands. The attributes vary from the daily set of trips, drivers and non-homogeneous vehicles fleet, maximum capacities of the bus, maximum riding time of students and time window to the school.

The different are mainly on the method solution approach and results where Arias-Rojas *et al*., [1], use ant colony optimization (ACO) that lead to a cut in transportation times with on-time delivery to the school and more optimized bus utilization. It also reduced the total distance travelled by 8.3 percent and 21.4 percent respectively in the morning and afternoon. While Oughalime *et al*., [10], use a sequential approach where integer programming and a goal programming model presented to solve vehicle scheduling problem and driver scheduling problem respectively. It is concluded that the inputs for the driver scheduling problem is obtained from the results of integer programming model used to solve vehicle scheduling problem.

Kim et al., [6], Fu [5] and Ornek *et al*., [9] made an attempt to seek an objective that optimize the number of buses used to meet a given schedule of trips with varying demand. They consider a different type of constraints which are the start bus stop, length of service time, the number of students using the buses, assigned school that are set for each trip and many more.

In Kim *et al*., [6], approach a solution by using a Hungarian method and branch-and-bound algorithm with assumption of homogeneous buses and fixed start time. While for an assumption of heterogeneous buses proposed a Heuristic approach consisting of an iterative access point (AP) based on construction algorithm and improvement algorithm. Through the proposed algorithm, the number of buses for Case 1 and Case 2 could reduce by 43 (17.6 percent) and 34 (14.0 percent) respectively compared the current routine. Fu [5] showed a result that the number of deployed buses reduced to 25 percent which in a way helps to reduce the operating cost that was presented by an integer linear programming model with branch-and-cut algorithm. While for Ornek *et al*.,[9] is modelled as a tactical fixed job scheduling (TFJS) problem since the time window and departure and arrival point are already fixed and the passengers cannot be split. Six heuristic were proposed to solve this problem as it is difficult to obtain an optimal solution in acceptable CPU times.

Bektaş and Elmastaş [2]and Li and Fu [7] conducted a study school bus routing problem where the objectives are to minimize the total number of buses required, the total travel time spent by students at all stops, the total bus travel time in order to decrease the total cost of transportation. The constraints of distance and capacity are considered in this study. Bektaş and Elmastaş [2] approach a solution by using a commercial integer programming optimizing that results where 28.6 percent of the total cost were able to be saved compared to the current routing scheme. Next, Li and Fu [7] present a heuristic algorithm in solving the multi-objective combinatorial optimization problem. In their approach, it shows an effectual result with a saving of 29 percent in total travelling times compare to current practice.

Brah and Shah [3] carried out a study on mathematical modelling of scheduling problems too. The aim of scheduling is to establish a planning of activities to improve pre-set criteria. The three decision-making goals common in scheduling are well-organized utilization of resources, quick response to demands and close conformances to the deadlines. In this paper, they recognize most criteria effecting the scheduling decision and create a scheduling cost model. Furthermore, they develop mathematical models for most scheduling situations. These include single machine, parallel machine, flow shop, flow shop with multiple processors and job shop. The objective in these mathematical models is to minimize cost based upon a complete scheduling cost model. This paper shows that Lagrangian relaxation method can be used to resolve majority scheduling complications for optimal or near optimal solutions for diverse measures of performance.

Previously, a study on bus scheduling in UiTM Shah Alam has been carried out by Omar *et al*., [8]. The objective of the study is to minimize the number of bus for in-campus trip. An integer programming model is formulated to solve the scheduling problem. As the result, during peak hours the number of buses used is 22 buses, the same number of buses provided by UiTM. Out of 22 buses, only 13 buses with optimal trip are used to transport students during off peak hours. Result shows that the objectives are achieved. This project however will focus on scheduling of bus provided by the private bus operator.

In this research, the numbers of buses are fixed at every zone. There are 3 buses available at zone *Dalaman* and 5 buses at zone Section 7. The main problem is the availability of proper schedule to be followed by the bus drivers. Since the arrival time of the bus is not fixed students are not able to plan ahead their journey. Besides, the bus carries more number of passengers than its capacity to fulfil request from students who are rushing to go to class. This will also endanger the students' safety. Another problem occurs when more than one bus takes up one same trip which is very wasteful of time and cost.

A survey was conducted to measure the level of satisfaction of the private bus service among UiTM Shah Alam students. Result shows that 44.2% of the respondents chose average related to the availability of bus and 34.6% of students which is the majority also chose average for satisfaction for waiting time of bus to arrive. On top of that, 28.8% of the students are less satisfied on the crowd of the bus. This is due to the absence of scheduling for the private bus that caused the irregularity of bus arrival and their availability.

This project focuses on the private bus service that is available for the use of UiTM Shah Alam students. The objectives of this study are to identify the pattern of private bus services in UiTM Shah Alam in terms of number of buses, trips and routes and plan a schedule that will optimize the number of trips taken by each bus according to passenger based on peak/off-peak hours. Although there are a total of 4 routes provided by the bus operator, this research only consider 2 most widely routes, that is zone Section 7 and zone *Dalaman*. Fig 1 and 2 shows the routes for both zones.

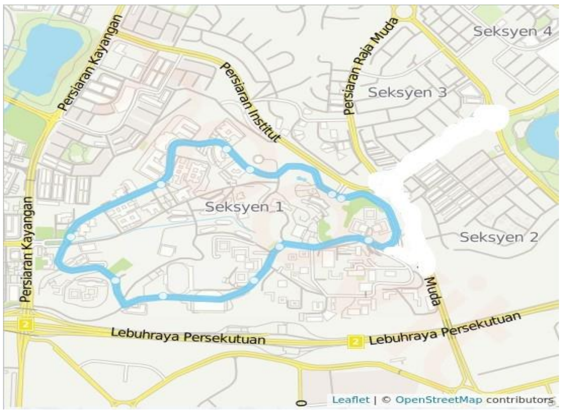

Fig. 1. Zone *Dalaman*

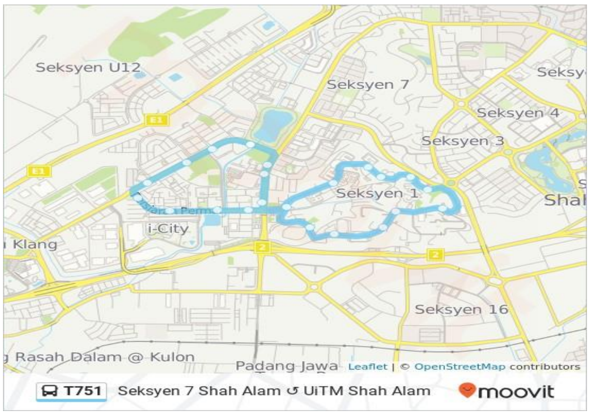

Fig. 2. Zone Section 7

3. Research Methodology

The aim of this research is to determine a bus schedule that will optimize the number of trips taken by each bus according to passenger based on peak and off-peak hours. The daily bus operation is from 7 a.m. until 7 p.m., Monday to Sunday on every route. Omar *et al.*, [8], model of bus scheduling has been chosen to be the base model for this research and is modified according to the data, variables and constraints based on this study. Below are the parameters used in this research.

T: Trips set during the scheduling period
V: Set of bus available during the scheduling period
CT_t: Set of trips that clashes in time with trip *t*

A 0 – 1 variable is used in this problem is as follows:

$$Y_{v\_t} = \begin{cases} 1 & \text{if trip } t \text{ is served by bus } v \\ 0 & \text{otherwise} \end{cases}$$

The objective (1) is to minimize the number of trips taken by each bus for respective zone

$$\text{Min Z} = \sum_{v \in V, t \in T} Y_{v\_t} \tag{1}$$

Subject to:

$$\sum_{v \in V} Y_{v\_t} = 1, \quad \forall t \in T \tag{2}$$

$$Y_{v\_t} + Y_{v\_t'} \leq 1, \quad \forall t \in T, \forall v \in V, t' \in \{CT_{t'}, CT_t \neq \varnothing\} \tag{3}$$

$$Y_{v\_t} \in \{0,1\}, \qquad \forall t \in T, \forall v \in V \tag{4}$$

Constraint (2) ensures that only one bus be assigned for corresponding trip. Constraint (3) ensures that only a bus would serve for each trip and there are no conflicting trips. Constraint (4) impose the 0 – 1 restriction on the decision variables and respectively.

4. Findings

The results were obtained using MATLAB Software. This scheduling process involves two cases which are peak hours phase and off-peak hours phase with morning and afternoon session respectively. The number of buses that has been set by the bus company for zone *Dalaman* is 3 buses and for zone section 7 is 8 buses. Below are some of the results and explanation that have been obtained from MATLAB. The 0 – 1 integer programming approach is used.

ZONE: *DALAMAN*

Table 1
Results for bus 1 in zone *Dalaman*

Variables	Remark	Time
y1_2	Bus 1 will take trip 2	7.10-7.30
y1_5	Bus 1 will take trip 5	7.40-8.00
y1_8	Bus 1 will take trip 8	8.10-8.30

Table 2
Results for bus 2 in zone *Dalaman*

Variables	Remark	Time
y2_1	Bus 2 will take trip 1	7.00-7.20
y2_4	Bus 2 will take trip 4	7.30-7.50
y2_7	Bus 2 will take trip 7	8.00-8.20

Table 3
Results for bus 3 in zone *Dalaman*

Variables	Remark	Time
y3_3	Bus 3 will take trip 3	7.20-7.40
y3_6	Bus 3 will take trip 6	7.50-8.10
y3_9	Bus 3 will take trip 9	8.20-8.40

ZONE: SECTION 7

Table 4
Results for bus 1 in zone Section 7

Variables	Remark	Time
y1_4	Bus 1 will take trip 4	7.30-8.10
y1_9	Bus 1 will take trip 9	8.20-9.00
y1_14	**Bus 1 will take trip 14**	**9.40-10.20**

Table 5
Results for bus 2 in zone Section 7

Variables	Remark	Time
y2_3	Bus 2 will take trip 3	7.20-8.00
y2_8	Bus 2 will take trip 8	8.10-8.50
y2_13	Bus 2 will take trip 13	9.30-10.10

Table 6
Results for bus 3 in zone Section 7

Variables	Remark	Time
y3_5	Bus 3 will take trip 5	7.40-8.20
y3_10	Bus 3 will take trip 10	9.00-9.40
y3_15	Bus 3 will take trip 15	9.50-10.30

Table 7
Results for bus 4 in zone Section 7

Variables	Remark	Time
y4_1	Bus 4 will take trip 1	7.00-7.40
y4_6	Bus 4 will take trip 6	7.50-8.30
y4_11	Bus 4 will take trip 11	9.10-9.50

Table 8
Results for bus 5 in zone Section 7

Variables	Remark	Time
y5_2	Bus 5 will take trip 2	7.10-7.50
y5_7	Bus 5 will take trip 7	8.00-8.40
y5_12	Bus 5 will take trip 12	9.20-10.00

Based on the MATLAB results, the overall results that show the schedule for every zone according to its case has been simplified and showed below.

CASE 1: PEAK HOURS

During peak hours, all buses in both zones are running simultaneously. Based on the constraints and policies set by the private bus operator, the results for bus scheduling model during peak hours is shown in Table 9, Table 10, Table 11 and Table 12.

<u>ZONE: *DALAMAN*</u>

Table 9 and Table 10 show all buses that have been provided in zone *Dalaman* are fully utilized with an optimal trip. Each bus is assigned to its respective trip. The bus arrives every 10 minutes and the journey time for each trip is 20 minutes for both peak hours and off-peak hours. The first bus will take the first trip followed by the next bus for the following trip. Once the particular bus is done with the first trip, it will take another trip according to the time in the schedule.

Table 9
Computational Results for Zone *Dalaman* During Peak Hours (Morning)

TIME	7.00	7.10	7.20	7.30	7.40	7.50	8.00	8.10	8.20	8.30	8.40
BUS	2	1	3	2	1	3	2	1	3	2	1

Table 10
Computational Results for Zone *Dalaman* During Peak Hours (Afternoon)

TIME	12.00	12.10	12.20	12.30	12.40	12.50	1.00	1.10	1.20	1.30	1.40
BUS	1	3	2	1	3	2	1	3	2	1	3
TIME	1.50	2.00	2.10	2.20	2.30	2.40					
BUS	2	1	3	2	1	3					

ZONE: SECTION 7

For Table 11 and Table 12, it shows that all 5 buses in zone Section 7 are fully utilized with an optimal trip. The objective to optimize the number of trips is achieved. Each bus is assigned to its respective trip. The bus arrives every 10 minutes and the journey time for each trip is 40 minutes for both peak hours and off-peak hours. The first bus will take the first trip followed by the next bus for the following trip. Once the particular bus is done with the first trip, it will take another trip according to the time in the schedule.

Table 11
Computational Results for Zone Section 7 During Peak Hours (Morning)

TIME	7.00	7.10	7.20	7.30	7.40	7.50	8.00	8.10	8.20
BUS	4	5	2	1	3	4	5	2	1

Table 12
Computational Results for Zone Section 7 During Peak Hours (Afternoon)

TIME	12.00	12.10	12.20	12.30	12.40	12.50	1.00	1.10	1.20	1.30	1.40
BUS	3	4	5	2	1	3	4	5	2	1	3
TIME	1.50	2.00	2.10	2.20							
BUS	4	5	2	1							

CASE 2: OFF-PEAK HOURS

During off-peak hours, the private bus operator also does not specify the scheduling in zone *Dalaman* and zone Section 7. Below are the results for the schedule as in Table 13, Table 14, Table 15 and Table 16.

ZONE: *DALAMAN*

Table 13 and Table 14 show all buses that have been provided in zone *Dalaman* are fully utilized with an optimal trip. Each bus is assigned to its respective trip. The bus arrives every 10 minutes and the journey time for each trip is 20 minutes for both peak hours and off-peak hours. The first bus will take the first trip followed by the next bus for the following trip. Once the particular bus is done with the first trip, it will take another trip according to the time in the schedule.

Table 13
Computational Results for Zone *Dalaman* During Off-Peak Hours (Morning)

TIME	9.00	9.10	9.20	9.30	9.40	9.50	10.00	10.10	10.20	10.30	10.40
BUS	3	2	1	3	2	1	3	2	1	3	2
TIME	10.50	11.00	11.10	11.20	11.30	11.40					
BUS	1	3	2	1	3	2					

Table 14
Computational Results for Zone *Dalaman* During Off-Peak Hours (Afternoon)

TIME	3.00	3.10	3.20	3.30	3.40	3.50	4.00	4.10	4.20	4.30	4.40	4.50
BUS	2	1	3	2	1	3	2	1	3	2	1	3
TIME	5.00	5.10	5.20	5.30	5.40	5.50	6.00	6.10	6.20	6.30	6.40	
BUS	2	1	3	2	1	3	2	1	3	2	1	

ZONE: SECTION 7

Table 15 and Table 16 show that all 5 buses in zone Section 7 are also fully utilized with an optimal trip. Each bus is assigned to its respective trip. The bus arrives every 10 minutes and the journey time for each trip is 40 minutes for both peak hours and off-peak hours. The first bus will take the first trip followed by the next bus for the following trip. Once the particular bus is done with the first trip, it will take another trip according to the time in the schedule.

Table 13
Computational Results for Zone Section 7 During Off-Peak Hours (Morning)

TIME	9.00	9.10	9.20	9.30	9.40	9.50	10.00	10.10	10.20	10.30	10.40
BUS	3	4	5	2	1	3	4	5	2	1	3
TIME	10.50	11.00	11.10	11.20							
BUS	4	5	2	1							

Table 14
Computational Results for Zone Section 7 During Off-Peak Hours (Afterboon)

TIME	3.00	3.10	3.20	3.30	3.40	3.50	4.00	4.10	4.20	4.30	4.40	4.50
BUS	3	4	5	2	1	3	4	5	2	1	3	4
TIME	5.00	5.10	5.20	5.30	5.40	5.50	6.00	6.10	6.20			
BUS	5	2	1	3	4	5	2	1	3			

5. Conclusion

For the students of UiTM Shah Alam, bus services are their main choice of transportation for them to move from one place to another in the campus. However, there are many problems that they have encountered in the earlier study regarding to bus scheduling that affect the quality of private bus service in UiTM. The problems do not just affected the bus operator in term of operating cost but also the students. Due to absence of a proper schedule, they are not able to plan their journey well, came late to class and are faced with all sorts of other difficulties.

The objectives of this study were achieved. Firstly, pattern of the current private bus service in UiTM Shah Alam has been identified. It was discovered that there was no schedule prepared as a reference for students. Because of this, every bus runs endlessly without caring which trip should be taken by them. This end up in different buses to move simultaneously for one same trip which will cause the bus operator to suffer loss in term of cost and time. With regards to this, based on the enhanced model, a bus schedule has been developed to find a solution for this problem in UiTM Shah Alam. From the schedule, it can see how each bus in each zone operates during peak hours and off-peak hours and the number of trips taken by each bus.

For further research, it is recommend to develop a schedule combining of both private bus and UiTM bus into one system to achieve a better scheduling that benefits the students and bus operator. By combining them, it is anticipated that mismatching of demand and supply of bus could be avoided. In addition, a better scheduling is presented that can lessen the traffic congestion in UiTM Shah Alam.

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