JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY (JMMST)
e-ISSN: 2636-9575
VOL. 5, ISSUE 2, 69 – 77
DOI: https://doi.org/10.15282/jmmst.v5i2.6855

ORIGINAL ARTICLE

# Completion of Capacitated Vehicle Routing Problem (CVRP) and Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) Using Bee Algorithm Approach to Optimize Waste Picking Transportation Problem

C. Natalia[1*], V. Triyanti[1*] , G. Setiawan[1], and M. Haryanto[1]

[1]Department of Industrial Engineering, Atma Jaya Catholic University of Indonesia, Indonesia.

**ABSTRACT** – Bee Algorithm (BA) is an algorithm that adapts the way of life of bees and their intelligence in finding food sources. This research is a combination of two projects that both use BA as the completion algorithm. BA is applied to solve CVRP and CVRPTW problems, both aim to provide effective and efficient advice solutions related to waste transportation routes of the upcoming ITF Sunter project. Using CVRP approach, the capacity of the waste transported will not exceed the capacity of the waste transport vehicle owned. Meanwhile, using CVRPTW approach, the route formed also considers the travel time and the results are divided into applicable transportation shifts which called as the time window. Both methods then were used to minimize the distance that occured when vehicle goes shipping and visiting each points of the routing problem. The optimum route is decided using the Bee Algorithm. The analysis shows that the traveling times and distances are less that the current method used, compared to the current method used by the government. The result proves that the BA is potential approach to select the optimum routes of the waste transportation.

**ARTICLE HISTORY**
Revised: 9th August 2021
Accepted: 24th August 2021

**KEYWORDS**
*Bee Algorithm,*
*CVRP and CVRPTW problems,*
*Waste Transportation*

## INTRODUCTION

The development of the times and technology that continues to increase is getting more advanced every time, of course it brings various impacts on human life, one of which is the increase in fulfillment of needs. And the negative impact arising from this increase is the continued increase in piles of waste which have various types and different management methods. Indonesia itself is listed as a country that ranks second in the world's largest waste producer after China. This is evidenced by the condition of the volume of waste in Jakarta itself which is always increasing every year. Due to this also, Bantargebang, which is the Final Dumpsite from Jakarta's waste, is predicted to no longer be able to accommodate waste and reach its limit (overload) by 2021. Therefore, to deal with this, the Government built the ITF (Intermediate Treatment Facility) Sunter. With the aim that DKI Jakarta is able to accommodate and process the waste it produces itself without having to throw it away and throw it back to Bantargebang. However, at this time the ITF Sunter itself is still under construction and there is no specific design at all that regulates the routes and areas of which Temporary Dumpsite are served by the ITF Sunter. And based on the results of interviews conducted with the West Jakarta Environmental Office, it was found that the most likely TPS plans to be served were those in West Jakarta, Central Jakarta and North Jakarta. From this, the transportation of waste that occurs must not be separated from the role of transportation itself, and based on the results of the interview it was also obtained that the recommended vehicle for the three areas of Jakarta is Big Typer with a capacity of 16,000 kg.

So, in accordance with the matters previously described, of course a good and precise (optimal) route solution is needed for the transportation of waste from Temporary Dumpsite in West Jakarta, Central Jakarta and North Jakarta to the ITF Sunter. This route aims to minimize the total distance traveled and the vehicles used and the maximum possible carrying capacity. To solve this problem, the CVRP (Capacitated Vehicle Routing Problem) method is used, which is a type of VRP with limited capacity [1]-[3], the solution of which is assisted with the help of the concept of Bee Algorithm. Here with CVRP, the resulting route is only passed once by one vehicle with the demand for waste being transported not exceeding the capacity of the vehicle so that the optimal route destination can be achieved.

There is also CVRPTW method used to finish the vehicle routing problem [4]-[5]. CVRPTW is one of many other NP-hard problem, which this method using time duration or the time window to determine the best routes of a set of limited capacity vehicles between a depot and each point or node that considered as the customers that need to be visited by the vehicle [6]. CVRPTW also used for achieving many other objectives such as: optimizing the number of vehicles that must serve points or nodes, determining the customers that each vehicle should serve on the route, and determine the order of cost that could be minimized as much as possible [6]. This method has objective to minimize distance with the limitation of capacity and the time window of the vehicle to do the shipment. Therefore, this method

*CORRESPONDING AUTHOR | C. Natalia & V. Triyanti | ✉ chrisnatalia@atmajaya.ac.id & vivi.triyanti@atmajaya.ac.id

produces most optimum distance by using Bee Algorithm as tool to solve the VRP problem.

For the Bee Algorithm (BA), this algorithm itself is an algorithm created from the bees' way of life in looking for food. This BA will play a role in helping find the closest optimal solution in each iteration by using fitness evaluation (fitness value) to encourage random searches so that they are exploratory and sometimes exploitative [7]-[8]. And with BA's ability to do both local and global searches at the same time, it is hoped that the solution results can't be trapped at a local optimum [9]. Therefore, with the research being designed at this time, it is hoped that the results related to the optimal route obtained can be a suggestion, input or consideration for the ITF Sunter itself so that it can support its work optimally

## THE VEHICLE ROUTING PROBLEMS

The VRP case is actually quite complex, but it is familiar and has been discussed a lot in research. In real life, VRP is often applied to solve problems related to regulation and route determination so that the distance that must be traveled in the distribution of goods is optimal [1]-[2]. In addition, with this VRP in distribution as well as transportation, other things such as time, cost and the number of vehicles used can also be optimized [3]. And in this study focuses on 2 types of VRP variants, namely CVRP and CVRPTW.

### Capacitated Vehicle Routing Problem (CVRP)

For CVRP itself, there are several rules that apply [10], where the depot is the ITF Sunter. Then each point visited was temporary dumpsites located in West Jakarta, Central Jakarta and North Jakarta. Each node (Temporary Dumpsite points) is only visited exactly once by a garbage truck; the total amount of waste demand transported in one route does not exceed the capacity of the garbage trucks serving that route; each garbage truck route, starting from and ending at the depot; route continuity, meaning that garbage trucks that visit a node (a certain Temporary Dumpsite point), after finishing serving, will leave that node (a certain Temporary Dumpsite point). Equation 1 represents the function of CVRP in this case [1], [10]:

Minimize Z:

$$\sum_{k\in K}\sum_{i\in V}\sum_{j\in V} C_{ij}\, X_{ijk} \qquad (1)$$

Where:

$X_{ijk} = \begin{Bmatrix}1\\0\end{Bmatrix}$ 1 means vehicle k visits node i to node j, and 0 means does not

K = Number of vehicles/ garbage truck.
Cij = Distance acquired from node i to node j.

### Capacitated Vehicle Routing Problem with Time Windows (CVRPTW)

For CVRPTW, rules used by this method almost the same with normal CVRP but, there are some rules that related to the Time Windows that used by the vehicle during the shipments. With these method used, then the result of the distance will constrained with the time windows. The main areas of this problem the same with the CVRP problem which consists of West Jakarta, central Jakarta dan North Jakarta that each Temporary Dumpsite from each region will be visited once by the vehicle (garbage truck). This method also tells how long the times needed to visit each points by measuring the serving time, traveling time and beginning time of the waste picking process [11]. By these constraints, it can be formulated into objective function that refer to (2) [10]:

Minimize Z:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\left(Wt_{ij}\sum_{k=1}^{m} X_{ijk}\right) \qquad (2)$$

Where:

- $X_{ijk} = \begin{Bmatrix}1\\0\end{Bmatrix}$
  - 0 means if vehicle k visits node i to node j.
  - 0 means the opposite, that is, if vehicle k does not visit node i to node j.
- K = Number of vehicles/ garbage truck.
- Wtij = Total time for vehicle to do the shipment.

## BEE ALGORITHM (BA)

The BA algorithm was first developed by Pham et al. [13], where this algorithm is one of the swarms intelligent inspired by the life of an insect, namely bees [7]. More precisely, Bee Algorithm using bee nature habits in search of food in the wild [14]-[18]. The BA algorithm itself has been widely tested and used to solve optimization problems [19] which can be categorized into two groups: continuous optimization problems and combinatorial optimization problems [8]. This BA algorithm is different from the ABC algorithm [20]-[21]. They using several types of bee to do the hunting for food. There are Scout Bees dan Forager Bees [9], [22]. These two types of Bees have different job where scout bee do the scouting for food [23] in the term for searching food locations which have nectar on it. Scout bees gathering all the food locations as solutions for the optimization problem. Those solutions are measured by the fitness of the locations. The fitness represent how many nectar or food on that solution location. The more fitness gained for the location is better.

After the scout bees return, they will recruit bees to foraging all the solutions that scout bees found before, these are called as Forager Bees. There are bees which recruited to foraging the locations for food. The location or the solution also separate into two kind, there are elite sites dan best sites. Elite sites represent the highest location fitness for all solutions had been found. Best sites represent some location which have better fitness than other solutions found, but not better than the elite sites. These two sites will be foraged by their own recruited bees, and the remaining solutions will be always updated for the fitness for each location until maximum iterations reach [6], [9], [22], [24]. Those steps are shown on a flowchart on Figure 1 [16], [25]-[26].

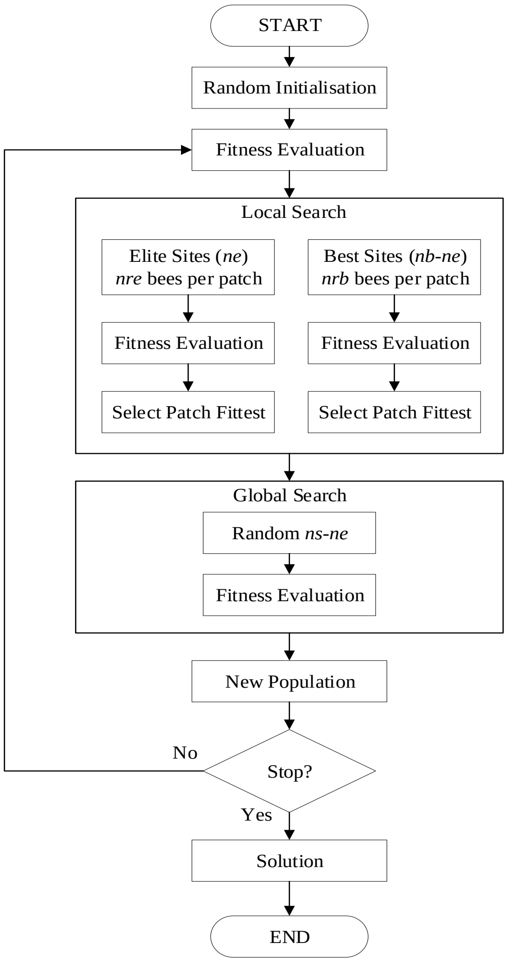


**Fig 1.** Bee Algorithm Process Flowchart

## METHODS

In short, the case problems in this study cover three areas in Jakarta. With each area of Jakarta, namely West Jakarta with 31 TPS locations, then Central Jakarta with 31 TPS locations and North Jakarta with 36 TPS locations. Where all these points must be visited by vehicles originating from each of these areas. Thus, each region has a different number of trucks, with West Jakarta and Central Jakarta with 20 trucks and North Jakarta with 22 trucks. In this case, the vehicles used are assumed to be homogeneous, that is, vehicles of the same type and capacity, in this case the Big Typer truck. Because Big Typer is indeed recommended and more often used by the three regions. The trucks used are intended to transport waste from each TPS locations to the ITF Sunter. With the amount of demand/ waste that is owned and must be transported from each TPS, have the amount varies. Therefore, in this case CVRP and CVRPTW will help to produce a route where the demand for transported waste cannot exceed the capacity of the truck itself.

Then, to get the distance between locations needed in processing both CVRP and CVRPTW, the euclidean distance formula is used [6], producing a distance matrix, where in this matrix it can be seen that the distance formed that connects the coordinate points between TPS and TPS locations with the ITF Sunter location. Meanwhile, for the required travel time matrix in CVRPTW processing, the travel time calculation formula is used [1]. With the data that has been summarized then processed with the help of Bee Algorithm solutions using MATLAB software. Meanwhile, the programming steps in MATLAB are as follows:

1. In the initial step before starting the iteration process, the determination of parameters such as:
   - Number of scout bees (*ns*), assigned to give number of route solutions for waste transport from West Jakarta, Center Jakarta and North Jakarta.
   - Number of best locations (*nb*), as route solution that has a large amount of garbage collection or accumulation.
   - Number of elite locations (*ne*), as route solution that has the highest amount of garbage collection or accumulation among other solutions in the best locations.
   - Number of best collecting bees (*nrb*), as forager bees that have been selected and recruited to transport waste on the path of the best solution that has been chosen.
   - Number of elite collecting bees (*nre*), as forager bees that have been selected and recruited to transport waste on the path of the elite solution that has been chosen.
   - Number of iterations (*iteration*), as the maximum number of iterations (looping/ repetitions) to produce the best optimal value.
2. Random initialization process, which is the process of initializing a random initial population solution of a number of search bees (*ns*).
3. The process of evaluating the initial fitness value, the process of evaluating the fitness value of all solutions obtained by a number of *ns*.
4. Local Search Process (Local Search),
   - The process of determining the best location, which is the process of finding the best location with a specified parameter value then sorting the solutions based on the fitness value and the best location with the best fitness value chosen.
   - The process of determining the elite location, which is the process of finding the elite location from the best location, a number with predetermined parameter values, then sorting the solutions based on the fitness value and the elite location with the best fitness value chosen.
   - The process of determining the best bee, which is a process of collecting bees assigned to evaluate the fitness value at the best location and a neighborhood search process occurs where if the new fitness value solution is better than the initial solution it will replace the initial fitness value.
   - Elite bee determination process, which is the process of collecting bees assigned to evaluate the fitness value at elite locations and a neighborhood search process occurs where if the new fitness value solution is better than the initial solution it will replace the initial fitness value.
5. Global Search Process, which is the process of determining residual bees, which will look for and evaluate the fitness value of new solutions outside the elite and best solutions.
6. Update Fitness, is the process of updating the solution obtained so that only the most optimal solution is maintained.
7. Stop Criterion, is a process where the iteration will repeat itself until the set number of iterations is reached.

The integration that occurs between the CVRP/ CVRPTW function and the BA algorithm lies in the coding fitness. In other words, the fitness value obtained is influenced by the objective function and limitation function rather than the CVRP/ CVRPTW itself. Because the fitness value referred to here is the total distance resulting from the route that has been formed.

Then, in the process of evaluating the fitness value at the elite site and the best site here, a neighborhood structure is applied using the Exchange method, which functions the same as the swap or inversion process. The goal is to move / swap / move index / node values in order to find the right sequence (route order). If the fitness results from this exchange process, for both the elite and the best, are more optimal (smaller) than the previous (initial) fitness results, then the new fitness results will be selected as a new alternative solution. For the flow and process of programming in MATLAB, it is described in Figure 2.

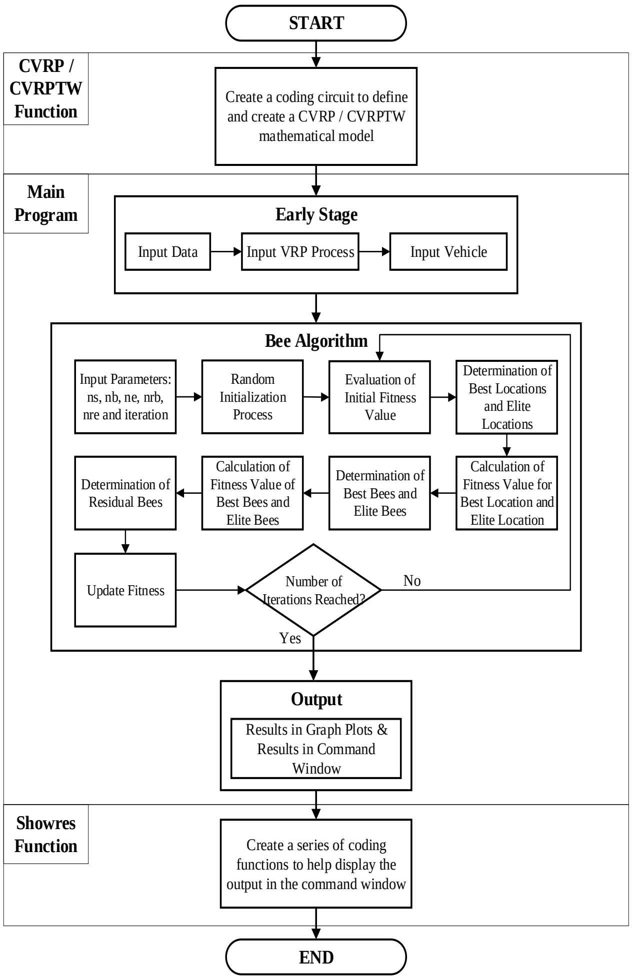


**Fig 2.** Bee Algorithm Processing Flowchart using MATLAB

For the validation of the program itself, first of all, validation is to check and get an idea whether the program and algorithm model used can represent the problem and answer and provide the required solution or not. This validation is done by seeing the output of the resulting program that does not violate the predefined CVRP/ CVRPTW model and shows no signs of error. If there is still a program code that is wrong, insufficient or incomplete, MATLAB will notify or give a warning to the programmer. So, the warning that will show due to the error that have been made. This is one of the example when the code inputted for the data code in program is incorrectly, then program will show these warning shown by Figure 3.

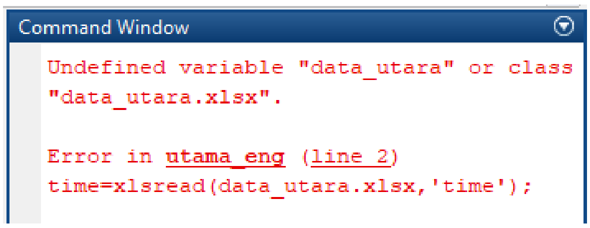


**Fig 3.** Warning Sign for Wrong Input Code

And in this example, if there any wrong function code inputted to the program, then a warning like this will appear in the program as shown in Figure 4.

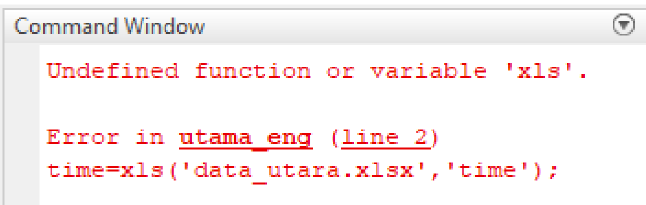


**Fig 4.** Warning Sign for Wrong Function Code

## RESULT AND DISCUSSION

The objective to be achieved in this research is the optimal route solution so that the distance can be minimized to a minimum with the maximum carrying capacity from West Jakarta, Central Jakarta and North Jakarta to the ITF Sunter. And from these objectives, here are some tables that show the parameter values used and the results obtained.

**Table 1.** BA parameter value for West Jakarta, Central Jakarta and North Jakarta regions

| Parameters Used | Jakarta Regions | | |
|---|---|---|---|
| | West | Central | North |
| Number of Iterations (*Iteration*) | 500 | 500 | 1500 |
| Number of Scout Bees (ns) | 30 | 30 | 30 |
| Number of Best Solutions (nb) | 4 | 4 | 4 |
| Number of Elite Solutions (ne) | 2 | 2 | 2 |
| Recruited Bees for Remaining Best (nrb) | 10 | 10 | 10 |
| Recruited Bees for Elite Solutions (nre) | 10 | 10 | 10 |

From the parameter values that have been obtained in Table 1, then the running process is carried out 10 times to get the best value execution results for CVRP problems, which are shown in Table 2.

**Table 2.** Results of BA route solutions for West Jakarta, Central Jakarta and North Jakarta regions

| Regions | Distance (km) | # of Route | *Demand* (kg) | Remaining Truck Capacity (kg) |
|---|---|---|---|---|
| West Jakarta | 498,08 | 18 | 259.220 | 28.780 |
| Central Jakarta | 271,58 | 17 | 251.310 | 20.690 |
| North Jakarta | 276,45 | 21 | 297.290 | 38.710 |
| Total | 1.046,12 | | 807.820 | 88.180 |

And based on Table 2., if the BA results are compared with the “door to door” initial transportation system which is usually applied to Bantargebang and also wants to be applied to the Sunter ITF, then BA will prove to be more effective and efficient as shown in Table 3.

**Table 3.** Result Of Comparison Of Initial Routes And BA Routes

| Regions | Starting Route | | Bee Algorithm Result Route (BA) | | Difference in Derating for the Initial Route & BA (km) |
|---|---|---|---|---|---|
| | Distance (km) | Number of Route | Distance (km) | Number of Route | |
| West Jakarta | 827,63 | 31 | 498,08 | 18 | 329,55 |
| Central Jakarta | 467,39 | 31 | 271,58 | 17 | 195,81 |
| North Jakarta | 462,13 | 36 | 276,45 | 21 | 185,68 |
| Total | 1.757,16 | | 1.046,12 | | 711,04 |
| **Percentage of Distance Drop (%)** | | | | | |
| West Jakarta | | | | | 39,82 |
| Central Jakarta | | | | | 41,89 |
| North Jakarta | | | | | 40,18 |
| Total | | | | | 40,47 |

There are several results for CVRPTW method applied to the problem using Bee Algorithm as the solving algorithm. There also some summary for the result shown by the CVRPTW problem. These result show number of vehicles used, remaining capacity, traveling distances and traveling time for each regions as shown on Table 4.

**Table 4.** Results Summary BA solutions for CVRPTW problem

| Regions | Number of Vehicle Used | Remaining Capacity (kg) | Traveling Distance (km) | Traveling Time (minutes) |
|---|---|---|---|---|
| West Jakarta | 18 | 28.780 | 497,18 | 615 |
| Central Jakarta | 17 | 38.710 | 275,32 | 348 |
| North Jakarta | 21 | 20.690 | 278,48 | 340 |
| Total | 56 | 88.180 | 1.050,98 | 1.303 |

This method concerns in total time that needed to done shipment on the route that created. Table 5. show the traveling time comparison between current system and Bee Algorithm solution that measured by minutes.

**Table 5.** Traveling time comparison between current system and Bee algorithm solution

| Regions | Total Traveling Time Current System (minutes) | Total Traveling Time Bee Algorithm Solution (minutes) |
|---|---|---|
| West Jakarta | 1.057 | 615 |
| Central Jakarta | 597 | 348 |
| North Jakarta | 590 | 340 |
| Total | 2.244 | 1.303 |

These vehicles used then separated by shifts that has been used by government for the waste picking on Jakarta Region. Government using three shifts, which these shifts use 8 hours for each. For shift one ranges from 07.00 – 15.00, shift two range from 15.00 – 23.00, shift three range from 23.00 – 07.00. Vehicle separated by time window shown on Table 6.

**Table 6.** Vehicle used by shift or time windows

| Regions | Shift | Number of Vehicle |
|---|---|---|
| West Jakarta | 07.00 – 15.00 | 1,2,3,4,5,6 |
| | 15.00 – 23.00 | 7,8,9,10,11,12,13,14 |
| | 23.00 – 07.00 | 15,16,17,18 |
| Central Jakarta | 07.00 – 15.00 | 1,2,3,4,5,6,7,8 |
| | 15.00 – 23.00 | 9,10,11,12,13,14,15,16 |
| | 23.00 – 07.00 | 17 |
| North Jakarta | 07.00 – 15.00 | 1,2,3,4,5,6,7 |
| | 15.00 – 23.00 | 8,9,10,11,12,13,14,15,16,17,18 |
| | 23.00 – 07.00 | 19,20,21 |

According to the result above can be calculated from the CVRPTW results for the efficiency percentages of the capacity that used for all regions. This result count from every region that served by the ITF Sunter. This result also helps the government to know the efficiency of the plan when ITF Sunter is done. Table 7 show the result for the capacity efficiency percentages.

**Table 7.** Vehicle capacity efficiency percentages that used for shipment

| Region | Number Vehicle Used | Vehicle Capacity (kg) | Total Capacity (kg) | Grand Total |
|---|---|---|---|---|
| West Jakarta | 21 | 16.000 | 336.000 | |
| Central Jakarta | 18 | 16.000 | 288.000 | 896.000 |
| North Jakarta | 17 | 16.000 | 272.000 | |
| **Total Capacity** | | 896.000 | | |
| **Total Remaining Capacity** | | 88.180 | | |
| **Total Used Capacity** | | 807.820 | | |
| **Using Percentages (%)** | | 90,16 | | |

Considering the result, CVRP shows a good and optimal route for the transportation of waste from Temporary Dumpsite in West Jakarta, Central Jakarta and North Jakarta to the ITF Sunter. Using the bee algorithm, the total traveled distance could be minimized, and the utility of vehicles can be maximized. Using the CVRP approach, the resulting route is only passed once by one vehicle with the demand for waste being transported not exceeding the capacity of the vehicle so that the optimal route destination can be achieved. However, this approach has not been able to completely solve the problem because it only considers a few things related to distance and vehicles. In fact, road condition factors such as congestion and road quality can also affect the route. In addition, the quality of the vehicle, the driver's preference for the road, as well as public acceptance of the dumpsite truck can also affect the truck route. In the future, research can be directed to consider more complex factors.

## CONCLUSION

Based on the objectives to be obtained from the research and considering the results of the data processing itself, it is known that with the Bee Algorithm (BA) the route obtained is proven to be optimal because it is more effective and efficient than the initial route (door to door system). This is shown in Table 3, which shows the results of the BA route which is able to minimize the distance for CVRP problems.

For CVRPTW problems, seen from the results of the total travel time and mileage for all regions to make deliveries in Table 4, shows that the BA solution does produce a minimum yield solution, much better than the current system. The percentage of capacity utilization also shown in Table 7, shows good results by exceeding 90% for usage. Where these results prove that the Bee Algorithm solution for the ITF Sunter plan is better than the current system with more minimum and optimal results.

## REFERENCES

[1] W. K. Cahyaningsih, E. R.Sari, and K. Hernawati, “Solving the capacitated vehicle routing problem (CVRP) using the sweep algorithm for the optimization of the distribution routes of the kedaulatan rakyat newspaper,” *Proc. National Seminar on Mathematics and Mathematics Education*, pp. 1–8, 2015.

[2] R. R. D. Setiady, A.N. Jati, and F. Azmi, “Design and implementation of heuristic methods for vehicle routing problems in garbage transportation,” *E-Proceeding of Engineering*, vol. 3, no. 1, pp. 802–809, 2016.

[3] S. Suprayogi, (2009) "Determination of garbage collection and transport truck routes in Bandung," *Journal of Industrial Engineering*. [Online]. 11(1). pp. 51–60. Available: https://doi.org/10.9744/jti.11.1.pp.51-60

[4] C. Natalia, A. Silalahi, and J. Khantidevi, "Pendekatan Metode Tiga Fase dalam Optimasi Masalah Rute Kendaraan dengan Varian Jenis Kendaraan dan Jenis Produk," *Metris*, vol 18, no 2, pp. 125–132, 2017

[5] C.W. Oktavia, C.Natalia, and I. Adigunawan, "Penentuan Jalur Rute Distribusi Produk Fast Moving Consumer Goods dengan Menggunakan Metode Nearest Neighbour : Studi Kasus PT.XYZ (Determination of Product Distribution Route for Fast Moving Consumer Goods by Nearest Neighbour Method : Case Study PT.XYZ)," *Jurnal Al-Azhar Indonesia Seri Sains Dan Teknologi*, vol 5, no 2, pp.101-110, 2019, doi: http://dx.doi.org/10.36722/sst.v5i2.357

[6] R. Rosdiahti, “Capacitated vehicle routing problem (CVRP) modeling to optimize halal and non halal product distribution routes (computational study approach),” *Undergraduate Thesis, Faculty of Science and Technology, Sunan Kalijaga State Islamic University*, Yogyakarta, 2018

[7] Z. A. Çil, Z. Li, S. Mete, and E. Özceylan, "Mathematical model and bee algorithms for mixed-model assembly line balancing problem with physical human–robot collaboration," *Applied Soft Computing*. pp. 1–31, 2020 https://doi.org/10.1016/j.asoc.2020.106394

[8] M. Alzaqebah, S. Jawarneh, H. M. Sarim, and S. Abdullah, "Bees algorithm for vehicle routing problems with time windows," *International Journal of Machine Learning and Computing*, vol. 8 no 3. pp. 236–240, 2018, https://doi.org/10.18178/ijmlc.2018.8.3.693

[9] Kamsani, S. H., “Improvements on the bees algorithm for continuous optimisation problems,” *Thesis, Dept. Mechanical Engineering*, Birmingham Univ., Birmingham, United Kingdom, 2016

[10] D. Karaboga and B. Gorkemli, "A quick artificial bee colony (QABC) algorithm and its performance on optimization problems," *Applied Soft Computing Journal*, vol. 23. pp. 227–238, 2014, https://doi.org/10.1016/j.asoc.2014.06.035

[11] B. Yuce, M. S. Packianather, E. Mastrocinque, D. T. Pham, and A. Lambiase, "Honey bees inspired optimization method: the bees algorithm", *Insects*, vol. 4, no.4, pp. 646–662, 2013, https://doi.org/10.3390/insects4040646

[12] H. Hutomo and E. R.Sari, "Solving the capacitated vehicle routing problem using genetic algorithms and nearest neighbor in bread distribution", *Mathematical Journal*, vol. 6, no. 2, pp. 52–62, 2017, http://journal.student.uny.ac.id/ojs/index.php/math/article/viewFile/6850/6591

[13] Buhrkal, K., Larsen, A., & Ropke, S., “The waste collection vehicle routing problem with time windows in a city logistics context,” *Procedia - Social and Behavioral Sciences*, vol. 39, pp. 241–254, 2012

[14] B. I. Kim, S.Kim, and S. Sahoo, "Waste collection vehicle routing problem with time windows," *Computers and Operations Research*, vol. 33, no. 12, pp. 3624–3642, 2006, https://doi.org/10.1016/j.cor.2005.02.045

[15] I. Reviladi, “Implementation of floyd warshall and nearest neighbor algorithms in optimizing capacitated vehicle routing problem with time windows (CPRPTW) routes,” *Journal of Mathematics and Science Education*, pp. 1–11, July 2016

[16] A. H. Ismail, N. Hartono, S. Zeybek, and D.T Pham, “Using the bees algorithm to solve combinatorial optimization problems from TSPLib,” *12th International Seminar on Industrial Engineering and Management (12th ISIEM)*, pp. 1–12, 2020

[17] D.T. Pham, A. Ghanbarzadeh, E. Koç, S. Otri, S. Rahim, and M. Zaidi, “The bees algorithm - a novel tool for complex optimization problems,” *Intelligent Production Machines And Systems - 2nd I*Proms Virtual International Conference 3-14 July 2006*, pp. 454–459, 2006.

[18] A. Fenton, “The bees algorithm for the vehicle routing problem,” *Thesis, Dept. Computer Science*, Auckland Univ., Auckland, New Zealand, 2016.

[19] Otri, S., “Improving the bees algorithm for complex optimisation problems,” *Thesis, Manufacturing Engineering Centre*, Cardiff Univ., Cardiff, United Kingdom, 2011.

[20] D.T. Pham and M. Castellani, “The bees algorithm: modelling foraging behaviour to solve continuous optimization problems,” *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, vol. 223, no. 12, pp. 2919–2938, 2009.

[21] H. Al, R. Lubis, and R.B. Frazila, "Application of the concept of vehicle routing problem in the case of urban garbage transportation," *Journal of Civil Engineering*, vol. 23 no. 3, pp. 213–222, 2016, https://doi.org/10.5614/jts.2016.23.3.6

[22] D.T. Pham, M. Castellani, and H. A. Le-Thi, "The bees algorithm: modelling nature to solve complex optimization problems," *Proc. of The 11th International Conference On Manufacturing Research (ICMR2013)*, pp. 481–488, 2013.

[23] D.T. Pham and M. Castellani, "A comparative study of the bees algorithm as a tool for function optimization," *Cogent Engineering*, vol. 2. no. 1, pp. 1–28, 2015, https://doi.org/10.1080/23311916.2015.1091540

[24] N. Irsalinda, "Global optimization problem solving using artificial bee colony algorithms," *Convergence Journal*, vol. 3, no. 2, pp. 9–17, 2013.

[25] K.O. Jones and A. Bouffet, "Comparison of bees algorithm, ant colony optimization and particle swarm optimization for PID controller tuning," *Proceedings of the 9th International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing, CompSysTech'08*, pp. 1–6, 2008