Campus Bus Service Planning for a Rural University in Thailand

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Abstract: To prepare for a new contract, this paper attempts to determine the minimum number of vehicles that required to provide a service according to the current bus schedule of a rural university in Thailand. Two methods are considered, the simple method and the blocking method, in which route switching can also be implemented. However, no difference can be observed among the results of these two methods. Possible explanation is due to all routes considered in this study have the same peak period. Thus no benefit can be extracted by switching route in this case. The results illustrate that the university can save about 7.7% to 15.4% of bus leasing cost.

Keywords: Bus, Transit, Scheduling, Blocking, Headway, Cycle time

1. INTRODUCTION

Increased awareness of climate change and energy crisis has caused several government organizations to focus more on the environmentally friendlier actions. Among which is Suranaree University of Technology, the first autonomous university in Thailand, which has also raised a campaign called “Green and Clean University”. One of the actions is to promote more usage of public transport among students and staffs for traveling inside the campus. The university provides free on-campus bus services, by leasing busses from a private company as well as to hire the same company to operate and manage the bus services, including drivers and maintenance of the buses, under the contract of five years. Currently the university leases 13 busses in total and operates for 3 different routes, each differs in a number of aspects. The current contract is about to end by the end of 2013, causing the university planners to prepare for a new contract before then. Many questions about the new contract have arisen and one of which is about how many busses are required to provide the current and future services. Is it possible to reduce the number of leased bus (and hence the cost) but maintain the current level of service to all users? How many busses will be required if there is a new route or the current routes are expanded to cover the future growth of the university. The objective of this study is to seek answers for these questions and provide recommendations to the university planners.

The problem of transit planning and operation can be divided into five steps according to TRB (1998): 1) service policy and schedule development, a process to setup route and frequency of service; 2) trip generation, a process to develop a master schedule; 3) blocking, a process of developing vehicle assignment; 4) run cutting, a process of developing the operator assignment; and 5) rostering, a process of grouping daily operator runs into weekly run packages. Because maintaining the current level of service is aimed, the first two steps are not the focus of this study. In fact, only the third step is considered because it can provide the information about the required number of vehicles. Butsingkorn (2013) and Butsingkorn et al (2013) considered the problem of vehicle assignment for some bus routes in Bangkok by modifying the original concept of TRB (1998). They found that manual assignment (the current practice) is not efficient and the algorithm-based method developed in their study could reduce a significant number of bus needed. In particular, it is even more efficient when the busses are allowed to switch route. Based on the premise that a more efficient vehicle assignment can reduce the number of bus needed, we follow similar approach and examine how many vehicles are needed to provide the same level of service under the current time table.

We first explain briefly about the study site and the current bus service operation. Then the methodology used in this study is elaborated. Next, the analyses and results are presented. Finally, some concluding remarks are given.

2. DESCRIPTION OF THE PROJECT

2.1 Study Site

Suranaree University of Technology (SUT) is situated in a rural area in the Northeastern of Thailand, about 19 km away from the city center of Nakhon Ratchasima. The total area of the university is 11.2 km^2 and has a total enrollment of 10,013 undergraduate students and 1,515 graduate students. Almost all students live on campus (55%) or in apartments nearby the campus (40%).

The active area of the campus can be grouped roughly into five zones: the student residence halls, the staff residential area, the classroom building complex, the commercial area, and the medical service center. The student residence zone comprises 16 buildings housing approximately 6550 students. Second, the staff residential area comprises of 8 apartments and 90 individual houses. Third, the classroom building complex includes the huge common classroom building, an office building for academic staff, an administrative building, a dining hall, a library, and the laboratory buildings, each of which is within walking distance from the others. Almost all of the classes take place in the common classroom building, thus students simply walk from one lecture room to another to change from one class to another during class periods. The classroom building zone is located approximate 2 km away from the student residence halls. Fourth, the commercial area houses a convenience store, a post office, two banks, and a bookstore. This area is located approximately 2 km from the classroom building complex, and 4 km from the residence hall area. Fifth, the medical service center is a newly utilized area (not exist on the map) which houses an administrative building, an apartment for nurses, and shortly will house a 10-story hospital building. Figure 1 shows the map of SUT.

2.2 Current Bus Operation

The university provides a free bus service with a fleet size of 13 vehicles. The university's transport department together with the contracted company manage the bus service. All buses are standard micro-bus size with 28 seats. Currently, there are two routes for on-campus service, the student residence hall route and the staff residential area route, namely route 1 and 2 respectively. In addition, there is also a special off-campus route to Nakhon Ratchasima city center for sending staff's children to school in the morning and picking-up them in the late afternoon, called as route 3. For the latter route, one dedicated vehicle is assigned for this purpose only.

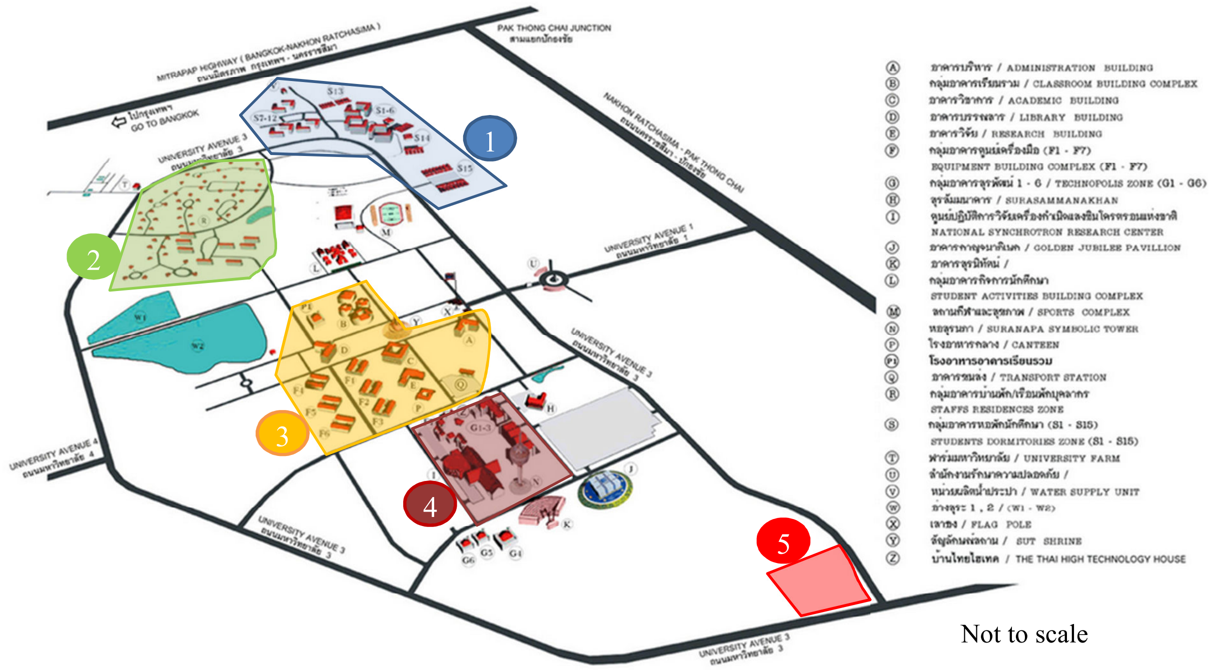
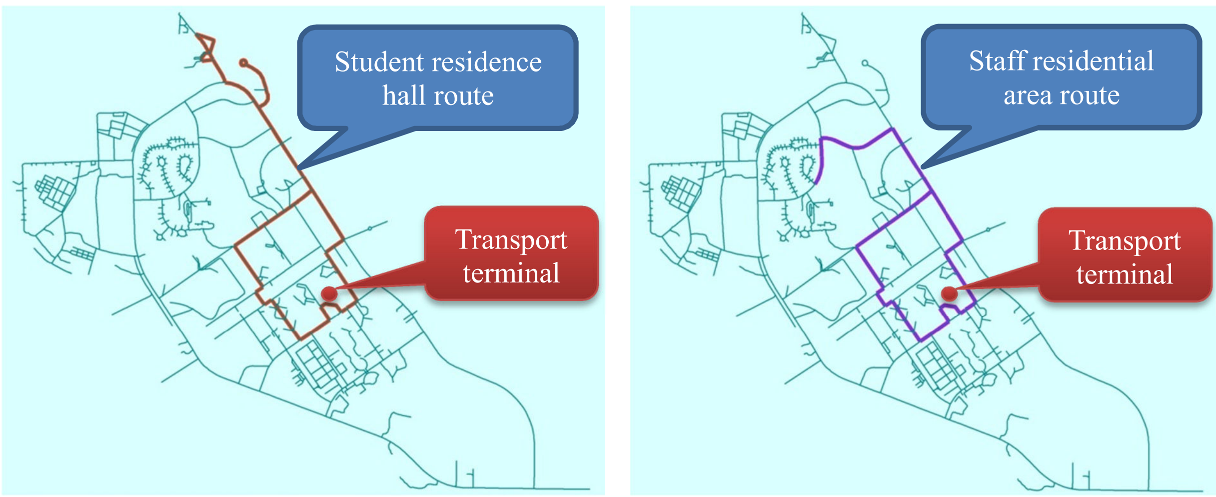


Figure 1 Map of SUT, 1) the student residence halls, 2) the staff residential area, 3) the classroom building complex, 4) the commercial area, and 5) the medical service center



(a) Student residential hall route (b) Staff residential area route

Figure 2 SUT on-campus bus routes

On weekdays, the student residence hall route operates between zone 1 and zones 3-4, with a minimum headway of 5 minutes during the peak periods and a varying headway of 10 minutes to half an hour during the off-peak periods. It operates from 7:00 am until 9:00 pm, with the exception of the periods of the mid-term and final exams, when the service extends until midnight. The staff residential area route operates between zone 2 and zones 3-4, with a minimum headway of half an hour before the start and after the end of the official work hour. Outside the peak period, the headway varies from one hour to about five hours. It operates from 7:10 am until 8:30 pm with a dedicated vehicle specifically assigned for this route only. Figure 2(a) and 2(b) illustrate respectively the student residence hall route and the staff residential area route. All three routes follow a loop pattern by starting and ending at the same location, the transport terminal as shown in Figure 2. Beside the regular scheduled trips, quite often that 2 or 3 busses are needed to provide a service for students involving in some activities outside the campus. But this is per request and may not happen regularly. Table 1 summarizes the frequency of each route by time of day and day of week.

Table 1 Bus schedule, depart from transport terminal

Route	Running time	Day	Departure Time	Frequency (headway)
1	Approx. 25 min	Weekday	7:00 – 9:00	Every 5 minutes
			9:00 – 12:00	Every 10 minutes
			12:00 – 13:00	Every 5 minutes
			13:00 – 16:30	Every 10 minutes
			16:30 – 18:00	Every 5 minutes
			18:00 – 19:00	Every 20 minutes
			19:00 – 21:00	Every 30 minutes
		Weekend & Holiday	7:00 – 9:00	Every 10 minutes
			9:00 – 19:00	Every 20 minutes
			19:00 – 21:00	Every 30 minutes
2	Approx. 30 min (35 min for trips depart at 11:55 and 16:50). The longer running time than route 1 is due to stopping and waiting for passengers at the stop in the staff residential area	Weekday	7:10, 7:41, 8:41, 11:55, 16:50, 17:31, 18:01, 19:01, 20:01	
		Weekend & Holiday	7:10, 8:10, 11:40, 16:40, 18:40, 19:40	
3	Approx. 2 hr for trip depart at 7:00 and 3 hr for trip depart at 14:30	Weekday	7:00, 14:30	
		Weekend & Holiday	No service	

2.3 Cost of Operation

As mentioned earlier, the buses are operated by the private company under a fixed contract. The contract covers most of the costs including leasing the buses, maintenance, and operation and management (i.e. payment for drivers). Not included in the contract is the fuel cost. Under the current contract, the total leasing cost is approximately about 590,000 Baht per vehicle per year. For 5-year contract, the leasing cost is about 2,950,000 Baht per vehicle. At this moment, there is no information about the new contract therefore the cost under the current contract will be used to illustrate the possible benefit of any modification.

3. METHODOLOGY

Two methods to determine the required number of vehicles are considered here, the simple method according to cycle time and desired headway and the blocking method.

3.1 Simple Method

TRB (1998) suggests that the number of vehicles needed to operate a given headway can be determined from the following equation

$$No.of\ vehicles = \frac{Cycle\ Time}{Desired\ \ Headway}. \tag{1}$$

Cycle time is defined as the time needed to make a round trip on the route, including layover/recovery time (break and buffer time). In other words, cycle time can be defined as the summation of round trip running time and layover/recovery time. Headway denotes the time interval between two consecutive vehicles operating in the same direction on a route. When headway varies by time of day, the most critical headway or the shortest headway during the peak period can be used to determine the number of vehicles. This equation is useful and can be used directly to estimate the required number of vehicles for any single route. However, when allowing vehicles to switch between routes for higher efficiency, determining the number of vehicles required for the service is more complicated because of possible differences in cycle time and desired headway among different routes. Butsingkorn (2013) modified the blocking concept illustrated in TRB (1998), formulated in terms of rule-based decision making problem which was solved heuristically to obtain the solution. A simplified version of their blocking formulation is adopted here and discussed in the next section.

3.2 Blocking Method

This is a process to assign work for each vehicle by connecting between all feasible trips according to some constraints. The input to this method is the master schedule which shall contain information about departure time from the terminal, arrival time to the terminal, break time (or sum of layover/recovery time at any points along the route), route, start terminal, end terminal, as well as some physical or policy-based constraints. The constraints are listed below

$$BreakMin \leq Break\_Time \leq BreakMax \tag{2}$$

$$Deadhead\_Time \leq AllowanceDeadhead \tag{3}$$

$$\sum Worked\_Time \geq RouteRunningMin \tag{4}$$

Constraint in equation (2) describes a condition that the break time of any vehicle for each round trip should be at least BreakMin but not longer than BreakMax. In equation (3), Deadhead_Time refers to the time the vehicle needs to move without passenger from the end terminal of the current route to the start terminal of the new route in order to switch route. This time shall not be longer than the maximum time allowed (AllowanceDeadhead). Finally, equation (4) specifies a condition to switch the route that accumulated work time of any vehicle shall be greater than the minimum running time (RouteRunningMin) in order to be eligible for changing the route. The process of this method is illustrated in a flowchart shown in Figure 3.

It is worth to note that all routes in this study start and end at the transport terminal. Therefore, the value of Deadhead_Time will always be zero. The value of constraints used in this study is shown in Table 2 and Table 3 shows the example of input data.

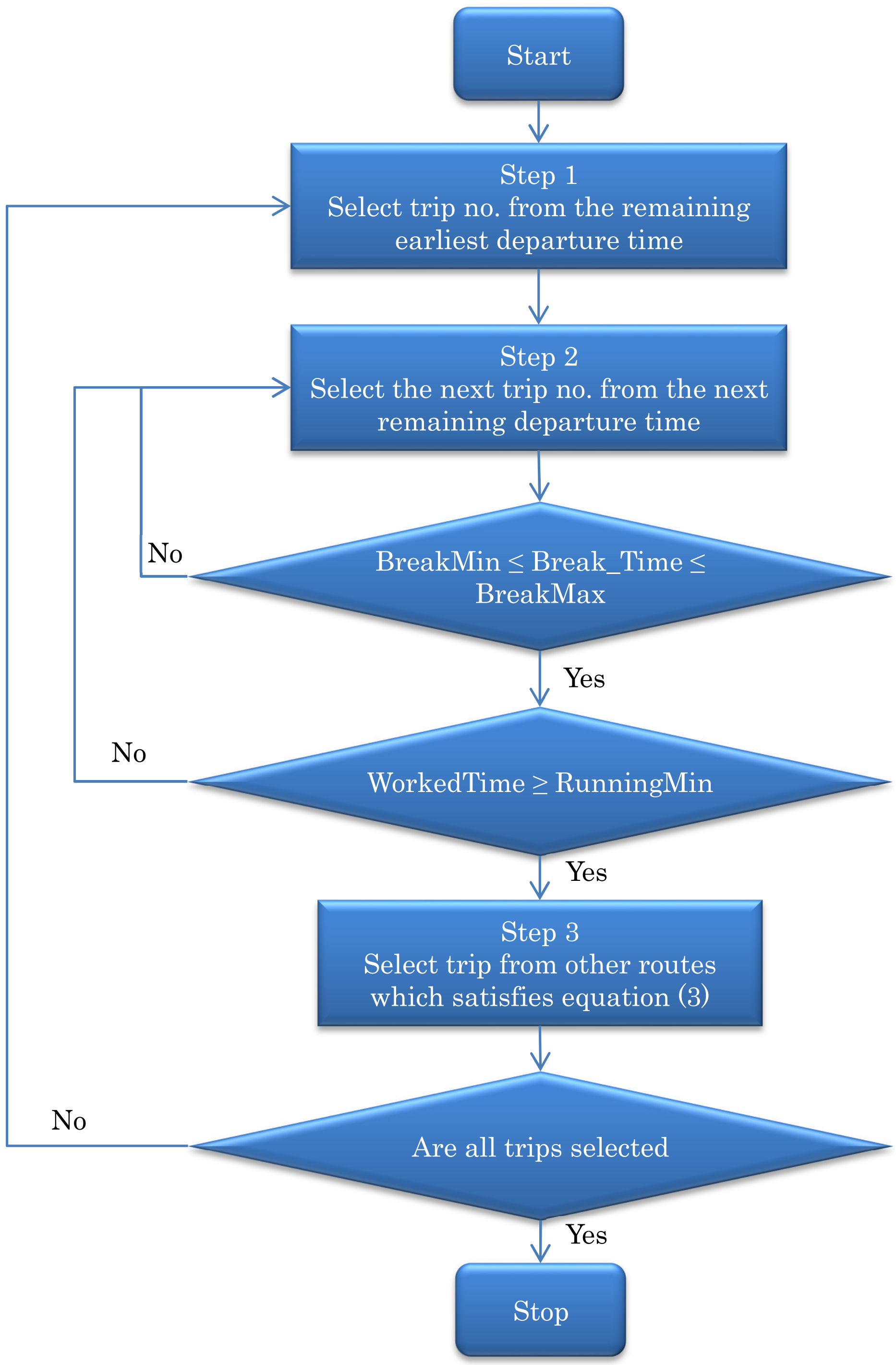


Figure 3 Procedure of the blocking method

Table 2 Value of constraints

Break_Max	0:00 hr OR 0:05 hr.
Break_Min	0:00 hr
Running_Min	0:25 hr

Table 3 Example of input data

N_Trips	Departure	Arrival	Running	Route	Location_Start	Location_End
1	7:00	7:25	0:25	1	1	1
2	7:05	7:30	0:25	1	1	1
3	7:10	7:35	0:25	1	1	1
4	7:15	7:40	0:25	1	1	1
5	7:20	7:45	0:25	1	1	1
6	7:25	7:50	0:25	1	1	1
7	7:30	7:55	0:25	1	1	1
8	7:35	8:00	0:25	1	1	1
9	7:40	8:05	0:25	1	1	1

4. ANALYSES

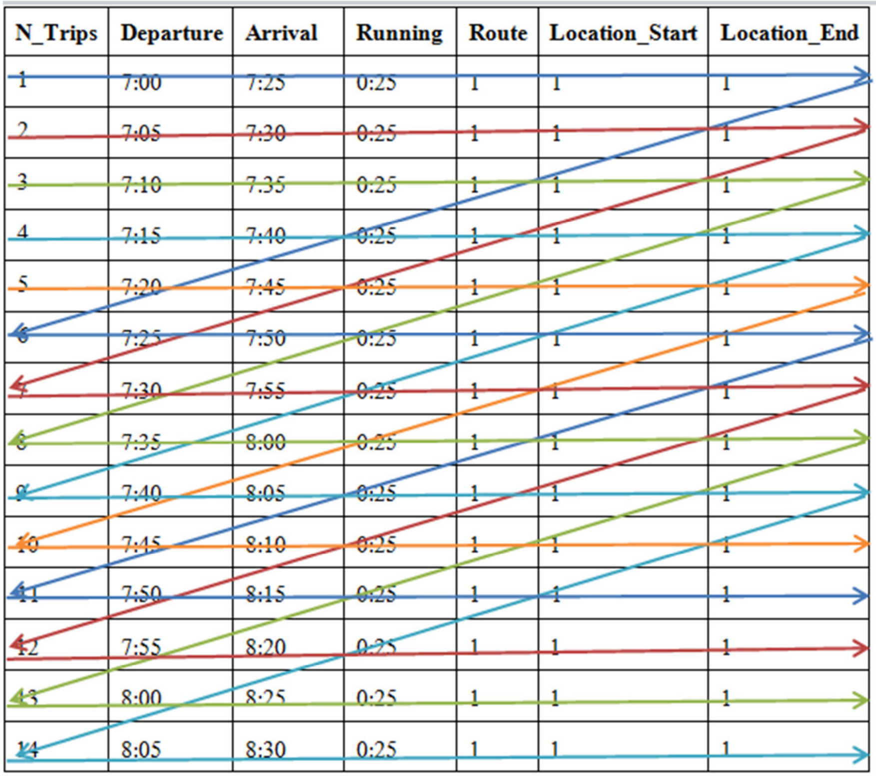
To determine the required number of vehicles, we apply both methods mentioned in the previous section. Firstly, the analysis based on the simple method is done separately for each route and the required number of vehicles is simply the sum of outcome from all routes. Two scenarios are considered here, breaking time of zero or five minutes. Secondly, the blocking method is applied under four different scenarios. The first scenario does not allow vehicle to switch route and attempts to maximize the bus utilization by assuming no break_time. The second scenario is similar to the first but differs only in terms of allowing vehicles to switch route. The third and fourth scenarios are similar to the first and second scenarios, respectively, but differ only in terms of providing a 5 minute break_time at the transport terminal instead of no break_time. Figure 4 illustrates the example of analysis of the first scenario. Table 4 summarizes the results from all analyses.

4.1 Effect of variation of Breaking_time (0 min vs. 5 min)

It can be seen from Table 4 that breaking_time does have an effect on the number of vehicles required for operation of route 1 and 2, but not for route 3. Each requires one more vehicle to cope with additional break_time of 5 minutes. In total, 7 and 9 vehicles are needed if the break_time is 0 min and 5 min, respectively.

4.2 Effect of route switching allowance

Surprisingly, under the same break_time, allowing vehicles to switch route does require the same number of vehicles as that in case of not allowing vehicles to switch route. This result is not in line as the results in Butsingkorn (2013). Possible explanation to this result is that the peak periods occur at the same time for all three routes, and thus maximum number of vehicles is required during this period. Therefore, no benefit can be gained from switching route in case of all routes have the same peak period.



N_Trips	Departure	Arrival	Running	Route	Location_Start	Location_End
1	7:00	7:25	0:25	1	1	1
2	7:05	7:30	0:25	1	1	1
3	7:10	7:35	0:25	1	1	1
4	7:15	7:40	0:25	1	1	1
5	7:20	7:45	0:25	1	1	1
6	7:25	7:50	0:25	1	1	1
7	7:30	7:55	0:25	1	1	1
8	7:35	8:00	0:25	1	1	1
9	7:40	8:05	0:25	1	1	1
10	7:45	8:10	0:25	1	1	1
11	7:50	8:15	0:25	1	1	1
12	7:55	8:20	0:25	1	1	1
13	8:00	8:25	0:25	1	1	1
14	8:05	8:30	0:25	1	1	1

Figure 4 Example of the blocking analysis for the first scenario

Table 4 Results of the analyses

Method	Description	Route	No. of vehicles required	Cost saving from existing condition (Million Baht)	% saving from existing condition
Simple-1	Simple method & 0 min. break	1	5	17.7	46%
		2	1		
		3	1		
		Total	7		
Simple-2	Simple method & 5 min. break	1	6	11.8	31%
		2	2		
		3	1		
		Total	9		
Blocking-1	No switch route & 0 min. break	1	5	17.7	46%
		2	1		
		3	1		
		Total	7		
Blocking-2	Switch route & 0 min. break	Total	7	17.7	46%
Blocking-3	No switch route & 5 min. break	1	6	11.8	31%
		2	2		
		3	1		
		Total	9		
Blocking-4	Switch route & 5 min. break	Total	9	11.8	31%

4.3 Simple method vs. Blocking method

There is no difference between the results of the two methods mainly due to the reason as discussed above. All routes have the same peak period thus dropping the performance of the blocking method.

4.4 Implication

In our study, it does not matter about which method to use or whether route switching is allowed or not because all result in the same number of required vehicles. However, the break_time does have some effects as two more vehicles are required when break_time increases from zero to five minutes. As mentioned in TRB (1998), the break_time is normally set at 10% of the round trip running time, thus about 2.5 minutes may be used for this purpose. It is worth to note that the 25 minutes running time of route 1 and 30 minutes running time of route 2 are only an approximation. Actual travel time varies slightly from 22 to 25 minutes for route 1 and from 27 to 30 minutes for route 2, depends on the drivers. In this case, therefore the break_time of zero minute is not too unrealistic and 7 vehicles are required. Nevertheless, having 9 vehicles in case of break_time of 5 minutes can assure that the vehicles have sufficient buffer time and future modification of route and schedule can be coped with for some levels.

Using a fleet size of 9 vehicles can save cost about 11.8 million Baht for 5-year contract (about 31% reduction). However, this fleet size is determined for the regular trips as existed in the schedule. Irregular trips such as those for students' activities outside the university were not yet considered. Adding 2 or 3 vehicles to the fleet size for this special purpose is still less than the current fleet size of 13 vehicles. In summary, about 1 or 2 vehicles are not necessary to provide the current service. Under this situation, the university can save about 2,950,000 – 5,900,000 Baht (7.7% or 15.4%). Nevertheless, further study shall be taken to consider about the off-campus activity trips, whether irregularly renting vehicles when needed to do some activities outside the campus is cheaper than leasing 3 vehicles for this purpose or not.

5. CONCLUSION

This study considers the problem of bus service planning for a rural university in Thailand. The current contract is about to end, therefore many questions have to be answer in order to prepare for a new contract. The focus of this paper is to determine the minimum number of vehicles that required to provide a service according to the current schedule. Two methods are considered, the simple method and the blocking method, in which route switching can also be implemented. However, no difference can be observed among the results of these two methods. Possible explanation is due to all routes considered in this study have the same peak period. Thus no benefit can be extracted by switching route in this case.

From the results, it can be recommended that 9 vehicles shall be used to operate the trips according to the current schedule, plus 2-3 vehicles for outside activities. Under this case, the university can save about 7.7% to 15.4%.

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