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Determination of Courier's Routes Delivery for Distributing Parcels in Perak

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Abstract: Courier services play a significant role in transporting the parcels from one location to another and ensuring that the parcels reach the customer's doorstep. Due to the rising demand for courier services, late delivery is a common delivery problem for courier companies. Meanwhile, the emergence of Covid-19 pandemic had brought a surge in demand for courier services. Hence, this study was applied route optimization for DHL Express to determine the shortest total distance and total average time spent to deliver the parcels effectively. It investigates the most effective method for DHL Express to employ as an optimization tool to optimize the delivery route for their company. Genetic Algorithm and Tabu Search were proposed in this study in order to solve the travelling salesman problem (TSP) using Python software. The main assumption of this problem was that each parcel hub would be visited once and then returned to its origin. This study mainly focuses on 15 parcel hubs in Perak, with the data on total distance travelled and average time spent collected at 3 different times frames, namely 9.00 am, 1.00 pm and 6.00 pm. There are two optimal routes generated respectively in terms of total distance travelled and total average time spent for both methods. The performance of both methods was evaluated by shortest total distance travelled and minimum total average time spent. The results revealed that Genetic Algorithm outperformed Tabu Search in solving small sample size problem. Thus, DHL Express was recommended to use the suggested route to deliver the parcels in order to achieve cost-effectiveness, improve efficiency and thereby improve customer satisfaction.

Keywords: Courier Services, DHL Express, Genetic Algorithm, Tabu Search, Travelling Salesman Problem

1. Introduction

Courier service is used to provide a quicker and more reliable alternative than traditional mail delivery service, sending the parcels from one place to another to customers. According to [1], the global courier, express and parcel (CEP) market is growing rapidly especially in developing countries.

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In late 2019 and early 2020, a pandemic outbreak called Covid-19 was discovered to spread rapidly all over the world. This has brought a direct effect on the global e-commerce market, increasing online sales as well as the delivery of parcels in 2020. According to the Postal and Courier Services report by [2], for domestic courier traffic in 2020, the number of documents was 107,301,100 and the number of parcels was 303,160,700, an increase of 17.10% and 152.01% respectively compared with 2019.

Service quality is one of the most important determinants of customer satisfaction in courier services delivery [3] while timeliness of delivery is one of the most important quality parameters in the service quality [4]. Customers always lay stress on the delivery time of their parcels. However, late delivery is the most common issue that occurs in courier service. The travelling distance and the time of sorting process of the parcels are the major factors that impact late delivery time. In order to maximize customer satisfaction, courier company should improve their service quality by minimizing the distance travelled and thereby reducing transportation costs. The real-time data from the courier service in the state of Perak, Malaysia was used to illustrate the efficiency of the algorithm. Due to the large population of 2.51 million residents and a total area of 20,976 km^2, this study was aimed to determine the best route for delivering parcels to minimize the distance travelled and time travelled between the 15 parcel hubs in Perak and at the same time alleviate the traffic congestion.

Genetic Algorithm is the optimization technique which is also a type of heuristic search that takes inspiration from natural evolution [5]. In the study of [6], Genetic Algorithm was applied to solve the TSP with small sample size of cities and proved that this method can achieve the optimal results in fast and effective way. Apart from that, [7] declared that Tabu Search is one of the effective algorithms that are easy to tackle with the complex combinatorial problem. According to the study of [8], it showed that Tabu Search was implemented to solve the travelling salesman problem to yield feasible solutions with the shortest distance travelled for small sample size data. This can be concluded that Tabu Search is efficient and capable of providing a good solution with the best route. Since the application of Genetic Algorithm and Tabu Search were showed the great efficiency in obtaining the optimal solution for solving TSP, this study was proposed Genetic Algorithm and Tabu Search techniques in solving the TSP for a small sample size data in order to improve delivery efficiency for courier service.

In this paper, Genetic Algorithm and Tabu Search were applied to determine the shortest total distance and total average time spent for the courier services. Then, the performance of the proposed method was compared in terms of total distance and total average time spent for the courier services. Lastly, this paper was examined the most effective method to increase the efficiency of the courier services with the shortest delivery route and total average time spent. The programming language used for this analysis for both methods is Python.

2. Materials and Methods

In this study, the data for the distance travelled and the time travelled for courier service to deliver parcels were collected via Google Maps (http://maps.google.com.my). These data sets are known as secondary data collection type. The secondary data collected was primarily focused on the 15 parcel hubs of the DHL Express in Perak. The distance between 15 parcel hubs was recorded in kilometer (km). Besides, 3 different delivery times were recorded in minutes (min), namely 9:00 am, 1:00 pm and 6:00 pm. Therefore, the data were collected from Monday to Friday at these three different time periods. Then, the average data was calculated and used for further analysis.

2.1 Data description

DHL Express has been providing courier services for 52 years and known as the world's leading logistics company. Both the merchant and customers benefit from DHL eCommerce's flexibility, control, convenience and quality. This has led to DHL Express to provide the excellent customer service, which allowing every customer to experience an efficient parcel delivery. Thus, this study was

interested in determining the shortest distance and time travelled to visit all parcel hubs of DHL Express in Perak area. There were a total of 15 parcel hubs in the Perak area that were used to analyze in this study as depicted in Table 1. While the location of the listed selected hubs was showed as Figure 1.

Table 1: List of selected parcel hubs

Hub	Name of Parcel Hub	District
1.	DHL Supply Chain	Kinta
2.	DHL eCommerce Premium Service Point Bercham	Kinta
3.	DHL Express Service Point Jelapang	Kinta
4.	DHL eCommerce Depot Teluk Intan	Hilir Perak
5.	DHL eCommerce Premium Service Point Station 18	Kinta
6.	DHL Express Service Point Simpang, Taiping	Larut, Matang and Selama
7.	DHL Express Service Point Ipoh Station 18	Kinta
8.	DHL eCommerce Premium Service Point Seri Iskandar	Perak Tengah
9.	DHL Express Service Point Setiawan	Manjung
10.	DHL eCommerce Premium Service Point Parit Buntar	Kerian
11.	DHL eCommerce Premium Service Point, Sitiawan	Manjung
12.	DHL Kamunting	Larut, Matang and Selama
13.	DHL eCommerce Depot Taiping	Larut, Matang and Selama
14.	DHL Express Service Point Greentown	Kinta
15.	DHL eCommerce Premium Service Point Teluk Intan	Hilir Perak

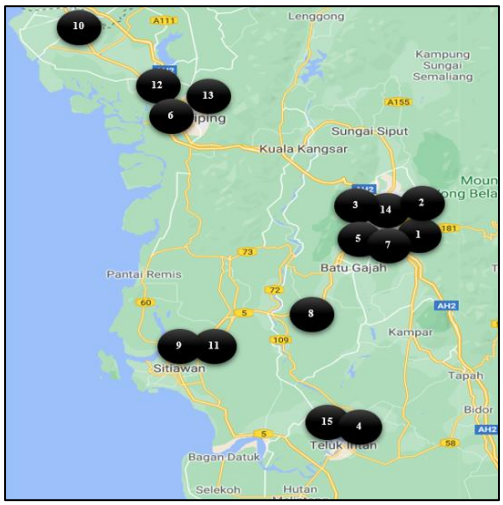

Figure 1: Location of listed hubs on Google Maps

2.2 Optimum delivery path based on travelling salesman problem

TSP as a well-known algorithm problem was focused on this study. The aim of TSP is to find out the shortest tour and return to the beginning location, with visits each city in a list precisely once [9]. Thus, the salesman can follow the best route to travel between cities in a shortest time. In this study, the introduced methods were based on the TSP problem which was used to determine the shortest path by visiting all the parcel hubs in Perak area at once and returning to the starting point.

2.3 Optimization model formulation of TSP

The objective function of this study was to minimize the total distance travelled and total time it takes to deliver the parcels to complete the entire delivery process. The constraint for TSP is to strictly limit the number of visits to one for each hub and the decision variables of x_{ij} for each (i, j) is defined. The evaluation function of a general TSP is as below which was mentioned by [10]:

Objective function: $Min\ z\ = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij} \quad Eq.1$

Subject to:

$$\text{(i)}\ \sum_{i=1}^{n} x_{ij} = 1,\ for\ j = 1, 2, \dots, n \quad Eq.2$$

$$\text{(ii)}\ \sum_{j=1}^{n} x_{ij} = 1,\ for\ i = 1, 2, \dots, n \quad Eq.3$$

$$\text{(iii)}\ x_{ij}\ = \left\{ \begin{matrix} 1\ if\ salesman\ travels\ from\ city\ i\ to\ city\ j \\ 0\ otherwise \end{matrix} \right\} \quad Eq.4$$

$$\text{(iv)}\ x_{ij} = 0,\ for\ i = j \quad Eq.5$$

where

$z\ =\ Minimize\ the\ total\ distance\ travelled\ or\ total\ time\ travelled$

$d_{ij} =\ Distance\ from\ city\ i\ to\ city\ j$

2.4 Genetic Algorithm

Genetic Algorithm, as the population-based metaheuristic is a well-known algorithm among the metaheuristic algorithms [11]. Genetic Algorithm is based on natural biological evolution and its elements consist of chromosome representation, fitness selection and biological-inspired operators. The overall process of Genetic Algorithms mainly includes four steps which are initialization, selection, genetic operators and termination. Figure 2 showed the general flow chart of the Genetic Algorithm which mentioned by [12].

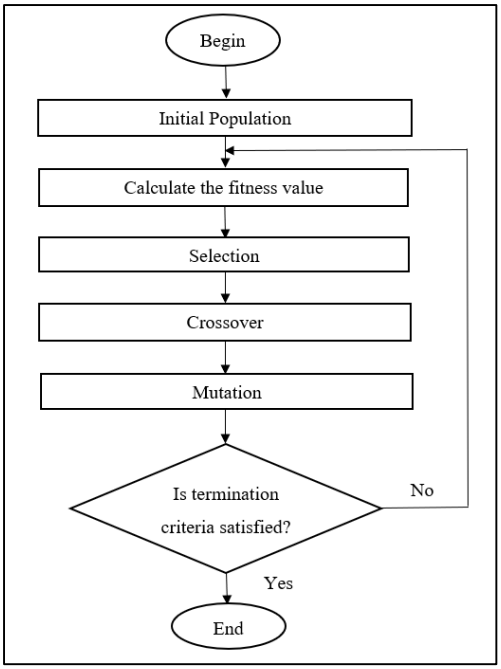

Figure 2: Flow chart of Genetic Algorithm

2.4.1 Parameter setting for Genetic Algorithm

The performance and effectiveness of the Genetic Algorithm is based on its parameters such as population size, probability of mutation and number of iterations. In other words, its parameters directly affect the quality of the solution. Table 2 showed the parameters used for the Genetic Algorithm. There was no need to set the crossover rate as the algorithm used was based on the random arrangement of the population and the binary tournament selection.

Table 2: Parameter used for Genetic Algorithm

Parameter	Value
Population Size	100
Elite Size	20
Mutation Rate	0.01
Number of Generations or Number of Iterations	1000

2.5 Tabu Search

Tabu Search, as one of the metaheuristics optimization methods, is widely used to optimize model parameters in TSP [13]. This is because its adaptive memory is one of the most important features, as it allows to create for more versatile search behavior. Tabu Search is a single-solution based metaheuristic which use a single candidate solution and utilize local search to improve the solution. There were some steps used to determine the shortest route using the Tabu Search algorithm as shown in Figure 3 which was proposed by [14].

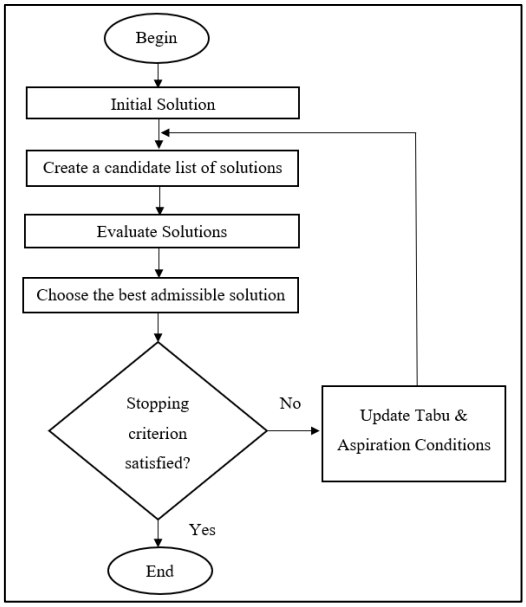

Figure 3: Flow chart of Tabu Search

2.5.1 Parameter setting for Tabu Search

This study only focused on the basic parameter of Tabu Search, namely tabu list, neighborhood size and number of iterations. The tabu content type was swapped pair positions and the move method used was swap nodes in a tour. Table 3 showed the parameters used for the Tabu Search.

Table 3: Parameter used for Tabu Search

Parameter	Value
Tabu List	100
Neighborhood Size	1000
Number of Iteration	1000

3. Results and Discussion

3.1 Results of Genetic Algorithm

One delivery route based on distance travelled and three delivery routes based on 3 different time travelled were generated by using Genetic Algorithm. All the routes that generated were started from

parcel hub 1, DHL Supply Chain and then returned back to parcel hub 1. Genetic Algorithm were run 10 times for each experiment, and the one with the shortest distance travelled and minimum total average time spent was chosen as the final result.

3.1.1 Delivery route based on distance travelled

In this study, there were 15 parcel hubs used to obtain the optimal solution by implementing Genetic Algorithm to solve TSP. The result obtained was shown that this method was able to deal with the small sample size data by providing a good solution which was illustrated in Figure 4.

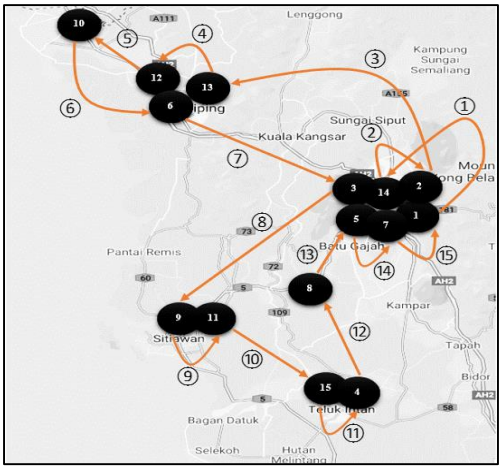

Figure 4: Delivery route based on distance travelled using Genetic Algorithm

In Figure 4, the shortest route to deliver parcels was illustrated according to the result, started with 1 – 14 – 2 – 13 – 12 – 10 – 6 – 3 – 9 – 11 – 15 – 4 – 8 – 5 – 7 and finally returned to 1. The total distance travelled of 15 parcel hubs for this delivery sequence was 403.7 km.

3.1.2 Delivery route based on average time spent

This study divided the data for average time spent into 3 categories to deliver the parcels from hub to hub. There were 3 different delivery time were recorded in minutes (min), namely 9:00 am, 1:00 pm and 6:00 pm. The results obtained was known as optimal solution with the minimum total average time spent to travel among 15 parcel hubs by applying Genetic Algorithm. Table 4 showed the details of delivery sequence based on average time spent using Genetic Algorithm.

Table 4: Delivery sequence based on average time spent using Genetic Algorithm

Sequence	9.00 am		1.00 pm		6.00 pm	
	Hub	Average Time Spent (min)	Hub	Average Time Spent (min)	Hub	Average Time Spent (min)
1.	1	13.8	1	18	1	14.2
2.	5	1.4	2	14.2	5	3.2
3.	7	32.4	14	14	7	33.4
4.	8	62.8	3	88.4	8	65.2
5.	4	6.2	10	47.8	4	8.6
6.	15	65.4	12	12.6	15	61.6
7.	9	5	13	9.4	11	9.6
8.	11	86	6	83	9	121.4
9.	6	10.2	11	6.6	10	54.4
10.	13	10.6	9	60.6	12	14.2
11.	12	48	15	7	13	11.4
12.	10	92	4	61.8	6	54

13.	3	15.8	8	34.8	3	20
14.	14	10.4	5	1.4	2	14.4
15.	2	18.6	7	12.2	14	16.4
16.	1	-	1	-	1	-
Total Average Time Spent		478.6		471.8		502

From Table 4, the total average time spent at 9.00 am was 478.6 minutes which was also equivalent to 7 hours 58 minutes and 36 seconds. Next, the total average time spent at 1.00 pm was 471.8 minutes which was also equivalent to 7 hours 51 minutes and 48 seconds. Then, the total average time spent at 6.00 pm was 502 minutes which was also equivalent to 8 hours and 22 minutes.

3.2 Results of Tabu Search

One delivery route based on distance travelled and three delivery routes based on 3 different time travelled were generated by using Tabu Search. All the routes that generated were started from parcel hub 1, DHL Supply Chain and then returned back to parcel hub 1. Tabu Search were run 10 times for each experiment, and the one with the shortest distance travelled and minimum total average time spent was chosen as the final result.

3.2.1 Delivery route based on distance travelled

In this study, there were 15 parcel hubs used to obtain the optimal solution by implementing Tabu Search to solve TSP. The result obtained was shown that this method was able to deal with the small sample size data by providing a good solution which was illustrated in Figure 5.

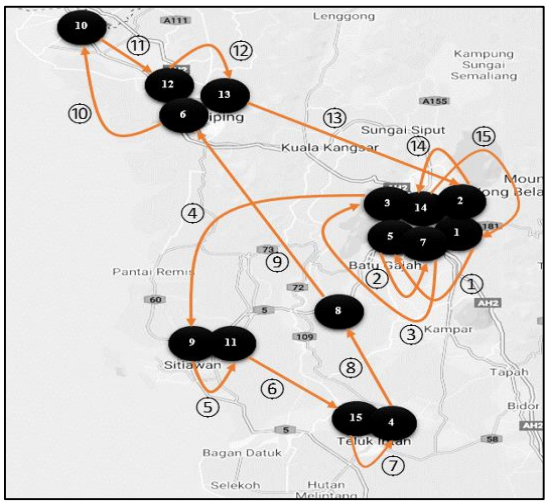

Figure 5: Delivery route based on distance travelled using Tabu Search

In Figure 5, the shortest route to deliver parcels was illustrated according to the result, started with 1 – 5 – 7 – 3 – 9 – 11 – 15 – 4 – 8 – 6 – 10 – 12 – 13 – 2 – 14 and finally returned back to 1. The total distance travelled of 15 parcel hubs for this delivery sequence was 410 km.

3.2.2 Delivery route based on average time spent

This study divided the data for average time spent into 3 categories to deliver the parcels from hub to hub. There were 3 different delivery time were recorded in minutes (min), namely 9:00 am, 1:00 pm and 6:00 pm. The results obtained was known as optimal solution with the minimum total average time spent to travel among 15 parcel hubs by applying Tabu Search. Table 5 showed the details of delivery sequence based on average time spent using Genetic Algorithm.

Table 5: Delivery sequence based on average time spent using Tabu Search

Sequence	9.00 am		1.00 pm		6.00 pm	
	Hub	Average Time Spent (min)	Hub	Average Time Spent (min)	Hub	Average Time Spent (min)
1.	1	13.8	1	18	1	14.2
2.	5	1.4	2	14.2	5	3.2
3.	7	18.8	14	14	7	23.6
4.	14	10.4	3	59.4	2	14.4
5.	2	20.4	6	10.6	14	16.4
6.	3	37.4	13	10.6	3	38
7.	8	62.8	12	45.6	8	65.2
8.	4	6.2	10	120.2	4	8.6
9.	15	65.4	11	6.6	15	61.6
10.	9	5	9	60.6	11	9.6
11.	11	86	15	7	9	87.2
12.	6	10.2	4	61.8	6	11.2
13.	13	10.6	8	34.8	13	13.2
14.	12	48	5	1.4	12	53.2
15.	10	100	7	12.2	10	99.6
16.	1	-	1	-	1	-
Total Average Time Spent		496.4		477		519.2

From Table 5, the total average time spent at 9.00 am was 496.4 minutes which was also equivalent to 8 hours 16 minutes and 24 seconds. Next, the total average time spent at 1.00 pm was 477 minutes which was also equivalent to 7 hours and 57 minutes. Then, the total average time spent at 6.00 pm was 519.2 minutes which was also equivalent to 8 hours 39 minutes and 12 seconds.

3.3 Comparison between Genetic Algorithm and Tabu Search

The performance of Genetic Algorithm and Tabu Search were measured in terms of shortest total distance travelled and minimum total average time spent for the complete delivery process in a closed loop. Figure 6 illustrated the bar graph to provide a visual comparison based on distance travelled to visit among 15 parcel hubs for both methods.

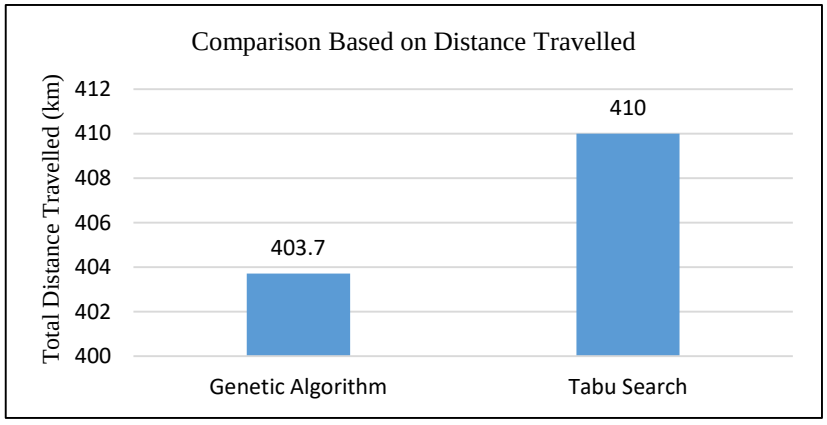

Figure 6: Comparison Based on Distance Travelled for Genetic Algorithm and Tabu Search

Based on Figure 6, the results were clearly indicated that the performance of Genetic Algorithm was better than Tabu Search because Genetic Algorithm yielded the shortest total distance travelled, which was only 403.7 km, while for Tabu Search required 410 km to travel. The percentage gap in terms of total distance travelled for both methods was 1.56%. This can be explained as Genetic

Algorithm was 1.56% more efficient than Tabu Search. Thus, the optimal route based on distance travelled was 1 – 14 – 2 – 13 – 12 – 10 – 6 – 3 – 9 – 11 – 15 – 4 – 8 – 5 – 7 – 1.

In addition, the results were compared based on total average time spent to travel between 15 parcel hubs. This study recorded 3 different times namely 9.00 am, 1.00 pm and 6.00 pm. After comparing all of the 3 different delivery times with both methods, it can be concluded that the performance of Genetic Algorithm was higher than Tabu Search in terms of total distance travelled and total average time spent. Next, the optimum delivery route for DHL Express to deliver the parcels was chosen after evaluating all 3 delivery time frames. Figure 7 depicted the bar graph to provide a visual comparison based on total average time spent to visit among 15 parcel hubs for both methods.

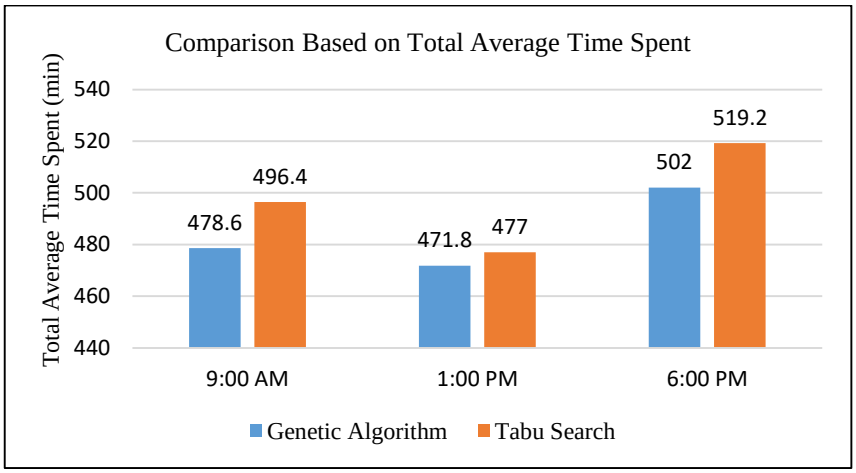

Figure 7: Comparison Based on Total Average Time Spent for Genetic Algorithm and Tabu Search

From Figure 7, it can be seen that compared with Tabu Search, Genetic Algorithm generated the minimum total average time spent for a small number of destinations at three different delivery times. The percentage gap in terms of total average time spent for both of the methods was 3.72%, 1.10% and 3.43% at 9.00 am, 1.00 pm and 6.00 pm respectively. This can be explained as the efficiency of Genetic Algorithm was 3.72%, 1.10% and 3.43% higher than Tabu Search at 9.00 am, 1.00 pm and 6.00 pm respectively. In conclusion, the ideal delivery time was at 1.00 pm, with only 471.8 minutes. This indicated that DHL Express required only 7 hours 51 minutes and 48 seconds to visit 15 parcel hubs in Perak to deliver parcels. Thus, the optimal route based on total average time spent was 1 – 2 – 14 – 3 – 10 – 12 – 13 – 6 – 11 – 9 – 15 – 4 – 8 – 5 – 7 – 1.

3.4 Interpretation of the most effective method

Overall, the findings of this study clearly revealed that the performance of Genetic Algorithm as the population-based metaheuristic was better than Tabu Search, a single-solution based metaheuristic in terms of distance travelled and total average time spent for a small sample size in the rural area. It is proven that Genetic Algorithm was the best method to deal with the small-scale TSP. The findings of this study are in accordance with the findings conducted by [15] and [16] in respect of minimum distance travelled. The findings of both studies were agreed that Genetic Algorithm was the best method to produce the optimum result for 10 to 150 cities of TSP problems compared to Tabu Search. From these results, it is clear that Genetic Algorithm was a robust metaheuristics algorithm since it can deal with a population of solutions rather than a single point [17]. In addition, Genetic Algorithm are able to obtain significantly better performance as it was good at finding a global minimum instead of local minima [18].

In recent years, Genetic Algorithm has been shown to be a viable option to solve TSP problem because it has proven to be more attractive and efficient in generating optimal or near-optimal solutions [19]. This study provides evidence to the performance and effectiveness of Genetic Algorithm as one

of the powerful algorithms to solve optimization problems. In short, Genetic Algorithm provides a high level of robustness, adaptability and global optimality.

4. Conclusion

This study had successfully determined the courier's routes delivery for distributing parcels in Perak by using Genetic Algorithm and Tabu Search. The courier routes were divided into two aspects which are shortest total distance and total average time spent in delivering parcels by DHL Express. In both of the scenarios, the experimental results revealed that Genetic Algorithm performed better in generating the shortest route for small sample size data compared to Tabu Search. Thus, Genetic Algorithm was the most effective method for DHL Express to plan their delivery routes in order to achieve cost-effectiveness and increase customer satisfaction with the timely arrival of parcels.

The delivery routes generated for shortest total distance travelled and total average time spent were different. However, DHL Express can choose the most suitable delivery path based on their needs and priorities. The transportation cost can be reduced by selecting the delivery route based on total distance travelled. In contrast, selecting the delivery route based on total average time spent can improve the productivity and ensure timely delivery of parcels. In conclusion, route optimization is a crucial contributor to the success of all the courier companies. Whether employing short-haul or long-haul routes, adopting an effective route optimization tool could make a huge impact in logistics management and customer services.

The main goal of this study is to minimize the distance travelled and total average time spent. However, from a different perspective, this study can also maximize the productivity and profitability of a courier company if the courier company keeps up with the rapid changes in the environment and technologies. Besides, the delivery route would be more realistic, precise and comprehensive to further include other factors such as traffic condition, transportation mode and labour utilization.

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