



Heterogeneous Vehicle Routing Problem with Fixed Cost using Vehicles with Genetic Algorithms

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Abstract. Vehicle routing problem is NP-Complete problem categories. Given the time complexity of these issues is higher degree of polynomials, by increasing the size of the exact solution problem increase with significant rate. The reason for the approximate solution of such issues and innovative creative solutions has been proposed. Vehicle routing problem with heterogeneous fleet regarding fixed cost of using a vehicle is examined. The problem is presented. The mathematical model of the problem, due to the nature of the problem is NP-Complete, innovative genetic algorithm for the problem-informed has been developed. Then for several examples of genetic algorithm, compared with the solution and the solution algorithm and answer exactly (by Lingo software) have been studied. The results show that the genetic algorithm, the performance is acceptable and in reasonable time give an answer with negligible error.

Keywords: Heterogeneous vehicle routing problem, using fixed fee vehicle, GA

1. INTRODUCTION

The vehicle routing problem is one of the most important industries in the world today due to real applications in industrial issues are taken into consideration. The basic problem of vehicle routing problem is vehicle routing problem with capacity constraints. The problem of multiple vehicles simultaneously from the storage depot to start moving, and after meeting the demand nodes (clients) will return to the warehouse, first, each node only if the demand is met by one of these vehicles secondly, every vehicle is not loaded more than its capacity along the way. It is appropriate to use about 5 to 20 percent of the total cost of transportation. The main applications of this problem can be garbage collected, distributing food and medicine, routing services, schools, and staff, distributing mail, ship route planning, delivering newspapers, robot motion is noted on the factory floor. Various purposes have been considered for this problem is that some of them are:

- Minimizing the route traveled by all vehicles (or the total cost)
- Minimizing the total number of vehicles
- Minimizing the function of the time delay or earliness service vehicles to customers

Depending on the problem, the problem of routing vehicles may have different restrictions. Some of these limitations are: the number of service centers, limited or unlimited capacity of the vehicle, definite or probable demand, presence or absence of restrictions along the way. VRP problem known issues integer that those problems are NP-Complete. And thus a higher degree of polynomial time complexity of this problem is solved by increasing the size of the problem increases exponentially [1].

Accordingly, in recent studies to solve this problem by approximation algorithms, special attention has been innovative.

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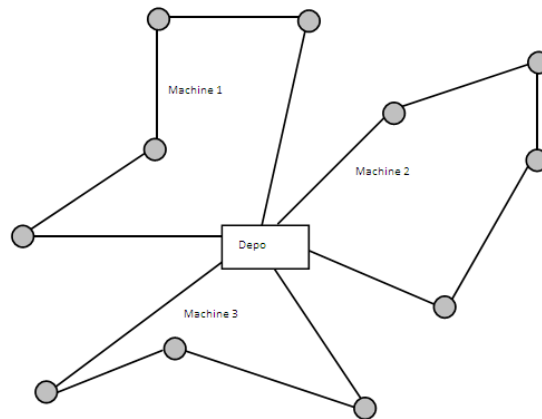


Figure 1. An example of a problem-solving vehicle routing, it is observable.

In the case of a heterogeneous fleet, the capacity of the vehicle will be different. Much research has been done in the 1960s and 1970s for solving VRP focused on exact methods some of which include dynamic programming and conversion to the TSP and VRP formulation of the index [1 and 2] For the foregoing, due to its NP-Complete, innovative algorithms are presented. Such as savings in 1964 by Clarke and Wright algorithm for solving the VRP with limited capacity [3] The way to create routes includes a center and a point in another application, started and at each step according to the highest savings possible by combining the two routes [4 and 5] Arc routing algorithm named by Stern and Dror about routing algorithms has been proposed [6] During the two-phase algorithm calculates optimal routes and restrictions with respect to the demand centers are classified. Golden and Wang algorithm called routing algorithm for Arcuate developed economies [7] The algorithm demand centers are located in separate directions considering the limitations of the test compound may pathways review and the way that provides the greatest savings, combined with each other. Also several innovative algorithms for solving VRP has been used in the literature the ant colony algorithm, including [8], algorithms birds Tabu search algorithm and gradual refrigeration noted [9 and 10].

2. DEFINE THE PROBLEM

The VRP problem studied in this paper are the assumptions we demand that the n nodes (cities). All requests must be met. Storage depot is located at zero nodes. From any node to another in a straight line is the path has its own arrival time and travel costs. Limited number of fleet vehicles and engines are heterogeneous, meaning that each has a different capacity [8]. Demand nodes are certain pre-specified all applications that provide a car during your trip should not exceed the capacity of the machine. Parameters and variables of the model are as follows:

n The number of demand points (customers)

q_i The demand for the i -th node

c_{ij} The cost of direct travel from node i to node j

K Total number of fleet vehicles

Q_k K my vehicle capacity

w_k The use of fixed cost k my vehicle.

x_{ijk} Variable zero and one, if the node i to node j directly by machine k , the direction, the value is 1.

y_k Variable zero and one that should be used if the machine k 1 and is zero otherwise.

Mathematical models:

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$$\min Z = \sum_{i=0}^n \sum_{j=1}^n \sum_{k=1}^K c_{ij} x_{ijk} + \sum_{k=1}^K w_k y_k \quad (1)$$

The first part of the objective function is the total cost of the trip, and the total fixed costs of car use.

$$\sum_{\substack{i=1 \\ i \neq j}}^n \sum_{k=1}^K x_{ijk} = 1, j=1, \dots, n \quad (2)$$

$$\sum_{\substack{i=1 \\ i \neq j}}^n \sum_{k=1}^K x_{jik} = 1, j=1, \dots, n \quad (3)$$

$$\sum_{i=1}^n x_{0ik} \leq 1, k=1, \dots, K \quad (4)$$

$$\sum_{i=1}^n x_{i0k} \leq 1, k=1, \dots, K \quad (5)$$

$$\sum_{i=0}^n x_{ijk} - \sum_{i=0}^n x_{jik} = 0, j=0, \dots, n, k=1, \dots, K \quad (6)$$

$$\sum_{i=0}^n \sum_{\substack{j=0 \\ i \neq j}}^n q_i x_{ijk} \leq Q_k, k=1, \dots, K \quad (7)$$

$$\sum_{h=0}^n x_{0hk} \geq x_{ijk}, i, j=1, \dots, n, k=1, \dots, K \quad (8)$$

$$y_k \geq x_{0ik}, i=1, \dots, n, k=1, \dots, K \quad (9)$$

$$x_{ijk}, y_k \in \{0, 1\} \quad (10)$$

Constraints 2 and 3 show that all requests must meet the entire demand of each customer and should only be provided by a car. Constraints 4 and 5 shows the limits of the car start to move from depot to depot back after the completion of service. 6 restrictions, limitations balance is the total inflow to a node means that the node is equal to the total output current. Constraints 7 show that the applications that meet the constraints of a car should not exceed the capacity of the machine. Constraints 8 are tours that include a depot, remove it. Constraints 9 exit the car depot and variable limits between zero and one related to the cost of using it. If you move the car depot, right relationship is increased from zero to 9 and therefore left to take the value 1 and the corresponding cost in terms of the objective function. 1 presents a genetic algorithm to solve the given problem due to the nature of the problem is NP-Complete VRP, in this section Beck innovative algorithm is based on genetic algorithms for the VRP is developed innovative Genetic algorithm is one of the most innovative algorithms that the first time in 1975 by John Holland and others were Abtda [11] Genetic algorithms, evolutionary and population-based algorithms to

handle the large combinatorial optimization problems have gained great success. In this method, an initial population is generated answers and the elegance of the solution is calculated [10] Then, according to their fitness value, the answer to the parents of the next generation is selected. The next generation of crossover and mutation operations is performed using the replaces the previous generation and the new generation to achieve mastery condition (typically a certain number of generations) continues the basic steps of genetic algorithm for VRP problem is as follows:

Display results:

Each chromosome represents an answer. V_n represents the number of genes per chromosome in answer. Array v represents the number of machines that have been used. Naturally, the size of the array v is equal to v_n Stract tour of the track is used for each of the machines. Node 1 is indicated depot. For example, suppose that the number of nodes including the depot is 7 and the total number of fleet vehicles is equal to 6. Suppose the answer is as follows:

```
sol =
    vn: 2
    v: [1 4]
    tour: {[1 2 3 6 1] [1 5 4 7 1]}
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The machine is used in the above answer. The first car is car 1, second cars is 4 Cars. 1 car out of the depot meets the demands of customers, 2, 3, 6, and returned to the depot. 4 cars after leaving the depot meet the demands of customers, 5, 4, 7 and returned to the depot.

3. THE INITIAL POPULATION IS GENERATED

The initial population of 100 is considered. At the beginning of the algorithm randomly generated 100 responses. The answer basic is vehicle capacity constraints. This trend may be that the first step is to choose one of the car accidents and net realizable (according to the machine capacity constraints) is chosen randomly. The tour starts from the depot and ends at the depot. Then if there is unmet demand, another car accident (the machines that have not yet used) is selected the car will also be randomly selected for the tour. This tour is made random nodes that have not yet met. If all the cars have been used and still meet demand, the last machine capacity constraints are not respected and supply demand nodes are added to the tour last car return. Naturally, the answers are endless tour; the refining process solutions according to their fitness of the population will be deleted.

Calculate the fitness Answers

The fitness of each solution with respect to the objective function value corresponding to the solution is calculated. Given that it is possible at intersections or mutations (or in the production of the starting solution) is an integral response and capacity constraints are violated, the penalty for exceeding the machine capacity constraints are added to the objective function. This penalty makes it inefficient and impractical solutions at refining the solutions to be removed from the population. With respect to the objective function value of the solutions, using a roulette wheel may be attributed to each answer. It is likely, the answer is likely to emerge as a parent, is at the crossroads. The total population of probabilities is equal to 1.

Fill the pool coupling

The child's parents to produce solutions have been selected and are coupled to the pool. The parents of two children per couple will be produced. Parent's even number is equal to half of the original population. Parents chosen according to the probability of selection (fitness) calculated in the previous step for each answer is occurred.

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Parents who have greater fitness are more likely to be chosen. Selection process so that the cumulative probability values are arranged in descending order is calculated and then every time a parent is selected, a random number between zero and one is generated and the parent who does his cumulative non-random value is less than is selected as a parent.

Intersection operator

At this stage, we combine the parent of two children per couple we produced. Thus, after this stage, the initial population, we will have a new child (half of the number of couples who have a parent of two children per couple is produced). At the intersection of the tour have used machines that only one parent, both children are copied (with car) and the car used in both child. The tours have been used in both parents, the accident only one child (with car) to be copied. In the next step if the node application on more than one tour a child be met, the accident remains only on one of the tours and the rest are deleted. After this process may persist tours leave from the depot and without providing for any kind of node returned to the depot. The tours are also used with the machine is deleted from children.

Mutation

After completion of the intersection, the children produced mutation operator is implemented. Each of the children is faced with the probability of 0.1 mutations. The mutation, or the crash of a tour of the answer is selected and then a tour of each node and the node where instead the tour. Or (if you have unused machine), one of the tours will be selected at random and the corresponding car tour of unused machines, replaced. If both answers are permitted to work (replacement of two nodes in two stages, replacing one of the machines used by the machine unused) A true random number between 1 and 2 is selected. If the value is 1, the first mutation occurs and if the random number is equal to 2, the second jump is executed. If the answer is just a tour, it will be the first leap, the two nodes are selected from the tour and their sequences are replaced. After the jump may be due to capacity constraints answer machine, in which case the penalty is unlikely is the objective function has a very low fitness and the outcome is likely to be negligible as the parents of the next generation of clean and with high probability in the refinement of solutions, the population will be deleted.

The refining process answers

After the crossing, the population becomes doubles. The refining process solutions, the suitability of each of the solutions are calculated according to fitness remains only half of the rest of the population will be deleted. That is the process of calculating the fitness and propriety of the population according to their decreasing order and then left upper half and the lower half removed (Laporte, 1992). The process is exactly the number of initial population, we have a new population and the population will replace the previous generation.

Stop condition algorithm

An upper limit for the number of generations that we have considered is equal to 100. If you've reached the 100 generation algorithm stops. But it may be generations before my 100, to reach convergence. In the event corresponding to a convergence of all answers will be answered. The convergence of the algorithm is stopped. Until none of these conditions not fulfilled and the algorithm continues.

3.1. Numerical results

6. To evaluate the performance of genetic algorithms, for example, the small size of 8 and a comparison between the Lingo and genetics has been done on these examples. Examples of these

parameters are made uniform discrete distribution. Lingo 8 and Labtop to run MATLAB 2013 Dell Inspiron 3 core operating system windows 7, 32 bit is used. The results are listed in Table 1.

Table 1. The results of genetic algorithms and lingo.

Name of problem	Number of nodes	Number of Cars	Optimum by Lingo	Lingo execution time (seconds)	Answer Genetics	Genetic execution time (seconds)	Genetic errors (percent)
n5	5	3	4348	0	4348	0.58	0
n6	6	3	7489	2	7489	0.96	0
n7	7	4	7230	6	7230	1.25	0
n8	8	4	8141	102	8141	1.52	0
n9	9	5	7870	161	7927	1.84	0.007242694
n10	10	5	11123	307	11200	1.86	0.006922593
n11	11	6	11120	1922	11287	2.87	0.015017986
n12	12	6	11138	2136	11344	3.73	0.018495242

The error is calculated as follows:

$$err = \frac{\text{genetic result} - \text{optimum}}{\text{optimum}}$$

Is the number of nodes including the depot? For each problem a genetic algorithm was run 10 times and the results are listed in Table. In Figure 2 the graph of the function obtained by Lingo and sees genetic please.

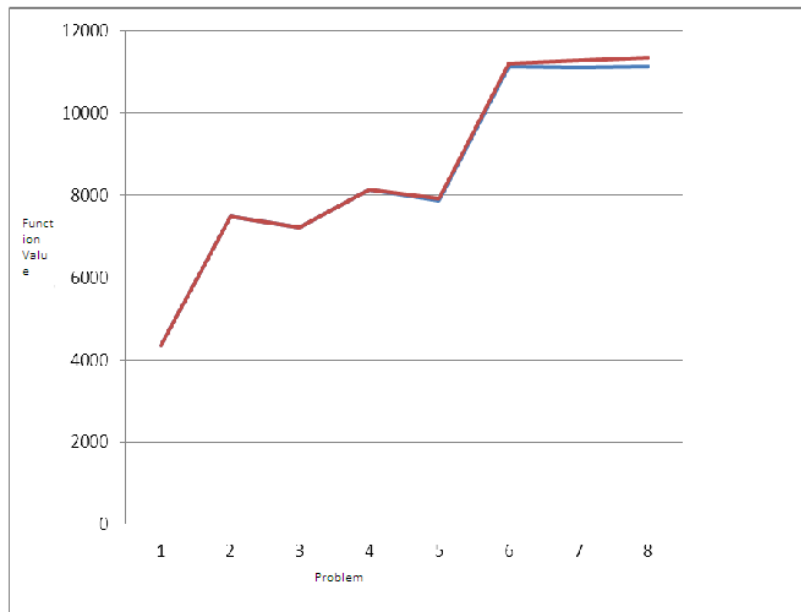


Figure 2. The graph of the function obtained by Lingo and sees genetic.

It can be seen that the error is zero issues with less size and drop the matches are in the last issue of error is minimal.

The diagram in Figure 3 Time resolved by Lingo and genetics can see.

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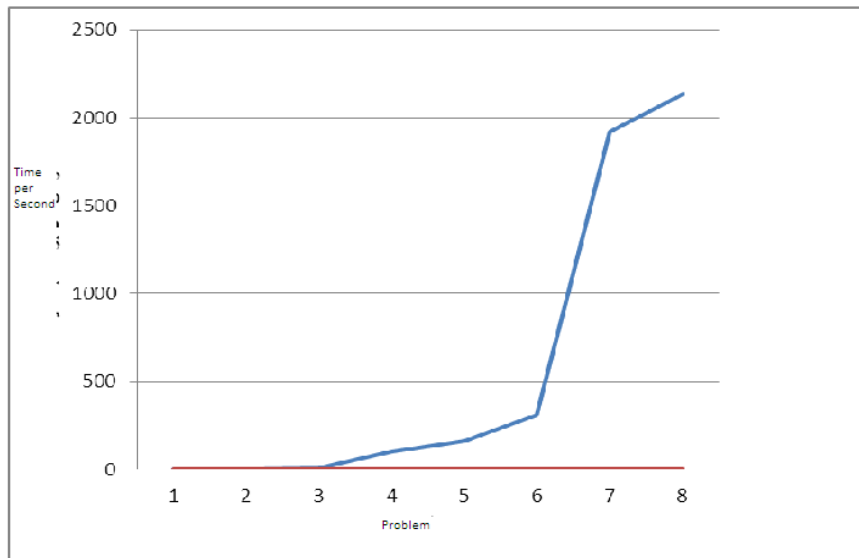


Figure 3. Time resolved by Lingo and genetics.

As can be seen, by increasing the scale of the problem, Lingo has dramatically increased since the implementation of the characteristics of the problem is NP-Complete. The complexity of these issues is polynomials of degree higher. So it is effective to solve large scale problems, the exact solution is to try and better heuristic or meta-heuristic algorithms use acceptable and near optimal solution in a reasonable time to lose. According to the model presented in this paper, we design a genetic algorithm. As you can see the problem of genetically solution increases linearly with very little slopes. Three questions designed with larger dimensions and were solved by genetic algorithm [5].

View questions and answers obtained in Table 2. It is observed.

Table 2. Questions and answers.

Name of problem	Number of nodes	Number of Cars	Best Answer genetics in ten runs	Number of machines used in the solution	Genetic execution time (seconds)
n20	20	8	20559	5	8.89
n25	25	10	28686	7	11.47
n30	30	12	32028	8	16.72

As is clear from the above table, the increasing scale of the problem, time complexity has little genetic and it takes hours to solve issues like with Lingo.

4. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The problem of heterogeneous routing vehicles with regard to the fixed cost using vehicles described. The mathematical model problem presented and then a meta-heuristic algorithm is based on genetic algorithm for the design problem. Computational results show that the genetic algorithm presented in this paper has good performance and within an acceptable time gives acceptable results. For future developments, it can be of service to some customers only for a certain subset of that fleet. These restrictions can be applied to the nodes and the arcs. Because in the real world may some clients have some way or the ability to pass or service by all types of vehicles. One can also assume that the number Depo more than one. The number of caches can be proved that in this case the number of nodes are the first to be elected as a depot. Or the number of decision variables can be Depo. In this case, each node will have the ability depot to depot

node itself without the use of the vehicle will meet demand. In this case, in addition to problem routing problem are presented depot housing will considering the cost of construction depot and transport costs and use machines have the best scenario. Innovative techniques also can be VRP problem with regard to the use of fixed-cost vehicles, and evaluate the performance of the solution and analyzed.

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