Comparison of Metaheuristic Techniques for Parcel Delivery Problem: Malaysian Case Study

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***Abstract*—Most people preferred e-commerce ensuing the Coronavirus Disease-2019 (COVID-19) outbreak, resulting in delivery companies receiving large quantities of parcels to be delivered to clients. Hurdle emerges when delivery person needs to convey items to a large number of households in a single journey as they never face this situation before. As a result, they seek the quickest way during the trip to reduce delivery costs and time. Since the delivery challenge has been classified as an NP-hard (non-deterministic polynomial-time hard)) problem, this study aims to search the shortest distance, including the runtime for the real case study located in Melaka, Malaysia. Hence, two metaheuristic approaches are compared in this study namely, Ant-Colony Optimization (ACO) and Genetic Algorithm (GA). The results show that the GA strategy outperforms the ACO technique in terms of distance, price, and runtime for moderate data sizes that is less than 90 locations.**

***Keywords*—Ant-colony optimization; genetic algorithm; delivery problem; comparison; cost; runtime**

I. Introduction

Ever since the chain of Coronavirus Disease-2019 (COVID-19) infections trend up worldwide, peoples' life has been turned upside down. So, do Malaysians. When the former Prime Minister, Tan Sri Dato' Haji Muhyiddin bin Mohd Yassin imposed national lockdown through Movement Control Order (MCO), Malaysians have slowly avoided brick-and-mortar shopping and shop on e-commerce. Previously, e-commerce was a generic buzzword, however, it has become a norm these days.

COVID-19 has led to a significant spike in e-commerce and rapid digitalization in the midst of weakening economic activity in most countries. For instance, in the 2nd period of 2020, Latin America's marketplace Mercado Libre managed to sell double things per day in comparison to the same period in the previous year. In addition, African e-commerce site, Jumia recorded a spike of 50% revenues over the first half of 2020. Throughout August 2019 and August 2020, China's e-commerce percentage of sales rose from 19.4% to 24.6%. Meanwhile, the online percentage of retail sales in Kazakhstan, grew from 5% in 2019 to 9.4% in 2020. In Thailand, installations of shopping applications surged by 60% within a week in March 2020 [1].

Transport plays an essential role in every supply chain and it has an impact on logistics' efficiency and effectiveness. Transportation, inventory keeping, bureaucracy, custom fees, hazard, as well as handling and packaging costs are among six major logistics cost aspects that should have good pre-planning. Route planning is a critical issue in distribution system, and as such, it has been an important topic in logistics field. By focusing on areas such as enhanced productivity and better vehicle usage, effective routing and scheduling can result big savings. According to [2], the goal of reducing transportation costs is to reduce the number of trips.

This research article presents a case study that utilizes Asymmetric Travelling Salesman Problem (ATSP), in which a delivery service is founded to alleviate the burden of delivering items to customers' doorsteps. As a result, this delivery service will travel and organise their routes carefully to multiple locations in order to meet the needs of their consumers within a designated time frame. The primary goal of this study is to evaluate two metaheuristics approaches, namely ACO and GA, and to compare its efficiency metric of minimizing cost and time. The delivery service drivers have a plethora of options, which will allow them to seek for the shortest distance and lowest cost throughout their excursions.

The entirety throughout this paper is organised as follows: Section II highlights relevant studies on the current challenges and ways to overcome, while Section III describes the methodologies used in the study. Section IV presents the outcomes and the discussions, and Section V finishes the article with future work.

II. Literature Review

A. Logistics in Malaysia

Malaysia reported 37% of growth in e-commerce revenues by 2020. The Department of Statistics Malaysia annotated a rise in 23.1% during the first 9 months of 2021, signalling that this pattern will remain [3]. A study by [4] indicated that e-commerce has boosted the number of buyers in both established and emerging countries, including Malaysia, Singapore, Thailand, and Pakistan since the outbreak. Most of retailers are changing their brick-and-mortar shop to e-commerce platform, as it can maintain the continuity and longevity of their business during these arduous circumstances.

Fig. 1 illustrated Malaysian's e-commerce users from 2017 – 2025 in three different categories, namely in the past, present and forecasted data of the upcoming years [5]. The figure demonstrates a significant basis on how intra-logistics have increased during this crisis in Malaysia. This is mostly due to the rise of internet purchases for daily necessities [6].

When consumers are actively purchasing online today, the need for shipments are escalating every day. Thus, an extra demand exists during festive seasons, monthly household demands, and monthly sales organised by e-commerce platforms. The warehouse space in courier companies is quite limited to cater these high parcel volumes, resulting dumping of parcels [7][8]. When there are countless of delayed parcels to be delivered, employees must work overtime. Pos Laju riders, one of the delivery companies in Malaysia, are deemed to work on weekends to avert overburdened goods, and deliver hundreds of items every day [7]. According to the previous study [8], this circumstance is frustrating as poor coordination of logistics providers and courier services has disrupted on other activities in the company.

The following figure indicates the number of domestic courier items delivered by courier service providers in Malaysia from 2016 to 2020 (see Fig. 2) [9]. In 2020, the parcel volume distributed by the courier service providers escalate during the endemic, thus, courier companies need to be well-prepared.

Logistics are in demand ever since the COVID-19 pandemic has started. Almost all countries were having lockdowns. The only way to purchase our daily necessities were through online order and have it delivered to our doorstep. Hence, courier companies play a vital role. Planning of dispatches and navigation of vehicles are critical in supply chain operations since it influence distribution of costs and contentment of customers.

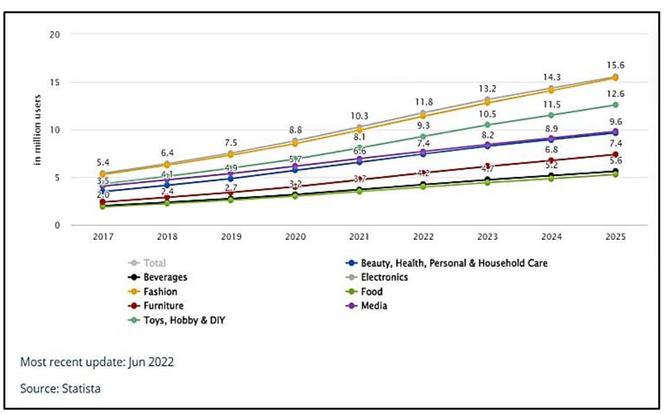


Fig. 1. Malaysian's e-commerce users from 2017 – 2025 in different Categories [5].

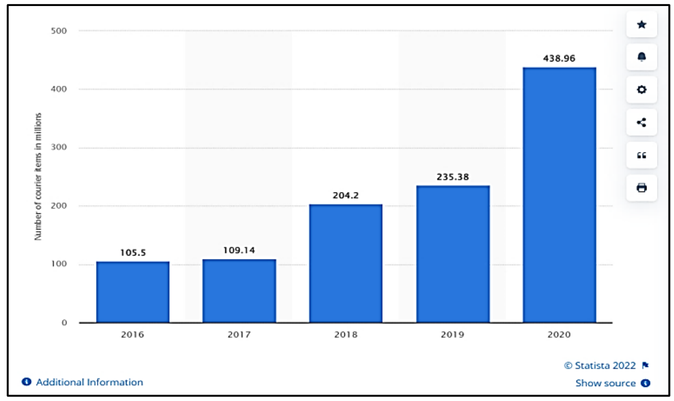


Fig. 2. The Number of Domestic Courier Items Delivered by Courier Service Providers in Malaysia from 2016 to 2020 [9].

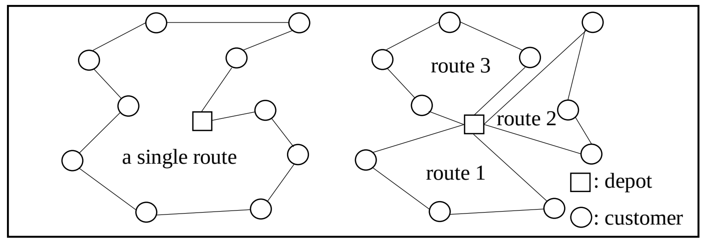


Fig. 3. The Difference between ATSP and VRP [11].

Since the distribution of goods is influenced by various factors such as the requirements of delivery providers, clients, and macro environment, Vehicle Routing Problem (VRP) is one of the most researched subjects in operational research [10]. Thus, logistics providers need to plan well if they want to use VRP or ATSP applications whenever they dispatch customers' packages. TSP examines a single vehicle visiting numerous customer sites before heading to the depot, and it is aimed that the total journey time or vehicle distance to be as short as possible. VRP is distinct from TSP as it can generate several routes that can travel through all customer locations. The Fig. 3 below shows the difference between ATSP and VRP are shown below [11].

Despite Malaysia's economic development rate is improving, the country's logistical advances remain modest. In order to stay abreast with other South East Asian countries, Malaysia's logistics development was meticulously mapped under the Third Industrial Master Plan (IMP3) in 2006, Unfortunately, Malaysia continues to lag behind neighboring countries such as Singapore, Thailand, and Vietnam in terms of transportation, bureaucracy, and logistics. The problems occur in logistics expansion are insufficient transport infrastructure, underdeveloped transport and logistics services, as well as delayed and costly administrative practices, which contribute to major factors of Malaysia's high logistics costs [12].

B. *Algorithms in Logistics Issues*

The ATSP is known as a combinatorial optimization problem in operation research and graph theory. It appears in numerous application scenarios, such as cloud computing resource deployment, efficient route search for transport, computational modelling of proteins, semiconductor manufacturing, X-ray crystallography, school and university scheduling, as well as drone navigation [13]. There is at least one scenario in the ATSP when cost or weight on an arc is not identical in either direction of to or from a node in a travelling graph [14]. ATSP is an efficiency problem that a salesman must solve in order to visit all cities. In an ATSP situation, the distance between cities A and B is not the same as the distance between cities B and A. As a result, the salesman must identify the quickest possible route.

In a study by [15], Farmland Fertility (FF) algorithm is utilized in the experiment to solve the problem. Farming action inspires FF as a metaheuristic. FF assists farmers in obtaining high-quality plant for sale at a premium price. During the process, farmers will typically split their fields into sections by using different materials or treatments depending on the soils. The study develops an agricultural fertility algorithm to tackle ATSP by identifying parameters that influence the outcome [15].

To handle continuous optimization challenges, Social Spider Algorithm (SSA) is proposed based on spiders' information-sharing foraging approach. By retaining SSA's strengths and outstanding performance, [16] propose a novel algorithm called Discrete Social Spider Algorithm (DSSA) to solve discrete optimization problems by making some changes to the computation of Euclidean distance, construction of follow position, movement method, and fitness function. TSPlib benchmark are used to demonstrate DSSA's effectiveness, and the results are compared to six different optimization methods: Improved Bat Algorithm (IBA), GA, an Island-based Distributed Genetic Algorithm (IDGA), Evolutionary Simulated Annealing (ESA), Discrete Imperialist Competitive Algorithm (DICA), and Discrete Firefly Algorithm (DFA). DSSA surpasses other strategies in the simulation data. The experimental results suggest that the DSSA approach is superior than the existing evolutionary algorithms for solving TSP issues and it can be applied to any optimization problems such as routing problems.

ACO is a nature-inspired metaheuristic that is frequently used to develop approximations to overcome optimization problems. Even though ACO is substantially faster than precise approaches, it still can be considered sluggish when it is compared to fundamental problem-specific heuristics. Recent research has demonstrated that algorithm modifications with proper parallel implementation using multi-core CPUs and specialized accelerators can be considered to enhance speed. In this study, [17] offered Focused ACO (FACO), a unique ACO variant. One of the FACO's basic elements is a system for managing large discrepancy between a freshly produced and a previously selected solution. This technique results a more concentrated exploration process, allowing improvements and maintaining performance of existing solution. In addition, it also provides seamless interaction of problem-specific local search. A computational study based on a variety of Traveling Salesman Problem instances reveals that FACO beats state-of-the-art ACOs in tackling big TSP instances.

As for the asymmetric travelling salesman problem, [18] proposed a new GA with optimal recombination and ATSP adaptive restarts. The crossover operator solves optimal recombination problem (ORP) using a new technique that solves the ATSP on cubic digraphs. Based on Schnabel census estimate, the researchers utilized an adaptive restart rule. A computational experiment on known benchmark examples demonstrates suggested algorithm able to produce results that are comparable to those state-of-the-art ATSP algorithms, confirming that the ORP can be utilized successfully in genetic algorithms. The study also discussed two restarting rules. The first solution employs the conventional restart rule, in which the GA is resumed as soon as the current iteration number equals double the number of iterations when the best incumbent is discovered (denoted GACL). The second strategy is based on the biometrics Schnabel census method that is combined with the maximum likelihood concept. When the population variation becomes low, novel solutions are unlikely to be identified, hence this criterion repeats the process.

Presently, there are lack of research when both methods perform their best at their own way. Hence, in this study, as for GA, it turns out to be the best when the crossover operator is removed, and subsequently the other three mutation operators, flip mutation, swap mutation, and slide mutation were added. Whereas for ACO, the best parameters were studied from various studies, and that parameter values were applied in this study. Therefore, both methods have been compared and evaluated to see which is the best to be applied in this study.

III. METHODOLOGY

In this study, the MATLAB version R2018a software is utilized to compare the effectiveness of the algorithms to some current works. The processor Intel(R) Core (TM) i5-1035G1 CPU @ 1.00GHz has an aspect of Intel Deep Learning Boost technology for speedier artificial intelligence-based computing. Below will further discuss the methods and parameters used in this study.

A. Genetic Algorithm

John Holland is the pioneer to propose GA on computational difficulties of game hypothesis and case recognition. It is based on the fundamental of Darwinian advancement principles of choice, hybridization, and transformation and aims to depict developmental methods [19]. Majority of GA-phrasing comes from the realm of inherited traits [20]. It is claimed to mimic the natural progression of living creatures. Fig. 4 depicts an illustration of a GA [20].

The GA’s fundamental structure can be described as follows:

1) Start: The process begins when a random pair of chromosomes from all best solution is identified, referred as the population.

2) Fitness: The fitness of each chromosome in the population is calculated using the fitness criterion. For an instance, based on a set of 5 genes, each of which would have one of the binary values 0 or 1, one must create a sequence with all 1s. Maximize the amount of 1s as much as possible.

This is an exemplar of an optimization problem. As a result, the fitness function is defined as the number of 1s in the genome. If it has five 1s, it has maximum fitness and solves the problem. If there is no 1s, it has the least fitness [21].

3) Selection: Two parent chromosomes are chosen from a population based on their fitness.

4) Crossover: Crossover on the specified parent chromosomes result a new offspring set.

5) Mutation: If necessary, the newly acquired progeny may also be mutated.

6) Check: If the specified criteria are achieved, return the optimal answer and stop.

This study applied the same approach as proposed by [22]. The crossover operator, was not included. According to [22], he does not regard the crossover operator as a necessary component of GA. The author in [22] tested different variants of the GA in terms of diverse crossover and mutation operator combinations in order to solve TSP. The crossover operator was discovered to be catastrophic as it resulted large changes to a given path and unable to impose good solution. As a result, [22] used three distinct mutation operators to generate modifications that were more important in promoting ideal results. Thus, the identical technique as described by Kirk was used in this case study. Fig. 5, Fig. 6, and Fig. 7 show three mutation operators which are elucidated in the following figures [22]:

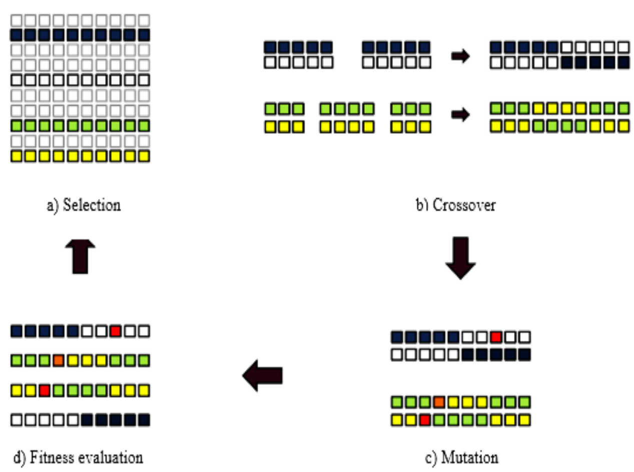


Fig. 4. Illustration of GA [20].

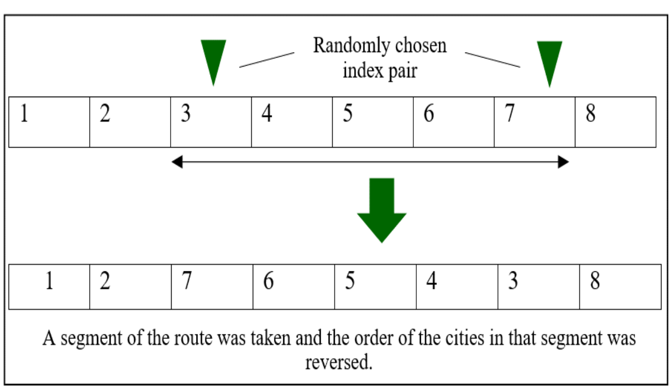


Fig. 5. Flip Mutation [22].

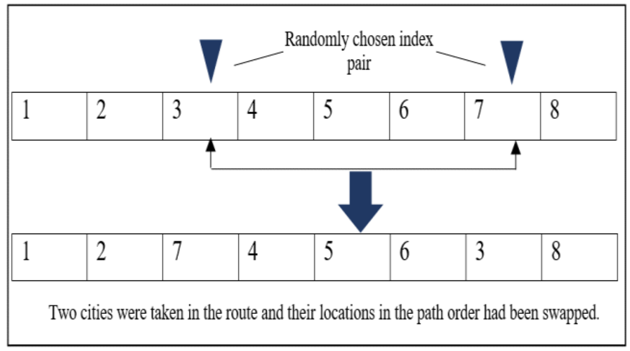


Fig. 6. Swap Mutation [22].

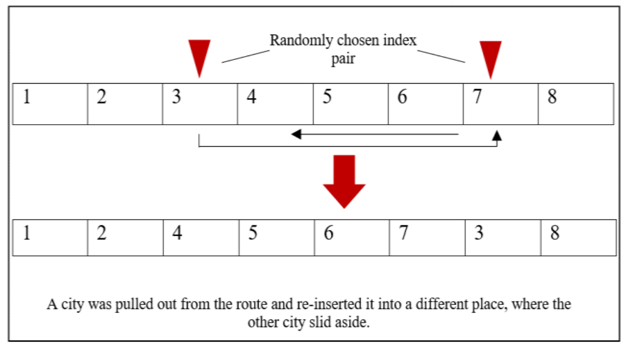


Fig. 7. Slide Mutation [22].

Fig. 8 Depicts the Flowchart of the GA.

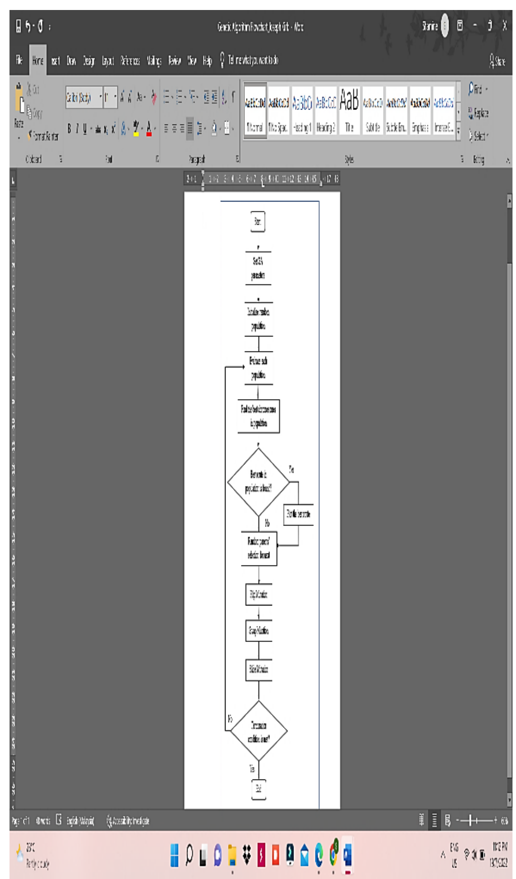


Fig. 8. Flowchart of GA [22].

TABLE I. PARAMETER VALUE FOR GA

Parameter	Value
No. of Houses	10, 20, 30, 40, 50, 60, 70, 80, 90, 100
Pop. Size	10
No. of Iteration	1e4
Mutation Probability	$P_m = 1.0$

Table I shows the parameter value of GA that was used in this study. The effect of parameters in both methods play a major role in this study. Among the parameters that are vital in the GA method are population of chromosomes, number of iterations and mutation probability. The population size used is 10. As there were no previous evidence studies on the recommended population size, hence, a simulation of ten-run was done between 10 to 100 population size. It was shown that when population size of 10 was used in the study, the result showed a positive performance. The iteration 1e4, (10000) was used as, right after that, the results occurred are same.

B. Ant-Colony Optimization

The ACO, which is based on ant foraging behavior, was first proposed by [23]. It portrays real-life of ants' behavior to find the short routes between sources of food and their nest, an evolving habit that emerges from an ant's decision to pursue the trail pheromones released by other ants. Fig. 9 shows the basic idea behind an ant colony, with black lines denoting pheromones on every route [24].

Initially, three ants contemplate to travel via the same route to their food. Each ant follows a different course, and one ant moves quicker than the others. This ant will exude a chemical substance (pheromone) while travelling to help other ants to trail and recall their path. The pheromone trail will be stronger on the shorter way than the longer path. Subsequently, the longer road pheromone trail will fade, but the shorter path pheromone trail will become much stronger, resulting the ants to choose the shortest route. Fig. 10 shows the flowchart of ACO algorithm [25].

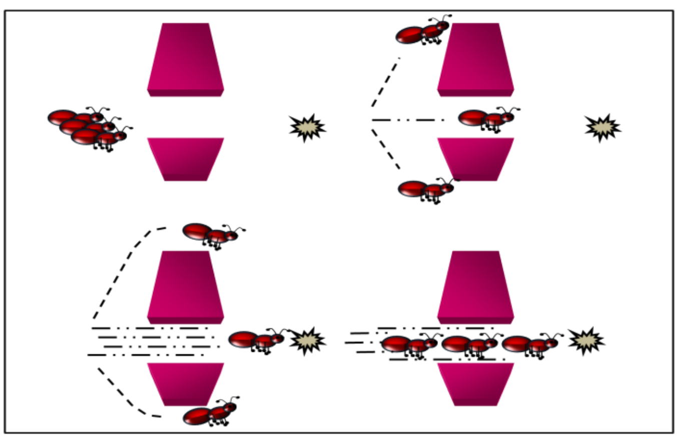


Fig. 9. ACO Behavior at Distinct Time Stamps [24].

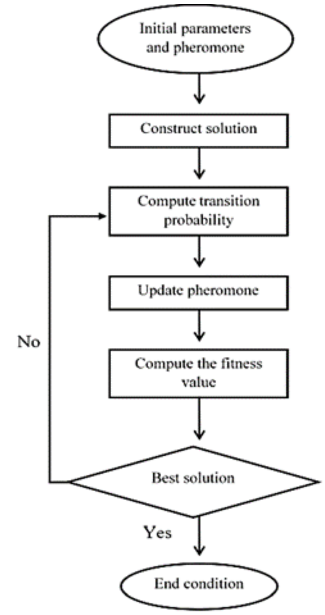


Fig. 10. Flowchart of ACO [25].

TABLE II. PARAMETER VALUE FOR ACO

Parameter	Value
No. of Houses	10, 20, 30, 40, 50, 60, 70, 80, 90, 100
No. of Ants	10
Pheromone Rate (rho)	0.15
No. of Iteration	300

Table II shows the significant parameter values of ACO that was used in this study as it affects the findings. The count of ants in this study is limited to 10. It is because, according to [31], it is suggested to assign the ants within the range of more than 6, but less than 20, for a small or medium scale TSP. Meanwhile, if the number of ants exceeds 16, it will result longer execution time when the complexity of the algorithm increases. Moreover, if the number of the ants is greater than 16, the evaporation rate of pheromone will be quicker resulting an impediment in finding the optimal solution. As a result, the number of ants is set to 10 and the rate of pheromone evaporation is determined to 0.15. This is because if the rate is lesser, there will be more pheromone and higher possibility to get the best findings. The iteration is set at 300 because if it is less, the optimum result cannot be achieved; if it is greater, simply the run time increases with the same outcome.

C. Formulation of Costing in Mathematical Model

The total cost of mathematical model is proposed for this study, as suggested by [26][27]. It has been employed in the pricing calculation after the distance of both approaches are obtained.

Total Cost, Z:

$$Z = \sum_{i=1}^{n} (LSD \times CS) \quad (1)$$

$$Z = \left[\sum_{i=1}^{n} D(L_i, L_j)\right] CS \quad (2)$$

$$Z = \left[\left[\sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}\right] CS\right] \quad (3)$$

i, j = $\{1,2,3,\ldots,n\}$

LSD = Length of the shortest path between two locations (D)

D = Distance between L_i and L_j

L_i = (x_i, y_i) initial point (location)

L_j = (x_j, y_j) second point (location)

CS = Cost per 1 kilometer = RM0.80

IV. Results

As a case study, we concentrated on Melaka Tengah district, which is known as one of historical capital in Malaysia. Melaka was discovered in year 1400, with an extent of 314 km^2. Years after, 3 districts and 29 divisions were identified [28]. Melaka Tengah is also recognised as Malacca's most developing city. The city is divided into residential, industrial, commercial, tourist regions, and administrative areas. According to [29], while the city creates enormous economic gains, it also has a variety of socio environmental implications due to poor transportation. Hence, it is chosen as a research topic for this study. Fig. 11 depicts a map of the Melaka Tengah District [30].

Oh My Foot Delivery is a new delivery firm that is established in this area, and its delivering statistics are used in this study. As a young company, currently there is only one branch located in Melaka Tengah's district. Since the company's position is strategic and there are few residential areas nearby, it has attracted the locals' attention for its delivery service. The company begins to grow when more consumers from further away requested its delivery services. As a result, this study is implemented in order to determine the ideal delivery route. Fig. 12 depicts the MATLAB result's that resembles Google Map.

As demonstrated in Fig. 12, the MATLAB findings are similar to Google Maps; hence the recommended routes from Fig. 13 to Fig. 32 are feasible. The yellow dot on Google Maps indicates both starting and ending point for the journey. Conversely, the red dots indicate the sites in which the deliver must travel in order to deliver packages to clients.

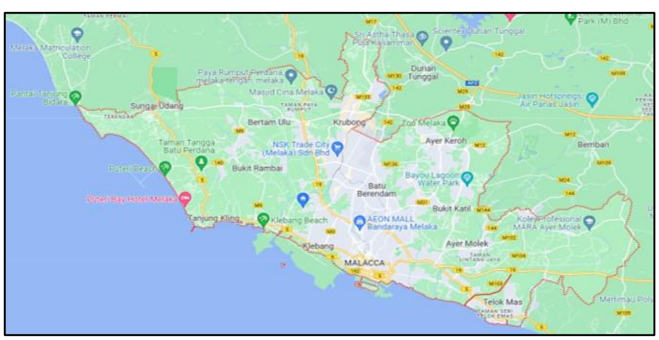


Fig. 11. Map of the Melaka Tengah District [30].

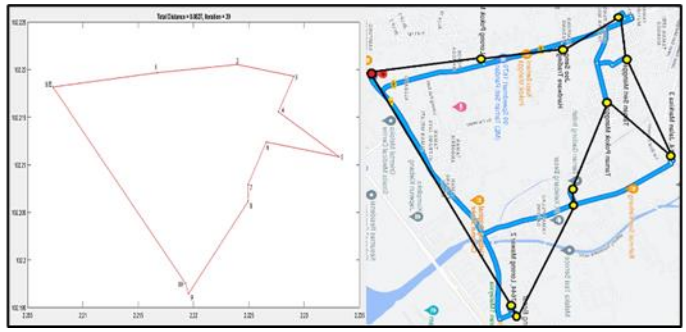
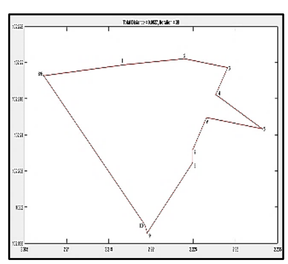
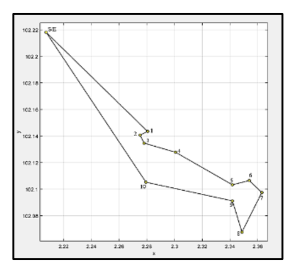


Fig. 12. The MATLAB Result's that Resembles Google Map.

Fig. 13 to Fig. 32 show the simulated results of both GA and ACO methods where each location has been identified from its starting/ending location (S/E) until 10th, 20th, 30th, 40th, 50th,60th, 70th, 80th, 90th, and 100th location simultaneously with its explanation. the starting and ending points are ensured in the same area (S/E). These roads are listed up to 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 houses based on insights of few riders who routinely deliver100 sites in a trip since the pandemic. At times, these riders need to cover ten areas per trip. As a result, from the data provided by the delivery firm, a total of 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 houses are selected for this case study.

The findings of 10 houses, 20 houses, 30 houses, 40 houses, 50 houses, 60 houses, 70 houses, and 80 houses reveal that GA depicts better way than ACO due to significant reasons. When 90 and 100 points of data are assigned to test, it is discovered that the distance and cost of the ACO approach is lesser than GA. This is due to the fact when the ants choose their path, they are likely to follow the trail indicated by the preceding ant who left a strong pheromone intensity. These ants will choose a path with high probability value that has higher pheromone concentration as it will proceed to the closest desired node. Nodes with low probability values are rejected because they are too far away from the ideal node. As a result of this mechanism, the number of possible paths from one generation to the next grows rapidly, causing ACO to converge faster than GA.

<table>
<tr><td colspan="2">For 10 Houses:</td></tr>
<tr><td>
Fig. 13. GA for 10 Houses.</td><td>
Fig. 14. ACO for 10 Houses.</td></tr>
<tr><td colspan="2">For 20 Houses:</td></tr>
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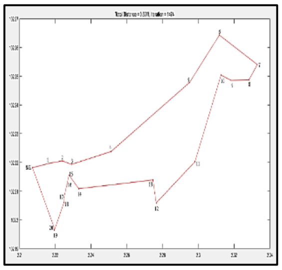

Fig. 15. GA for 20 Houses.

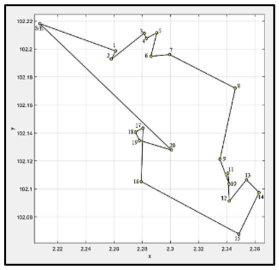

Fig. 16. ACO for 20 Houses.

For 30 Houses:

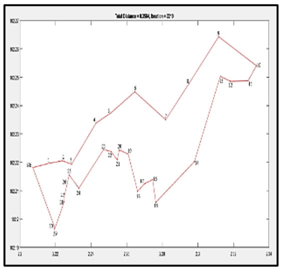

Fig. 17. GA for 30 Houses

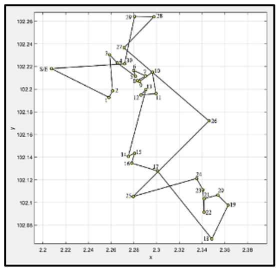

Fig. 18. ACO for 30 Houses.

For 40 Houses:

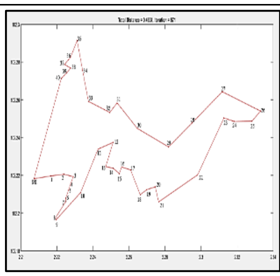

Fig. 19. GA for 40 Houses.

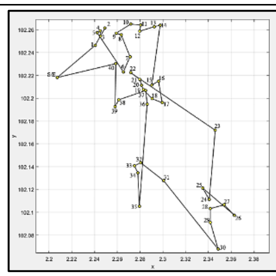

Fig. 20. ACO for 40 Houses.

For 50 Houses:

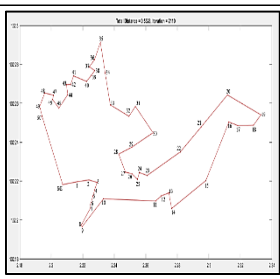

Fig. 21. GA for 50 Houses

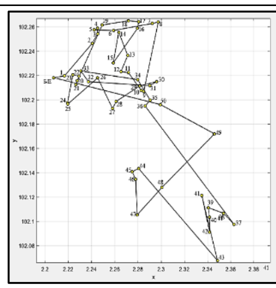

Fig. 22. ACO for 50 Houses

For 60 Houses:

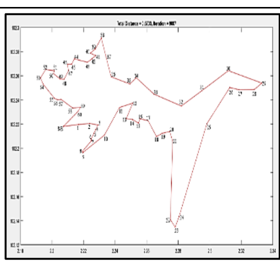

Fig. 23. GA for 60 Houses.

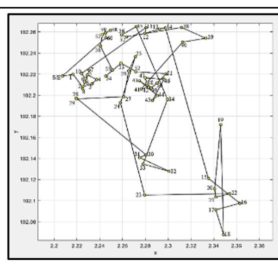

Fig. 24. ACO for 60 Houses

For 70 Houses:

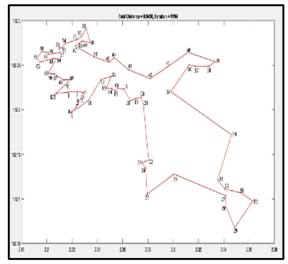

Fig. 25. GA for 70 Houses.

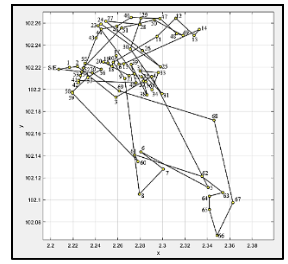

Fig. 26. ACO for 70 Houses.

For 80 Houses:

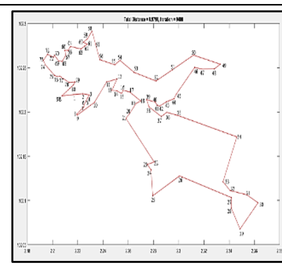

Fig. 27. FGA for 80 Houses.

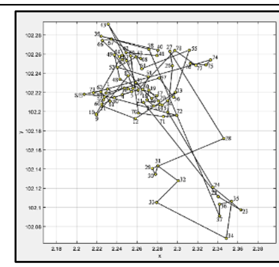

Fig. 28. ACO for 80 Houses.

For 90 Houses:

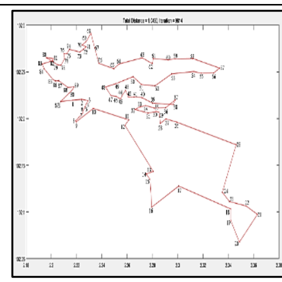

Fig. 29. GA for 90 Houses.

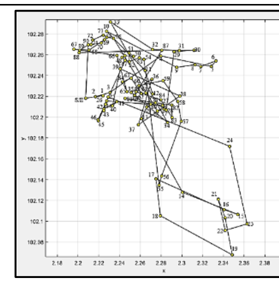

Fig. 30. ACO for 90 Houses.

For 100 Houses:

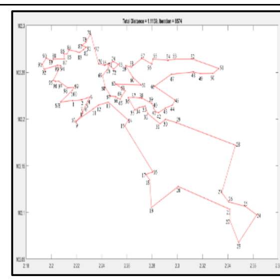

Fig. 31. GA for 100 Houses.

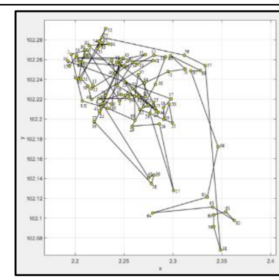

Fig. 32. ACO for 100 Houses.

Despite the fact that the ACO's parameters are set at its best according to previous study, there are various reasons why the GA technique is the best solution, including the fact that the run time for all 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 houses is significantly lesser than the ACO. The crossover probability, P_c, is set to 0 as the deciding factor. Although crossover probability has several effects on the GA studies, it tends to be disastrous because the crossover has significant impact on the given route due to the random changes made in it which will result in longer execution time. As a result, when the chromosome population is set to 50, the crossover probability parameter, $P_c = 0$, the mutation probability, $P_m = 1.0$, and the three mutation operators are utilized, the execution time of the GA is lower than the ACO. Flip mutation, swap mutation, and slide mutation are treated as three mutation operators in the study.

The delivery firm, Oh My Foot Delivery now can use the route proposed by GA method in this study. It is because, previously the delivers need to plan their location from one place to another by calculating it one by one. So, some locations that need to be visited has been missed and the delivers need to go the locations back and forth. However, although the distance has been calculated, but the outcome routes depend on the list the deliver enters. This results in high cost that the firm need to spend as more distances need to be travelled by the delivers.

The algorithms under consideration (the GA and the ACO) are employed to identify the shortest path within the range of scenarios of 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 home counts. The findings of both methods are compared. Fig. 33 reveals that least distance can be obtained when GA is used as the ACO trend in the distance graph increased compared to the GA trend. Hence, delivery service can save more money on their fuel as well.

TABLE III. COMPARISON OF GA AND ACO

No. of Houses	GA			ACO		
	Dist. (KM)	***Cost (RM)***	***Run Time (s)***	***Dist. (KM)***	***Cost (RM)***	***Run Time (s)***
10	**20.6**	**16.48**	**4.13**	92	73.6	15.74
20	**83.5**	**66.8**	**5.483**	141.7	113.36	16.752
30	**103.2**	**82.56**	**6.185**	176.8	141.44	16.857
40	**127.7**	**102.16**	**6.337**	190.05	152.04	17.552
50	**139.25**	**111.4**	**6.995**	207.25	165.8	18.163
60	**182.45**	**145.96**	**7.418**	266.35	213.08	18.496
70	**269.55**	**215.64**	**7.47**	285.35	228.28	20.461
80	**302.75**	**242.2**	**8.322**	316.95	253.56	21.256
90	335.15	268.12	**8.955**	**327.5**	**262**	22.269
100	346.9	277.52	**9.242**	**342.1**	**273.68**	21.364

Table III shows the result of this study that has been summarized, following by graphs in Fig. 32, Fig. 33, and Fig. 34.

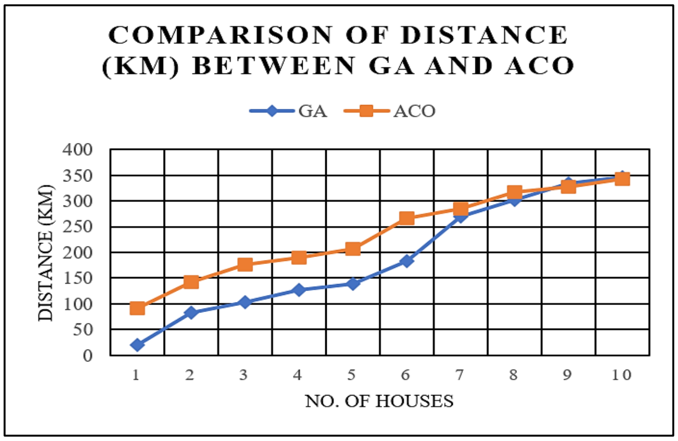

Fig. 33. Comparison of Distance (KM).

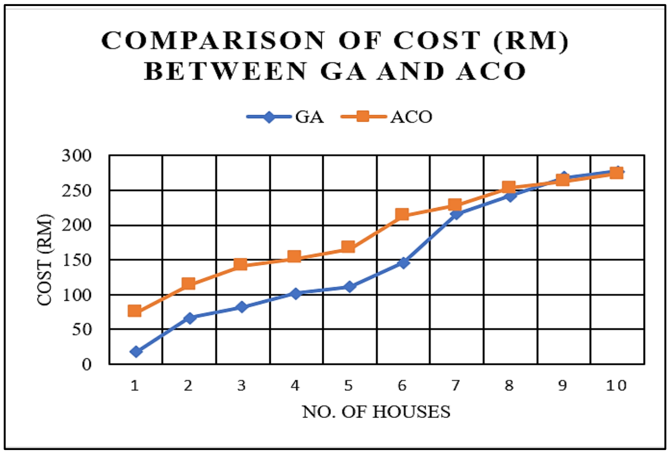

Fig. 34. Comparison of Cost (RM).

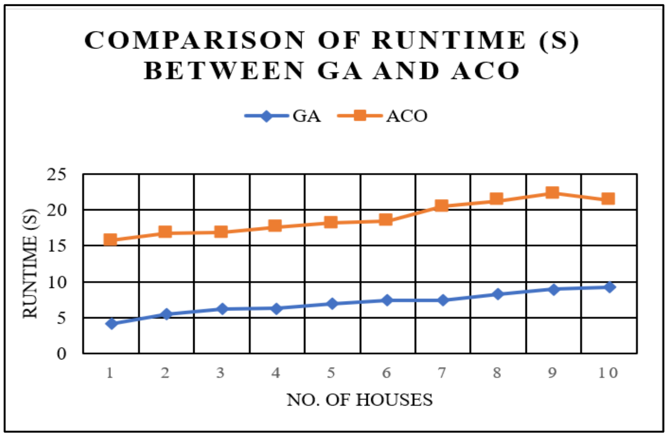

Fig. 35. Comparison of Runtime (s).

Furthermore, when the GA is applied, the graph in Fig. 34 demonstrates the lowest delivery cost which the company has to bear first, then it will be covered by the customers' delivery charge. Thus, it will be beneficial during this pandemic as both parties can save their money and profit from their delivery service. Nevertheless, when 90 and 100 dwellings are specified, the ACO algorithm scored averagely in respect of distance and cost when it is contrasted with the GA technique.

Nevertheless, the GA has yielded to be the most effective method in terms of its runtime under all conditions. It is corroborated through the graph in Fig. 35, which demonstrates a considerable difference in runtime between the GA technique and the ACO technique. From here, we can see that the objectives of this study which is to evaluate ACO and GA, and to compare their performance in terms of minimizing cost and time has been achieved. As a result, it is proven that the GA outperforms the ACO algorithm as it gives the least cost as it proposed the shortest route and minimal running time.

V. CONCLUSION

This research aims to evaluate two metaheuristics strategies to reduce the exact distance of one trip during delivery. The appraisal methodologies used are the GA and ACO, with distance and cost of delivery as significant presenting pointers. When the GA calculation is assigned to

10, 20, 30, 40, 50, 60, 70, and 80 houses, the most minimal distances and lowest expenses are obtained, according to the exhibition correlation. Thus, when it is compared to the ACO method, the GA outperforms in terms of distances, cost, and runtime. It is also acknowledged that the ACO algorithm performs moderately in terms of distances and prices for 90 and 100 houses. Since both methods are the finest in its individual investigations, both methods and its best parameters are compared. As a result, the objective of this study is achieved.

As a recommendation of future work in this research area, the best methodology that is chosen which is GA can be used in other applications of TSP. Those applications that can be taken into account are scheduling, planning, and manufacturing of microchips. It is because, as the crossover operator has been removed from GA in this study, and it shows a positive effect in terms of runtime, it will be intriguing to know what would be the outcome of the method on other applications.

ACKNOWLEDGMENT

Communication of this research is made possible through monetary assistance by Universiti Tun Hussein Onn Malaysia and the UTHM Publisher's Office via Publication Fund E15216, TIER 1 Grant (Q162) and also GPPS Grant (H633).

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