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Application Design for Optimizing The Distribution Of Mineral Water Gallons Using Improved Flower Pollination Algorithm

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Abstract

The distribution of goods is a process of distributing goods from distributors to consumers. Distribution of goods is an important element in the process of running a business. However, sometimes business people do not realize that the selection of distribution routes taken is not optimal so that the shipping costs are too large. Therefore, it is necessary to optimize the distribution of goods to optimize the results of shipping routes and total costs. The goods distribution application is designed in the form of a website using the Improved Flower Pollination Algorithm method with problem constraints from the Capacitated Vehicle Routing Problem. Then a comparison result of total distance obtained from the distributor, the FPA method and the IFPA method will be carried out which will simultaneously calculate the total distribution cost of each. The IFPA method produces a smaller total route distance, so that the minimum total cost is obtained.

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1. Introduction

The human need for mineral water continues to increase so that more and more mineral water producers are growing to meet these needs. With the large number of domestic mineral water industries, the level of competition is getting tougher. This also causes consumer demands for the quality and quantity of a product, one of the efforts to meet the demands of consumer needs is the accuracy of the distribution of an item **1**. Therefore, distribution plays an important role as a connector between the company and its customers. Problems that often occur related to distribution are making decisions about routes that can optimize distance or travel time, then the number of vehicles operating, and other resources. High distribution costs are influenced by the distance between customers, capacity or capacity of the vehicle. The route routes used to distribute products vary widely from point to point. The demand from each customer is also different, plus the route for each vehicle must pay attention to vehicle capacity. Optimal routing can produce the fastest distance or time, thus the use of fuel becomes more efficient **2**. The existence of obstacles in a distribution system, will have an impact on trade aspects. This happens because of the cost factor of distribution which can affect the selling value of the product and the company's profits **3**.

CVRP is a vehicle route determination problem that aims to minimize route distances and minimize transportation costs from a delivery problem. The purpose of CVRP is to find the optimum route for each vehicle and the order of customers served by that vehicle **4**. The limitation of vehicle capacity is a special characteristic in this CVRP model. Currently the route determination in the company is done manually. In one way of delivery, often the number of shops that must be visited is as many as 10 stores. However, it is also impossible for the number of shops to be visited more than that. When the number of shops that must be visited is more than that, the company has difficulty determining the delivery route if it is done manually. Then the optimization of the distribution of goods to the company by using the Improved Flower Pollination Algorithm method is carried out. Then an application was developed for the distribution route of gallons of mineral water to the company, and a comparison was made between the IFPA, FPA, and manual calculations.

Improved Flower Pollination Algorithm (IFPA) is the result of the development of the Flower Pollination Algorithm (FPA), which is one of the optimization algorithms that can be used to find positions with a minimum objective function value and one of the algorithms inspired by nature, which is inspired by the process of pollinating flowers on plants. The Improved Flower Pollination Algorithm method is used, because based on previous studies, it shows that the method is proven to be able to provide optimal results and can solve similar problems. Improved Flower Pollination Algorithm method has better performance than traditional algorithms, genetic algorithms, and others. Pollination can be done by self-pollination or cross-pollination, either through abiotic or biotic processes. From the point of view of biological evolution, the aim of flower pollination is the survival of the most suitable plants and optimal reproduction in terms of quantity and quality of fitness. FPA adopts and formulates the flow behavior of these plants for the solution of the constrained optimization problem **5**. IFPA can solve optimization problems more complex than FPA. In the process, the bad solution will be replaced with a better solution to achieve the optimal value on the objective function. The IFPA algorithm has a high level of convergence and is proven to be more convergent than Swarm Intelligence and Genetic Algorithm **6**.

1. Capacitated Vehicle Routing Problem (CVRP)

Capacitated Vehicle Routing Problem is the most basic form of the Vehicle Routing Problem, which can be seen as a combined formulation of two pre-existing problems, namely the Traveling Salesman Problem (TSP) and the Bin Packing Problem **7**. It was first introduced in 1959 by Dantzig and Ramser through their paper entitled "The Truck Dispatching Problem". The Capacitated Vehicle Routing Problem is an optimization problem to find a route with minimal cost for a number of vehicles with a certain homogeneous capacity, and serve the requests of a number of buyers whose demand quantity is known before the delivery process takes place **8**. Vehicles depart from the central depot to make deliveries and return to the central depot after making deliveries. It is assumed that the distance or cost of travel between all locations is known. Capacitated Vehicle Routing Problem (CVRP) is a VRP where vehicles with limited carrying capacity need to pick up or deliver goods at various locations.

Capacitated Vehicle Routing Problem (CVRP) can be modeled as follows **9**:

1. Notation

i, j: index of customers; i = 1…n, j = 1..n; 0 as depot

k: index of the vehicle: k = 1…m

cij: distance from customer i and j

in: order from customer i

Q: total vehicle capacity

1. Decision Variables

(1)

(2)

1. Purpose Function :

(To minimize total travel distance)

1. Function:
   1. It is defined that the number of vehicles arriving and departing from the same depot.
   2. It is defined that each customer is only visited exactly once.
   3. It is defined that the available vehicles can be used.
   4. Relationship between two decision variables (x, y)
   5. It is defined that the vehicle capacity is not exceeded.
2. Flower Pollination Algorithm (FPA)

Flower Pollination Algorithm is an algorithm invented by **10**, but the application of this algorithm is still little used in optimization problems. Flowers are used for reproduction in their species through the process of pollination **11**. The Flower Pollination algorithm is very fast in computing and is the development of an intelligent algorithm. Flower Pollination Algorithm is a metaheuristic algorithm that can replace classical methods related to optimization. Some of the phenomena of flower pollination are as follows:

1. Cross pollination occurs when pollen falls from flowers from different plants. This pollination follows the rules of the Levy distribution by jumping or flying long distances. This is known as the global pollination process.
2. Self-pollination occurs when pollen falls from the same flower or other flowers of the same plant. This process is called local pollination.
3. Flower constancy is a collection of pollinators and flower types. This is an improvement of the flower pollination process.
4. Local pollination and global pollination are controlled by a value between 0 to 1 which is called the switch probability.

The two steps used in the Flower Pollination Algorithm are as follows:

1. Local Pollination

Local pollination is seen as abiotic pollination and self-pollination. Abiotic pollination means the transfer of pollen to the stigma which does not require pollinating organisms, but only requires the help of wind and diffusion of water in the soil. On the other hand, self-pollination occurs if the pollen falls from different flowers but comes from the same plant. The local pollination stage is carried out using the second and third approaches.

Mathematically it can be described as follows:

(1)

Where,

: i (flower), t (iteration)

: i (flowers), t+1 (iteration)

: Real random number that is uniformly distributed between 0 and 1

j, k : The index of two different flowers that are still in the same plant

1. Global Pollination

Global pollination is seen as biotic pollination and cross pollination. Biotic pollination means that the transfer of pollen to the stigma is carried out by pollinating organisms such as bees, bats, birds and flies. While cross-pollination occurs when pollen falls from flowers from different plants, so that in the global pollination process, pollinating organisms can fly long distances and carry out Livy Flights based on Livy distribution️. This process can be displayed mathematically as follows.

(2)

Where,

: i (flowers), t (iterations)

: i (flowers), t+1 (iteration)

: Stepsize or flight distance based on the Lévy distribution with > 0

: Parameter at interval [1,2]

: Best flower elements in iteration t

1. Improved Flower Pollination Algorithm (IFPA)

Flower Pollination Algorithm found to work efficiently because global and local search are controlled by switching probabilities. Flower Pollination Algorithm has the advantage of solving complex problems because these two processes occur randomly one by one, so they have various solutions. However, FPA also has some drawbacks such as slow convergence rate and poor precision, based on the selected switching probability value sometimes causes FPA to lose direction and move away from the best solution **12**. Based on the shortcomings of FPA, the Improved Flower Pollination Algorithm introduced a random jump perturbation operator in the global pollination phase which increases the ability of FPA global search. Balancing the degree of global pollination is very important. Therefore, a random jump perturbation is made, which makes the particle random jump to the specified point, and controls whether the random jump results to the specified point or further away from the point. The randomness of global pollination is increased, and it is possible that local pollination is also enhanced. It is limited to only one-step jumps to prevent the convergence from being too slow **12**.

The formula for enhanced global pollination is as follows:

(1)

Where,

: i (flowers), t (iterations)

: i (flowers), t+1 (iteration)

: Stepsize or flight distance based on the Lévy distribution with > 0

: Parameter at interval [1,2]

: Best flower elements in iteration t

: Random integer [-1, 0, 1]

: Random pollen

Switching probability controls the ratio of global pollination and local pollination. When the switching probability is greater, global pollination can be strengthened, but local pollination weakens. When the switching probability is smaller, the situation is reversed. For switching probability, you can experiment regularly and get the best results. The switching probability commonly used is 0.25; 0.5; 0.8.

1. Improved Flower Pollination Algorithm (IFPA) for Capacitated Vehicle Routing Problem (CVRP)

Calculations were made using the Improved Flower Pollination Algorithm method for the Capacitated Vehicle Routing Problem. Here are the steps of the Improved Flower Pollination Algorithm for CVRP:

1. Determine the objective function f(𝑥), 𝑥 = (𝑥1, 𝑥2, …, 𝑥𝑛)𝑇 with the initialization parameters to be used.
2. Determine the initial population of flowers by doing random at intervals [0, 1] a number of agents and as many as the number of flowers.
3. Determine the destination function (total distance) and the initial route by sorting the agent value from the initial population value of flowers and is carried out for each flower.
4. Determine the best solution (️\*) temporary.
5. Determine the value of pi by doing random at intervals (0, 1) as many as the number of flowers.
6. If pi < p, then calculate the new flowers by global pollination. If pi > p, then calculate the new flowers with local pollination.
7. Obtaining new flowers from the results of calculations with global pollination and or local pollination.
8. Determine the new route and the objective function of the pollination results.
9. Choose the best flower that has the smallest objective function in the new iteration.
10. Repeat the calculation from step 5 to step 9 according to the number of iterations.
11. Determine the route results by comparing the results of the objective function of the new iteration with the previous iteration to get the best results.
12. Simulation Result 1 and Discussion

In the experimental simulation of finding the best route and calculating the total cost of the distribution, the program will run an experimental simulation, where the optimal route will be searched for the distribution along with the total cost using the IFPA method, FPA method, and manual calculations used by the company. The total agent sample data used is 30 original agent data from the company. A sample of 12 recipient agents was used and the sample was randomly selected by the authors from a total of 30 agents available in the total application sample data. At the end of the simulation, the author will compare the results between the IFPA method, the FPA method and the company's manual calculation, by comparing the results of the objective function. For searching and calculating the IFPA and FPA methods, the authors will use the main parameters in Table 1. The data used for calculating the total distribution costs of the IFPA and FPA methods will use the details in Table 2 and Table 3.

Table 1: Main Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Simulation | Stepsize (y) | λ | Switch Probability (p) | Amount of Flowers | Iteration |
| 1 | 0.2 | 1.5 | 0.5 | 10 | 20 |

Table 2: Details of Fixed Cost Calculation of Total Simulation Cost

|  |  |  |
| --- | --- | --- |
|  | Driver Salary | Vehicle Maintenance Fee |
| Fixed Cost | IDR 100,000.00 | IDR 10,000.00 |
|  |  |  |

Table 3: Details of Variable Cost Calculation of Total Simulation Cost

|  |  |  |
| --- | --- | --- |
|  | Pertalite Fuel | Gran Max Pick-up Fuel Ratio |
| Variable Cost | Rp7,650.00/liter | 11.6 km/liter |
|  |  |  |

Table 4: Result of manual calculation of simulation 1

|  |  |  |
| --- | --- | --- |
| Running | Total Distance | Total cost |
| 1 | 24,398 km | IDR 185,000.00 |
| 2 | 27,873 km | IDR 185,000.00 |
| 3 | 28,361 km | IDR 185,000.00 |

Based on Table 2, all distribution costs incurred by the company have been determined without considering the distance traveled. So the company does not have a variable cost as a parameter to calculate the total cost of distribution.Then,completion of simulation 1 with the FPA method, carried out with a number of trials running the application 3 times. Based on the parameters that have been determined in Table 1. There is the best flowers and the best route for each iteration. The following are the results of experiments with FPA calculations in Table 5 below.

Table 5: Calculation results using the FPA simulation method 1

|  |  |  |  |
| --- | --- | --- | --- |
| Running | x\_best, iteration | Total distance | Total cost |
| 1 | Flower 4, Iteration 20 | 21,131 km | Rp123,936.00 |
| 2 | Flower 2, Iteration 10 | 20.529 km | Rp123,539,00 |
| 3 | flower 2,  Iteration 13. | 22.161 km | Rp124,615.00 |

At the completion of simulation 1 with calculations using the IFPA method, carried out with a number of trials running the application 3 times. Based on the parameters that have been determined in Table 1. There is the best flowers and the best route for each iteration. The following are the results of experiments with IFPA calculations in Table 6 below.

Table 6: Calculation results using the IFPA simulation method 1

|  |  |  |  |
| --- | --- | --- | --- |
| Running | x\_best, iteration | Total distance | Total cost |
| 1 | Flower 10, Iteration 18 | 20,157 km | Rp123,293.00 |
| 2 | Flower 10, Iteration 2 | 19,356 km | Rp122,765,00 |
| 3 | Flower 10,  Iteration 20. | 20,753 km | Rp123,568.00 |

The best results for manual calculations are the results of running 1 with a total distance of 24,398 km at a cost of Rp. 185,000.00. Then the best results in simulation 2 for the FPA method are the results of running 2 with a total distance of 20,529 km at a cost of Rp123,539.00. So, the best result in simulation 2 is to use the IFPA method, namely the results of running 2 with a total distance of 19,356 km at a cost of Rp122,765,00. An error will be calculated in the calculation of the total distance generated by the three IFPA runs using the Mean Absolute Percentage Error (MAPE) shown in Table 4.19.

Table 7 : Mean Absolute Error IFPA Simulation 1

|  |  |  |  |
| --- | --- | --- | --- |
| Running | Total distance google maps ( | Total application distance() |  |
| 1 | 21 km | 20,157 km | 0.0401 |
| 2 | 20 km | 19,356 km | 0.0322 |
| 3 | 21.5 km | 20,753 km | 0.0347 |
| Total | | | 0.107 |

Mean Absolute Percentage Error (MAPE) =

In the comparison of results, the author will compare the results of the solutions obtained between the IFPA, FPA solutions and the company's manual calculations. The graph of the comparison of the total distance and the total cost generated between running 1, 2, and 3 with the IFPA method, FPA method, and manual calculations in simulation 1 can be seen in Figure 1 and Figure 2.

Chart, bar chart

Description automatically generated

Chart, bar chart

Description automatically generatedFigure 1: Comparison of Total Distance with IFPA Method, FPA Method and Company Manual Calculation

Fig 2: Comparison of Total Costs with IFPA Method and Company Manual Calculation

Table 8 below is a comparison of the results between the IFPA method, the FPA method, and manual calculations, the data in Table 8 is taken through the average of the results of running applications 1, 2, and 3.

Table 8: Comparison of Simulation Results 1

|  |  |  |
| --- | --- | --- |
| Search Type | Total Distance (Km) | Total Cost (Rp) |
| Company | 26,877 km | IDR 185,000.00 |
| Flower Pollination Algorithm (FPA) | 21,274 km | Rp124,030.00 |
| Improved Flower Pollination Algorithm (IFPA) | 20,089 km | Rp123,209,00 |

If the total distance generated between the IFPA method, the FPA method and the Company's manual calculation is compared, then the results obtained by IFPA have better results, with a total distance of 20.089 km. The difference with the total distance from the FPA method is 1,158 km shorter, while the difference with the total distance from the Company's route is 6,788 km shorter. In terms of the total distance, the quality of the solution obtained by the FPA algorithm is indeed lower than that of the IFPA. However, the quality of the FPA results still has better results compared to the total distance of the Company's data. If the total costs generated between IFPA, FPA and the Company's manual search are compared, then the results obtained by IFPA have a better result, which is Rp123,209.00. The total cost is directly proportional to the total distance, the shorter the total distance, the lower the total cost. Because the total distance from the path solution results has an effect on the value of the variable cost, namely the cost of spending gasoline. The difference with the total cost of the FPA method is Rp.821.00 and the Company's manual calculation is Rp.61.791.00. The total cost of the FPA algorithm solution is indeed higher than IFPA's, but the results of the FPA algorithm solution are still better than the results of the Company's data. 00 and the Company's manual calculation is Rp61,791.00. The total cost of the FPA algorithm solution is indeed higher than IFPA's, but the results of the FPA algorithm solution are still better than the results of the Company's data. 00 and the Company's manual calculation is Rp61,791.00. The total cost of the FPA algorithm solution is indeed higher than IFPA's, but the results of the FPA algorithm solution are still better than the results of the Company's data.

In the FPA method there are several shortcomings such as a slow convergence rate and poor precision, based on the selected switching probability value sometimes causes FPA to lose direction and move away from the best solution. IFPA processing speed from the beginning of the algorithm to produce a final solution depends on the parameters that have been determined at the beginning. The greater the value specified, the application will take longer to produce the final solution, but this can also affect the quality of the final solution produced by IFPA, because the more experiments that can be carried out, the more likely the best solution will be on the problem set can be found.

1. Simulation Result 2 and Discussion

In the second simulation, 10 samples of recipient agents were used and the samples were taken randomly from a total of 30 agents available in the total application sample data. For simulation 3, the authors make comparisons using parameters. The parameters to be compared in simulation 3 are switch probability, number of flowers and maximum iterations. The maximum iterations used are 10, 15 and 20. The switch probabilities used are 0.25, 0.5, and 0.8. The number of flowers used is 5 and 10. Stepsize used is 0.2 and used is 1.5. The results obtained can be seen in Table 1.

Table 1: Simulation Experiment Results 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Maximum Iterations | Number of Flower | *Switch Probability*(p) | | |
| 0.25 | 0.50 | 0.80 |
| 10 | 5 | 19,213 | 19.522 | 20,328 |
| 10 | 18,716 | 19.069 | 20,179 |
| 15 | 5 | 18,134 | 18,241 | 19,444 |
| 10 | 18,106 | 17,776 | 19.023 |
| 20 | 5 | 17,540 | 17,129 | 18,864 |
| 10 | 17,452 | 16,252 | 18,374 |

From the results of simulation 2 shows that the best objective function of the 10 agents is 16,252 Km. If seen from Table 1, it can be concluded that the higher the number of flowers, the better the objective quality. The higher the number of iterations, the better the quality of the objective function. While the greater the switch probability, it does not guarantee to produce a better-quality solution. It is necessary to adjust the value of the probability switch in order to get the best results. The following is a comparative graph of the total route distance generated for each switch probability 0.25, 0.5, and 0.8 using the IFPA method in simulation 2 with a maximum iteration of 10, 15, and 20. The graph can be seen in Figure 1, Figure 2, and Figure 3.

Chart, bar chart

Description automatically generated

Figure 1: Graph of objective function with maximum iteration is 10

Chart, bar chart

Description automatically generated

Chart, bar chart

Description automatically generatedFigure 2: Graph of objective function with maximum iteration is 15

Figure 3: The graph of the objective function with the maximum iteration is 20­­

From the graph of the objective function for 10 iterations, it shows that the smallest total distance is18,716 km with the number of flowers is 10 and the switch probability is 0.25. The results of the graph of the objective function for 15 iterations show that the smallest total distance is 17.776 km with the number of flowers is 10 and the switch probability is 0.5. The results of the graph of the objective function for 20 iterations show that the smallest total distance is 16,252 km with the number of flowers is 10 and the switch probability is 0.5.

1. Conclusion

Based on the discussion in this study, optimization using the Improved Flower Pollination Algorithm (IFPA) method in solving the Capacitated Vehicle Routing Problem obtained more optimal results for the total distance and total cost compared to the Flower Pollination Algorithm (FPA) method and the company's manual calculations. The development of the application for the distribution route for gallons of mineral water is carried out using the Improved Flower Pollination Algorithm (IFPA) and PHP, CSS, Javascript programming languages. The search for the shortest route was carried out 3 times in simulation using a problem set based on the actual agent data in the company.

Using different parameters shows the results of different values of the objective function. he higher the number of flowers and the number of iterations affect the quality of the value of the resulting objective function. The higher the number of flowers and the maximum number of iterations, the better to produce the quality of the total distance. The total distance is directly proportional to the total cost, if the total distance produced is small, the total cost will be low. As for the switch probability, periodic experiments are carried out in order to get the best objective function.

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