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Abstract Title: Development of the hotel shuttle bus-system using simulation: a case study of a new international airport in Thailand

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ABSTRACT

This research focused on the development of the shuttle bus system using a simulation technique to analyze the transportation service between Suvarnabhumi airport, a new international airport in Thailand, and hotels. The research objectives were to develop the service arrangement of the shuttle bus and to develop the shuttle bus route with highest efficiency. The study method was based on a simulation technique by analyzing a sample of 40 hotels located in inner Bangkok. The study tools to solve the routing management problem consisted of the utilization of nearest neighbor procedure (NNP), Clark and Wright algorithm (C&W), and Simulation technique using Genetic Algorithms (GA). The results indicated that Simulation technique using GA provided the shortest distance and the most efficient transportation service better than other techniques.

1. INTRODUCTION

Just in the year 2006, Thailand had a new international airport, named Suvarnabhumi airport, which is located about 15 km of the east-bound Bangna-Trat Highway in Bang Phli District, Samut Prakarn Province and is about 25 km from downtown Bangkok. The airport is one of the newest and the most modern airport in the region, and much better than the old Bangkok airport in both facilities and service provision for passengers. At current phase of service provision, the north section of the airport is able to accommodate 45 million passengers per year, 76 flights per hour, and 3 million tons of cargo handling per year.

By far, the airport is already about two years old and become a key economic strength for Thailand, especially for supporting tourism industry. The airport is now used by more than two million tourists each year for their domestics and international traveling.

Since Suvarnabhumi airport is the new airport and just finished in the short period of time, lots of ground transportation are still under constructions and in the processes of developments. There are still no mass transit system link between the new airport and Bangkok Metropolitan area in place yet, and not having hotel shuttle bus services like other metropolitan airport in major tourism towns. Most transportation now heavily depends on private cars, taxies, public and airport buses to bring tourists to their hotels.

This study introduces the methodology to develop the service arrangement of the shuttle bus and to develop the shuttle bus routes by using simulation technique using Genetic Algorithm.

2. LITERATURE REVIEW

Managing transportation routes is considered part of fleet management whose concept is based on the system that manages m vehicles to the predetermined n destinations with the lowest costs and shortest routes. The starting point/depot and the end point are at the same place (Bodin and Golden, 1981). Problems associated with vehicle management can be classified into two categories, i.e., the vehicle routing problem and the vehicle scheduling problem.

Vehicle routing problem (VRP) is the name used to describe the problem concerning transportation routes (Dantzing and Ramser, 1959), whose concept is further developed by Gavish and Graves (1979). Vehicle scheduling problem, on the other hand, is associated with the time scheduled to handle various activities. The issues concerning this problem are the total routing distance, the total service time each vehicle encounters in each round of transportation, and the allowable time at each target destination. All these problems are dependent on two key factors, i.e., traveling distance and traveling time.

Different methods have been applied in the past to solve transportation problems. Swersey and Ballard (1984) used difficult integer program and simple cutting planes to study the smallest number of buses that covered all the routes. Lee and Ueng (1997) used integer programming model to study the optimal vehicle size and the distribution of products. Later, Lee and Ueng (1999) developed a mathematical model to solve for the shortest total traveling distance and distribution of work to each employee. Taillard (1993) and Taillard, et al. (1995) studied the benchmark VRP by using Tabu search (TS) method. Mirchandani and Soroush (1987) studied the stochastic network and tried to solve for the appropriate routes with multiple products to be transported by considering the road traffic.

Routing scheduling problem has also been studied in the past. Eibl, et al. (1994) studied the routing scheduling and management in the beer industry in England. Su (1999) studied the dynamic routing scheduling associated with product distribution with multiple warehouses. Moreover, Gayialis and Tatsiopoulos (2004) focused their study on the routing management and scheduling associated with fuel transportation. Additionally, Genetic Algorithms (GAs) has been widely developed and applied to study VRP associated with time windows, multi-depot routing problem, school bus routes, and capacity problem (Harche and Raghavan, 1994; Salhi, et al., 1998; Vacic, et al., 2002).

3. A BRIEF REVIEW OF RELATED TECHNIQUES

Nearest Neighbor Procedure (NNP) – The NNP can be used to locate the shortest traveling distance and is the simplest calculation method. The procedure is to choose the route with the shortest traveling distance from the starting point. As a result, it is believed that the total traveling distance must also be the shortest. This method is useful when comparing to the starting point only. If the transportation route gets more complicated, NNP will not realistically yield the shortest route. This method is therefore adopted in this study only to provide a reference point in comparing different methods.

Clark & Wright (C&W) – C&W method can also be used to locate the shortest route. It is the problem solving technique associated with the traveling of salespersons (TSP) and is applied to solve the routing problem. In this study, C&W method is used to select traveling routes that yield the shortest distance without crossing over or intersecting other routes. However, when the transportation system gets larger, this method will not be able provide the authentic shortest route.

Genetic Algorithms (GAs) – Genetic Algorithms is the method used to locate the shortest traveling distance. It is based on the life evolution concept of Charles Darwin who states that "*problem solved by its evolution will always render the best result*." This concept was further developed into the concept referred to as "Genetic Algorithms or GAs." Genetic Algorithms is the technique that can be used to explore all the possible routes and examine the transportation routes that are likely to be the best. It uses complicated computation to find the shortest route without using the linear computation. In addition, the computation can be done from each point in calculating solutions without holding to the minimum and maximum values. This research will show that the Genetic Algorithms can be used to obtain better solutions than any other methods.

Arena Program – The Arena program is a Microsoft Windows based program. It was developed in 1970 by Rockwell Software Co., Ltd. This program is a simulation program used to calculate traveling time and distance for each round of shuttle bus transportation service. The advantage of this program is the graphic presentation of the output. Users with no background in computer programming or mathematics can easily use the program and understand the output. Arena program used in this research is version 7.01.00 whose language is based on SIMAN, the moderate level of computer language. This language is simple enough to deal with simulation and can be used together with Microsoft Visual Basic: C/C++. In this study, the researchers used the Arena program to handle the transportation routing problem and obtained the output in the form of Microsoft Excel.

4. DESCRIPTIONS OF THE PROBLEM and ASSUMPTIONS

Various simulation methods were used to obtain solutions for the transportation service problem from the Suvarnabhumi airport to various hotels in the surrounding area. The analysis was confined to 40 hotels situated around the Bangkok Metropolitan area (See Figure 1). The study was based on two key assumptions. First, each shuttle bus has the maximum capacity of 25 passengers with no standing on the bus and the bus leaves the depot/starting point when the capacity is full or when the waiting of the first passenger reaches 15 minutes.

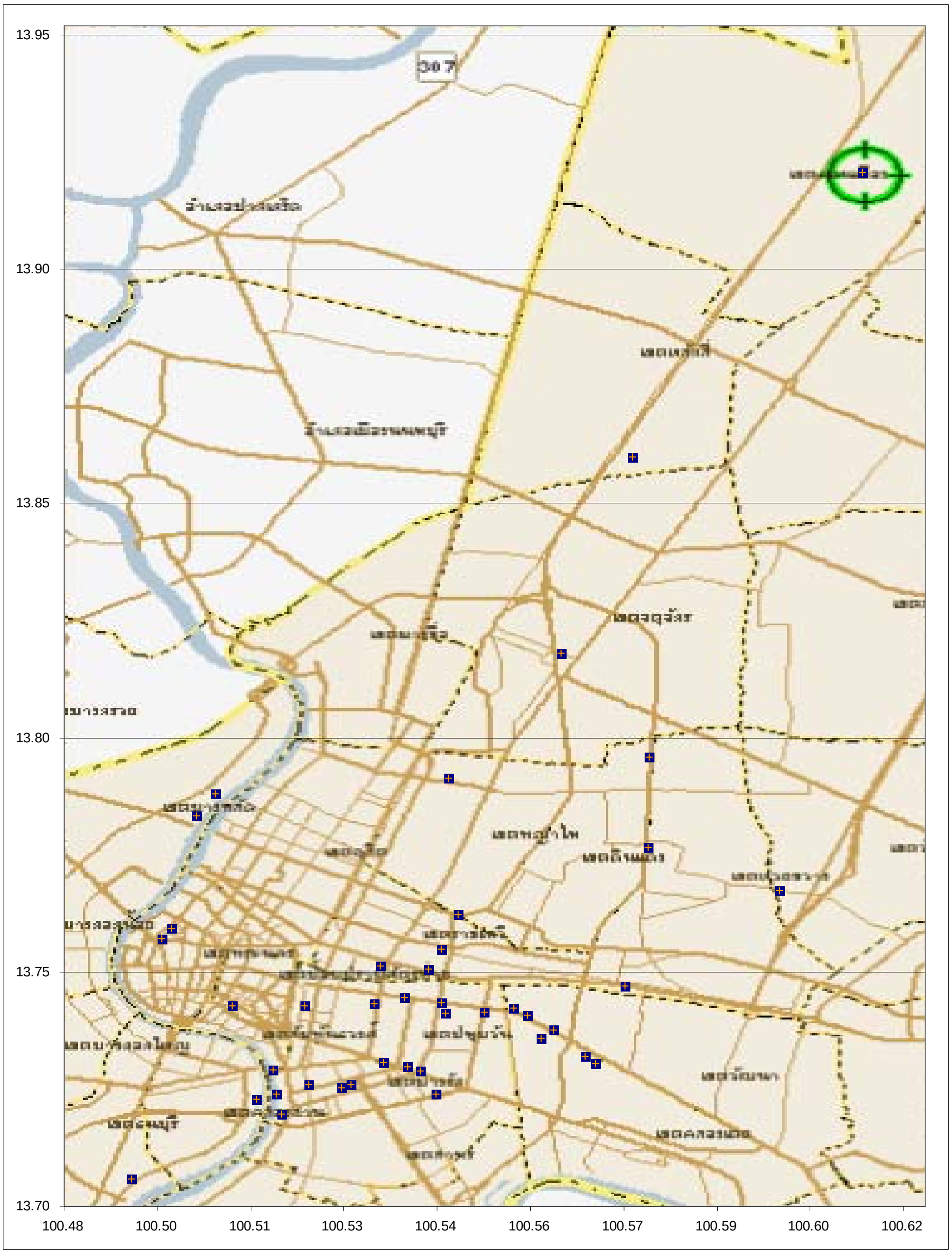

Figure 1 All 40 hotels located in Bangkok (represent by a square dot)

Second, each round of transportation service must have the shortest route so as to achieve the lowest cost and to provide customers with the shortest service time. And other operating assumptions as follows:

- The relationship between distance and time is based on a straight line pattern. The average traveling speed is fixed.
- The passengers' accommodation at the hotels must be known in advance. Each passenger will receive only one service from one vehicle throughout their travel.
- Passengers at every drop-off point will receive services under the predetermined service time.
- There will only be a drop-off of passengers at all hotels.
- The maximum time the passengers will be on the vehicle will not exceed the predetermined allowable time.
- The maximum capacity of each vehicle will not exceed 25 passengers.
- Under the predetermined service time, each vehicle will be allowed to travel as many rounds as possible.

5. ROUTING USING SIMULATION

To develop the shuttle bus routes and schedules using simulation techniques, the study needed to collect some real data for simulation inputs. First, the study began by collecting the itinerary of the foreign tourists who arrived at the Suvarnabhumi airport from other countries for the rate of arrival of foreign tourists within a day. And second, the study collected the geographic locations of major hotels located in Bangkok Metropolitan for calculating distance among hotels and the airport.

The objective of the routing is to find a route which results in the minimum travel. Since the determination of a route is performed in real data, the simulation approach is developed to obtain a result. As shown in Figure 2, the modules of the simulation and procedures are used. The procedures start from arrival of tourists (module 1) and available shuttle bus at the airport (module 2). Then the simulation check two key conditions, whether the shuttle bus still has seats available and the waiting time for other passengers still within 15 minutes limitation (module 3). So, if they pass both conditions, the process will go to calculate the suitable route (module 4). After that, the process will lead to module 5, which will drop off each tourist at his/her hotel. Finally, the process check whether the bus reach all destination within the route (module 6).

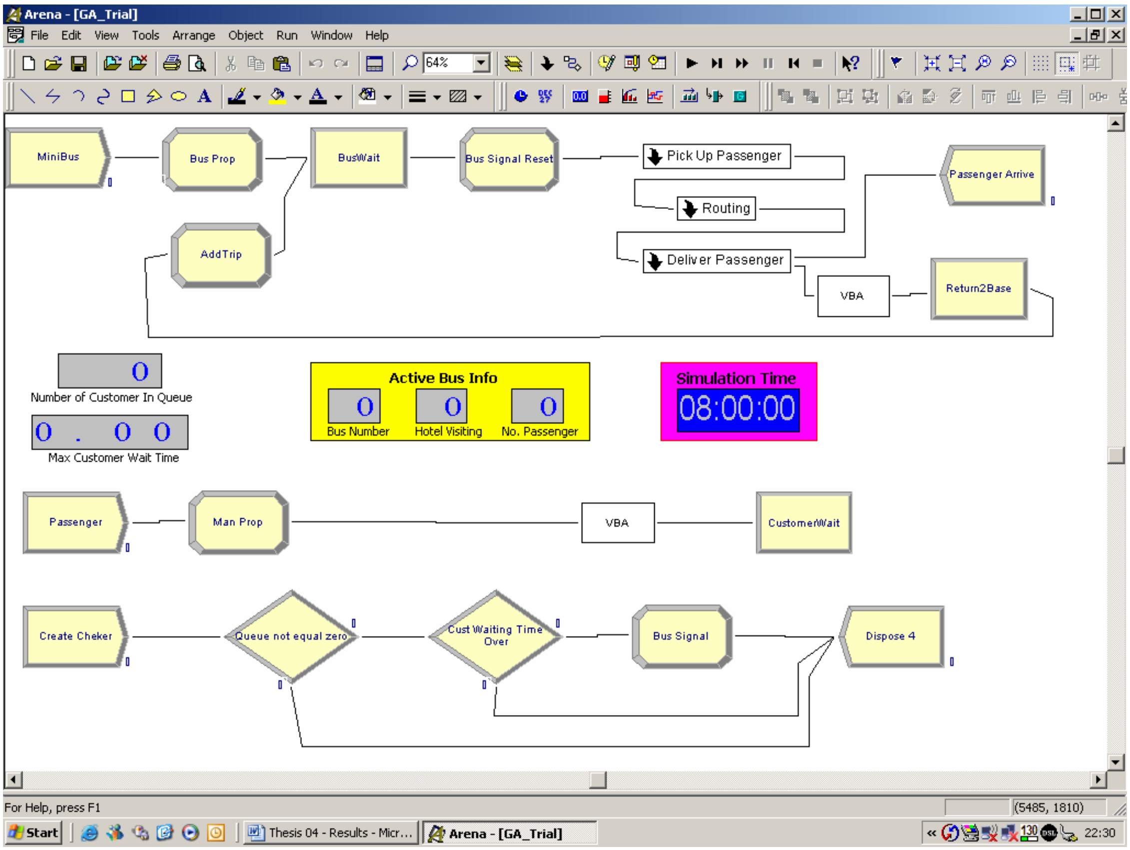

Figure 2 Simulation Model in ARENA consisting of six modules

6. SIMULATION EXPERIMENTS and RESULTS

To create route using simulation, the study use three different heuristics to construct shortest route within ARENA. All three heuristics to calculate suitable route (module 4) are NNP, C&W, and GA. Then, the study tests the result among the three based on the following situations

Situation A: The Shortest Route on All Known Routes with One Vehicle - The simulation was run on five known routes from simple connecting nodes/points to more complicated connecting nodes/points. Hand computation was only used as a reference point to do the comparison. The results are as Table 1.

Table 1 Summary of Simulation Results for All Five Routes

Route	Number of Nodes/Points	NNP	C&W	GA
1	10	22.5765	22.5765	22.5765
2	16	19.2361	19.2361	19.2361
3	14	33.1553	28.1197	25.7858
4	20 simple	28.7186	27.2001	27.2001
5	20 complex	45.9612	39.0640	36.4782

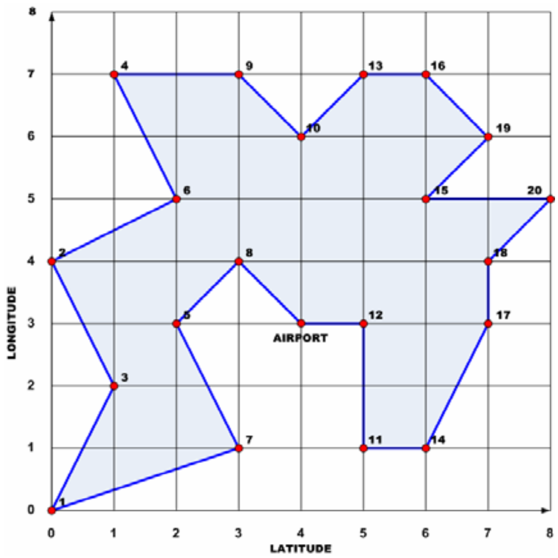

Figure 3 Simulation Result using GA on 20 known routes

Situation B: The Shortest Route on the Predetermined Map with Multiple Vehicles - The purpose of this investigation was to locate the appropriate number of vehicles that met the waiting time and traveling time constraints of 15 minutes and 2 hours. The simulation was based on 125 passengers at the depot and the maximum capacity of one vehicle is 25. The target destinations/nodes of all 125 passengers were the same without any changes no matter how many vehicles would be utilized. If the first vehicle picked up 25 passengers, the rest of the passengers would have to wait for the next available vehicle. Table 2 displays the results of the simulation using the GA method.

Table 2 Simulation Results Using the GA Method

Number of Vehicles	Waiting Time	Traveling Time
1	4.63	1.30
2	1.69	1.30
3	0.79	1.30
4	0.40	1.30
5	0.10	1.30

Situation C: The Shortest Route on the Predetermined Map with Five Vehicles and Scattered Rate of Arrival - In the real situation, all passengers do not arrive at the same time; the distribution of passengers is scattered. Hence, we are unable to compare vehicles in terms of traveling distance. In this case, the waiting time and the traveling time would differ depending on the distribution of passengers. Two hundred passengers and five vehicles were used in this simulation and the results are shown in Table 3.

Table 3 The Simulation Results with Different Arrival Rates/Patterns

Distribution of Passengers (Arrival Rate)	NNP		C&W		GA	
	Waiting Time (hr.)	Traveling Time (hr.)	Waiting Time (hr.)	Traveling Time (hr.)	Waiting Time (hr.)	Traveling Time (hr.)
Fixed	0.24	0.93	0.24	1.12	0.22	0.93

Up and Down Interchangeably	0.20	0.85	0.21	1.02	0.20	0.97
Continually Decreased	0.25	0.95	0.190	1.03	0.20	0.99
Continually Increased	0.40	1.08	0.24	1.13	0.22	1.08
Normally Distributed	0.29	0.96	0.27	1.09	0.22	1.08

Situation D: The Shortest Route with Five Vehicles Using Bangkok Metropolitan's Map - The results of the simulation to locate the shortest route from the airport to the hotels are presented in Table 4, and a sample of GA are showed in Figure 4. The assumptions in this simulation are based on five vehicles and normal distribution of passengers.

Table 4 Simulation Results of the Three Methods

NNP Method			C&W Method			GA Method		
Vehicle number	**Round**	**Distance**	**Vehicle number**	**Round**	**Distance**	**Vehicle number**	**Round**	**Distance**
1	1	0.59	1	1	0.57	1	1	0.56
	2	0.52		2	0.52		2	0.52
	3	0.73		3	0.69		3	0.69
	4	0.56		4	0.56		4	0.56
	5	0.77		5	0.70		5	0.70
	6	0.49		6	0.48		6	0.48
	7	0.46		7	0.46		7	0.46
2	1	0.54	2	1	0.54	2	1	0.54
	2	0.81		2	0.76		2	0.76
	3	0.63		3	0.62		3	0.62
	4	0.60		4	0.60		4	0.60
	5	0.56		5	0.55		5	0.55
	6	0.58		6	0.57		6	0.57
	7	0.64		7	0.63		7	0.61
3	1	0.52	3	1	0.51	3	1	0.51
	2	0.54		2	0.53		2	0.53
	3	0.79		3	0.72		3	0.72
	4	0.61		4	0.56		4	0.56
	5	0.61		5	0.61		5	0.60

	6	0.66		6	0.71		6	0.66
	7	0.00		7	0.00		7	0.00
4	1	0.65	4	1	0.61	4	1	0.61
	2	0.75		2	0.79		2	0.75
	3	0.64		3	0.61		3	0.61
	4	0.66		4	0.64		4	0.63
	5	0.49		5	0.49		5	0.49
	6	0.54		6	0.53		6	0.53
	7	0.00		7	0.00		7	0.00
5	1	0.50	5	1	0.50	5	1	0.50
	2	0.58		2	0.56		2	0.56
	3	0.62		3	0.62		3	0.62
	4	0.66		4	0.68		4	0.66
	5	0.51		5	0.50		5	0.50
	6	0.69		6	0.65		6	0.65
	7	0.00		7	0.00		7	0.00
Total traveling distance		19.48	Total traveling distance		19.07	Total traveling distance		18.91
Comparison (%)		100.00	Comparison (%)		97.90	Comparison (%)		97.08

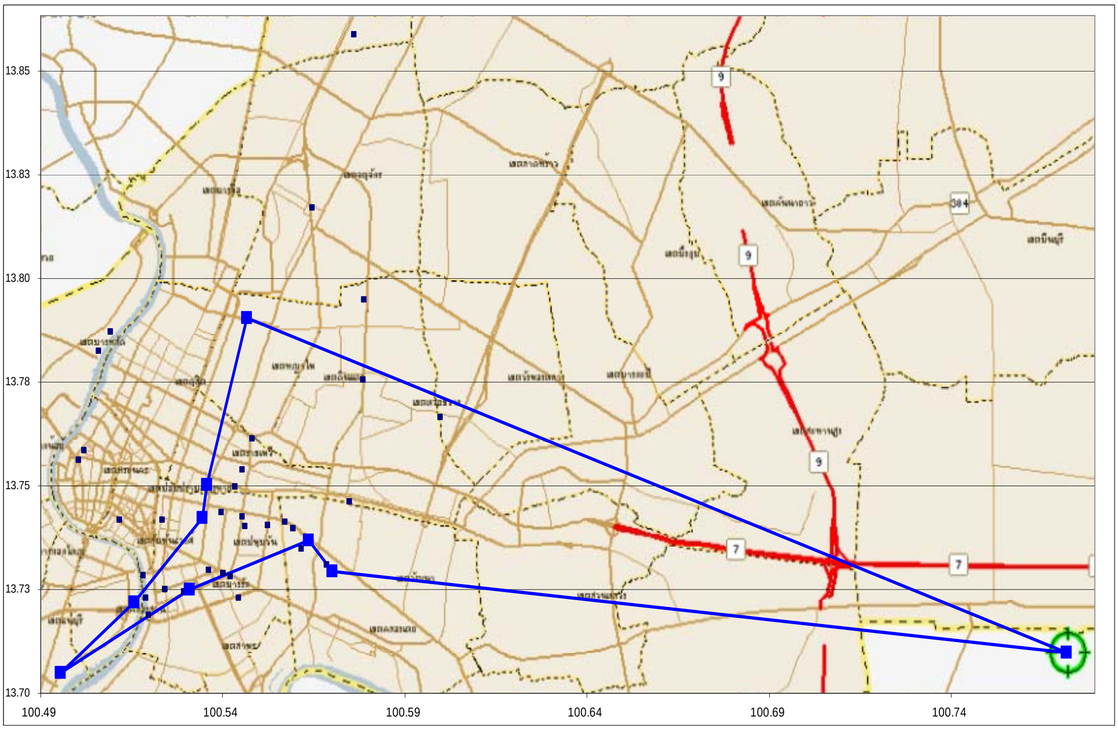

Figure 4 Shuttle bus routing based on the simulation results using GA

7. DISCUSSION

The results of the vehicle routing simulation using varying methods indicate that there are various methods that can be used to solve the vehicle routing problem. These include the Nearest Neighbor Procedure (NNP), a simpler method, the Clark & Wright (C&W), and the Genetic Algorithms (GA), the most complicated method. In summary, the GA method yields the optimal solution. However, other methods can also be used in those situations that are not complicated.

If there are more destination points/nodes to travel to, the NNP method will be the simplest method to be used since it contains only one condition, i.e., moving to the node/point that is the closest to the current node/point. However, the transportation route resulting from this method may be the longest route since multiple routes may cross over or intersect with one another. The C&W method can also be used to solve vehicle routing problems. The traveling distance will be reduced by using the C&W method and there will be no cross-over of routes. As a result, the traveling distance derived from this method will be shorter than the NNP method.

The GA method is the most complicated method to solve the vehicle routing problem. This method involves the computation of the total distance when considering each and every route. The new route will be randomly generated before choosing the optimal one. It provides a solution that is better than NNP and C&W methods. In addition, the Gas method can also be used to handle problems with different number of vehicles and different arrival rates of passengers.

The research provides solutions to the shuttle bus service used to pick up passengers from the airport and deliver them to the target hotels in the Bangkok

Metropolitan area. The proposed transportation service combines the advantage of the limousine service and the advantage of the public bus service with fixed routes. Hence, the proposed shuttle bus service can provide services to multiple passengers with different target destinations. The link between these two services will help yield the optimal routes and maximize customer satisfaction. Additionally, the results can provide transportation service providers a guidance to modify their services that will enhance efficiency and customer satisfaction.

8. CONCLUSION

Managing traveling routes to be optimal in terms of traveling distance and traveling time is considered to be the most important factor to satisfy foreign tourists. In this study, the researchers applied three simulation methods, i.e., the nearest neighbor procedure (NNP), Clark & Wright (C&W), and the Generic Algorithms (GA) to solve the vehicle routing problems (VRP) and obtain the shortest route with waiting time and traveling time under the predetermined constraints. The focus was on the development of the optimal shuttle bus system that provides services between Suvarnabhumi airport and the target hotels. The results suggested that Genetic Algorithms provided the optimal route in all situations and was considered to be the best method to solve the vehicle routing problem associated with shuttle bus service system provided by the airport. The researchers are confident that the proposed shuttle bus service system will enhance passengers' satisfaction since it combines the advantages of both the limousine service and the public bus service.

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