Asian Research Journal of Mathematics

18(11): 148-161, 2022; Article no.ARJOM.88541
ISSN: 2456-477X

A Hybrid Optimization Model for Vehicle Routing Problem, a Case Study at Zoomlion Ghana Limited, Shama District

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JK, HO and JA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors managed the analysis, proof read the manuscript and approved the final manuscript.

Article Information

DOI: 10.9734/ARJOM/2022/v18i1130432

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/88541

Original Research Article

Received 05 May 2022
Accepted 02 July 2022
Published 21 September 2022

Abstract

The aim of this study was to develop a hybrid optimization model for solving the routing problem identified at Zoomlion Ghana Limited in Shama district in the Western Region of Ghana. Two main optimization models were considered: Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). A hybrid algorithm was developed from the two by merging crossover and mutation operators of GA with PSO. A sample of 20 breakpoints was run through 10,000 iterations for all the models and the results of the proposed hybrid model was compared with PSO and GA separately. The optimal results of PSO, GA and the proposed models are 1160.6km, 1190.3km and 1132.3km respectively. The proposed model's results were also compared with other hybrid models to test the robustness of the new model. This result was achieved because the new model eliminates the low convergence rate in PSO and also prevents it from easily falling into local optimum in high-dimensional space and the inclusion of crossover and mutation operators of GA improves the diversity of the iterations. After the iterations, PSO reduced a field distance of 1700 km to 1160.6 km within 780.4098 seconds. GA on the other hand reduced the same field distance of 1700 km to 1190.3km within 397.3308 seconds. The proposed hybrid model reduced the same field distance from 1700 km to 1132.3 km within 550.2527 seconds. This indicates that the proposed hybrid model performed better than PSO and GA separately. A performance test between the proposed hybrid model and other hybrid models showed that merging crossover and mutation operators into PSO gives a better optimal result. MATLAB was used for the iterations.

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Keywords: Vehicle routing problem; particle swarm optimization; genetic algorithm; crossover; mutation; optimization; Zoomlion Ghana Limited.

1 Introduction

In our world of work, optimization plays an important role in every aspect of production and service. In the transport, shipping and delivery sectors, proper routing plan ensures that customer satisfaction is improved, routing cost is drastically reduced, less time is spent on the road resulting in reduced cost of fueling. Resources for production are scarce but there is a need to achieve the best from the limited resources. This requires the implementation of optimization techniques to rationalize the available resources so as to achieve the optimal best. Mathematically, optimization requires the selection of the best elements (with regards to some criteria) from some set of available alternatives. That is, maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function [1].

In our day-to-day activities, we benefit from Optimization and its application almost all the time. It is used by shipping and delivery companies to ensure products or packages get to their clients within the stipulated time [2], optimization algorithms are employed in GPS systems manufacturing as well as airline reservation systems. Many scientific, social, economic and engineering problems have parameters that must be adjusted to produce a more desirable outcome. It is evident that there will always be a need for a better and more reliable Optimization model to solve our daily challenges, since the complexity of the problems that we attempt to solve is ever increasing [3].

Waste management remains a major global problem competing with other social and economic interventions for a place in every country's budget. Africa is spending huge sums of money to manage all forms of waste in order to maintain sanitation which Ghana is not exempted [4]. In most of the urban cities in Ghana, there is widespread dumping of wastes in water bodies and uncontrolled dumping sites leading to low sanitation in the country [5], urbanization is the root cause of increase in waste production in urban areas than in rural areas [5], urbanization in Africa is on the rise and this trend is expected to continue in future. The higher the population in a particular geographical area, the more waste they are likely to generate on daily basis. There is a widening gap between the rate of waste production and the interventions to manage these wastes in many African countries [6]. In Ghana, there are inadequate waste management policies, legislation and practices to solve this problem. It will require major investments, planning, education and access to technical know-how in order for this problem to be solved [5].

In Ghana, like many other African countries, the rate at which waste is generated in the urban areas is very alarming. Government is providing financial and technical support to enhance the services of waste management companies like Zoomlion Ghana Limited, FG Plastic Recycling Ghana Limited, TrashSmart, etc. in order to maintain sanity in the country but the situation still remains a challenge due to some pertinent problems faced by these companies [7], the proportion of populations living in urban areas in Africa is expected to increase from 40% in 2010 to about 57% in 2050 which definitely implies that the generation of waste will continue to increase in these areas. In respect of that, there is a need for a proper waste management plan for urban areas in order to curb the situation.

As part of the Government's 'Keep Ghana Clean' agenda, many of these waste management companies are resourced to enable them do their work efficiently. According to Seth et al. (2014), the number of waste management companies in Ghana is inadequate because it does not meet the demand of Ghanaians. Accra and Kumasi which are the largest cities in Ghana are estimated to generate about four thousand (4,000) tons of waste daily [8]. Till today, the rate of waste generation in Ghana stands at 0.47 kg per person per day, which translates into about 12,710 tons of waste per day on average [9]. In places where the government provides waste collection services, only 88% of the total waste is collected. Waste collection service is limited in some areas of the city due to poor road network [4], only 40% of the households within Shama District own waste collection bins

Routing plays an important role in ensuring that goods and services get to the end users after production. It is a link between manufacturing and consumption. Route Optimization is the process of finding the most cost-efficient set of routes for a set of stops or designations. In finding the shortest path between the starting point and the destination, so many factors such as the number of clients to be served, the demand of each client, the locations of these clients, the intensity of traffic on the route, etc. determines the optimality of the routing process. Waste management companies have commercial and domestic waste bins scattered across a geographical area and with a defined number of garbage trucks, they are to assign the trucks to traverse the routes connecting all the bin centers and empty the bins as often as possible and this usually led to the high cost of routing [2], it is evident that the advancements in this field have established a direct relationship with economic development, social growth and environmental management. The inversion of new ideas and technologies has spread throughout countries and served as a source of answers to eliminate numerous problems that are experienced through transportation. Waste management companies are among those companies that depend greatly on transportation to run their daily operations. In 2019 budget statement of Ghana, almost half a million was budgeted for maintaining sanitation and solving water problems in the country [7].

Proper route optimization can save a company up to 20% in mileage and improve the order capacity by as much as 100% without increasing the fleet [3]. It can also help businesses cut planning time by up to 80%, save significantly on fuel costs and driver wages [6], route optimization can also improve customer satisfaction with real-time notifications and more on time deliveries. It helps Improve employee retention with better workloads, and fair dynamic planning to avoid weighing down individual drivers. Many research has been carried out in the area of route optimization. Many of this research aim at optimizing the numbers of fleets for routing, minimizing time constraints, minimizing cost of routing, minimizing routing distances, etc. The differences in the results of these researches are as a result of the differences in optimization algorithms used. The main task of route optimization [6], is to develop a suitable model for finding the shortest possible set of routes connecting numerous destinations or stops making sure that each destination is not visited by a single truck more than once or not visited by any other truck after is has already been served.

Many of these optimization techniques are either for minimizing or maximizing certain objective function [8], optimal design formulation follows the following steps: (1) Need for optimization, (2) Choosing design variables, (3) formulating constraints, (4) formulating objective function, (5) setting up variable bounds, (6) choosing an appropriate optimization algorithm and (7) obtaining a required solution. Some of the widely used optimization algorithms include Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Simulated Annealing (SA), Gravitational Search Algorithm (GSA), Salp Swarm Algorithm (SSA), etc. Every algorithm has its own strength and weakness and only the right algorithm can be applied to the right optimization problem [8], route planning and optimization cannot be done manually because as the team, orders and the business begin to grow, certain tasks cannot be handled by hand. The efficiency, scalability, accuracy, flexibility and robustness of the optimization process will be greatly impacted if handled by hand.

Zoomlion Ghana Limited is the biggest waste management company in the country and it has been serving the country since 2006. Even though there are many equally good competitors in the waste management industry, Zoomlion has been ranked to be among the best waste service providers in the country [10], despite the rate of success achieved by the company over the years, sanitation continues to be a problem in the country. Almost all the sanitation problems in the country are either attitudinal or optimization related [4], mostly in the urban cities, when people clean their houses and gutters, they leave the waste sitting in piles nearby and eventually these wastes find their way back into the gutters, bleeding mosquitoes and spreading malaria. In areas where the government has provided big waste collection bins, these bins full of trash are left unattended to in the streets and are picked on by birds every now and then, spreading the waste back into the community. After the slightest storm, these trashes find their way back into the street and gutters leaving unpleasant scents [11] while waste management is a nationwide issue in Ghana, it’s most obvious in Accra, a fast-growing city of approximately five (5) million people generating about 3,000 metric tons of waste every day. In 2012, the World Bank estimated that poor sanitation was costing Ghana’s economy around 420 million Ghana cedis ($290 million) each year, equivalent to 1.6% of its GDP. The study confirmed that the annual premature death of about 3,000 Ghanaians is largely due to poor sanitation and hygiene. All this is due to the fact that, waste management companies don’t have proper routing plan to carry out their daily emptying of waste bins to ensure waste free country.

Shama district is located at the south-central part of the western region of Ghana. It shares boundary with Sekondi metropolitan assembly and Daboase district. The district covers a land area of about 213 km square. According to the 2010 population and housing census, the population of the district is about 88,314 and the main occupation of the people in the town is fishing and farming. As characterized by many of the towns along the beaches, one of the biggest problems faced by the district is sanitation. Many of the people along the beach dump all their trashes in the sea so the waves bring it back almost every day, making the beaches very dirty. The sizes of the waste bins located at vantage points are very small and extremely inadequate compared to the population of the communities to the extent that, it gets full to the brim after few people dump their waste. Sometimes, the overflown trashes can be left in the rain for days leaving unpleasant smell in the communities. This has been a standing problem for the community for some time now.

Over the years, many researchers have applied various optimization algorithms to solve different routing problems. These include Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Simulated Annealing (SA) etc. [12], many of these algorithms performed better than others depending on the objective function and also because each of these algorithms has its own limitation. To improve on the functionality of these algorithms, some researchers considered developing hybrid versions of these optimization algorithms such as hybrid particle swarm Optimization (HPSO), Modified Genetic Algorithm, etc. and most of the hybrid performed better as compared with individual algorithm results. However, none of these hybrid versions introduces the crossover and mutation operators of GA with PSO to determine the optimal solution with only one working garbage truck, serving 35 towns in the district, the branch of the company in Shama district need a working model to regulate the movement of the truck to serve all the towns in the district at the lowest possible distance. This study therefore seeks to solve this routing problem by developing a hybrid optimization model that introduces crossover and mutation operators of Genetic Algorithms into Particle Swarm Optimization to prevent premature convergence and to maintain diversity.

2 Methodology

2.1 Source of data

A secondary data was taken from the head office of Zoomlion Ghana Limited, Shama District. The data contained distance and time routing records of the company from January 2010 to December 2020, a period of 10 years. The content of the records contained the Towns in the district, the number of waist bin centers, towns with and without waist bins, bins ownership type, available trucks, trucks in good condition, etc.

The data collected was put into the following groups: Approximate Population in the town (A) Number of bins in the town, (B) Bin Capacity, (C) Number of times bin is emptied in a week, (D) Bin owned by private or Government, (E) Town has accessible route, (F) Approximate Distance from depot. The data was further grouped based on the need of the study. That is; Town Name, Number of waist bins in town and the Bin Capacity (liters). The 35 towns and villages in the district are scattered on a land area of 25km square unit with a population of about 103,320 people. There were two (2) villages which have not been provided with waste bins. The Zoomlion branch head is located at Shama, the district capital. The company’s branch has only two garbage collection trucks and only one (1) is operational. Once a week, this single truck is expected to set off from the premises of the head office at 4:00 am, traverse all the bin centers once and return to the depot when the capacity of the truck is reached, until all bin centers are visited and bins emptied A total of 50 breakpoints (bin location centers) were identified in the district. These breakpoints are scattered across the 35 towns and villages. Majority of the routes connecting the breakpoints are untired routes and the remaining few are footpaths. The hybrid model is used to find the shortest distance between the breakpoints.

2.2 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is one of the Evolutionary Computation (EC) techniques belonging to the field of Swarm Intelligence proposed by Eberhart and Kennedy in 1995. It is a population based stochastic optimization technique inspired by the social behavior of birds flocking or fish schooling. The motivation behind this algorithm [7], is that, a group of birds are looking for food in a vast valley. None of the birds know exactly where the food is, but all the birds have an idea of how far away they are from the food. In other words, the group of birds, which can be referred to as (particles), are potential solutions to the global minimization or maximization problem in the research space. There is only a global minimum or maximum point in this search space that need to be obtained. None of the particles know where the global minimum or maximum point is located, but all the particles have fitness values evaluated by the fitness function to be optimized at each progressive step. It is one of the iterative algorithms that engages a number of entities (particles) iteratively over the search space of some defined function.

The following are the main assumptions guiding the implementation of Particle Swarm Optimization [13].

1. All the swarms (particles) begin at a specific (defined) point
2. The movement of the swarm (particles) are guided by a defined function which either minimize or maximize the outcome
3. There is only one minimum or maximum point (value) to be achieved
4. Each swarm's (particle) movement is regulated by its velocity and position

The findings of Particle Swarm Optimization, after several studies [8] showed that:

i. It has rapid convergence rate towards an optimum
ii. Encoding and Decoding are easy to do
iii. It is fast and easy to compute when applied in research areas such as global optimization, artificial neural network training, fuzzy system control, engineering design optimization, logistics & supply chain management, etc.
iv. iv. Nevertheless, many researchers have also noted that PSO tends to converge prematurely on local optima, especially in complex multimodal functions

Given *D* - dimensional search space, the population of particles is called **swarm** and is denoted by *S*. Each individual particle in the swarm is a *potential solution* to the problem at hand. That is, a swarm is a set of *N* particles denoted by

$$S = (x_1, x_2, x_3, \ldots, x_n) \tag{1}$$

where each particle represents a point in the *D* dimensional space;

$$x_i = [x_{i1}, x_{i2}, x_{i3}, \ldots, x_{iD}]^T \ \epsilon\ A, i = 1, 2, \ldots, N \tag{2}$$

where $A \subset R^D$ is the search space, and $f: A \rightarrow Y \sqsubseteq R$ is the objective function. It is assumed that *A* falls within the feasible search space of the problem at hand. *N* is the user-defined parameter of the algorithm. The objective function, *f*(*x*), is assumed to be defined and unique for all points in *A*. Thus, $f_i = f(x_i) \in Y$

During iterations, the particles move iteratively within the search space, *A* and each particle's position changes with respect to time. The mechanism for adjusting each particle's position is a proper position shift, called **Velocity**, and is denoted by

$$v_i = [v_{i1}, v_{i2}, v_{i3}, \ldots, v_{iD}]^T \ \epsilon\ A, i = 1, 2, \ldots, N \tag{3}$$

where $v_{i1}, v_{i2}, \ldots, v_{in}$ represents the individual particles velocities during *N* iterations. Velocity is also adapted iteratively to render particles capable of potentially visiting any region of A. The velocity regulation aims at achieving a balance between exploration and exploitation.

2.2.1 PSO algorithm

PSO like many other algorithms, follows a systematic implementation steps. The execution at each step depends on the results from previous steps.

Fig. 1 shows the implementation steps of PSO. The algorithm accepts inputs, generates random initial population and run simulations on a number of iterations. Throughout the iterations, the algorithm searches for the minimum value through the fitness function *f*(*X*) based on defined termination criteria. The Algorithm begins with a randomly generated population, followed by the calculation of fitness values which aids in updating the velocity and positions of the particles through the iterations. The algorithm terminates when the defined stopping criteria is met.

Require: Initialize $x_i, v_i, iteration(t), pbest(p_i), gbest(p_g)$
Generate n random particles (i)
for $t = 1 : Max_{it}$ **do**
  for $i = 1 : n$ **do**
    $f(x_{i,d}(t)) = \sum x_i d_{ij}$
    if $f(x_{i,d}(t)) < f(p_i(t))$ **then** $p_i(t) = x_{i,d}(t)$
      $f(p_g(t)) = \min_t(f(p_i(t))$
    end if
    Update $pbest$, $gbest$
    for $i = 1 : n$ **do**
      $v_{i,d}(t+1) = wv_{i,d}(t) + c_1 r_1 (p_i - x_{i,d}(t)) + c_2 r_2 (p_g - x_{i,d}(t))$
      $v_{i,d}(t+1) = x_{i,d}(t) + v_{i,d}(t+1)$
      if $v_{i,d}(t+1) > v_{max}$ **then** $v_{i,d}(t+1) = v_{max}$
      else if $v_{i,d}(t+1) < v_{min}$ **then** $v_{i,d}(t+1) = v_{min}$
      end if
      if $x_{i,d}(t+1) > x_{max}$ **then** $x_{i,d}(t+1) = x_{max}$
      else if $x_{i,d}(t+1) < x_{min}$ **then** $x_{i,d}(t+1) = x_{min}$
      end if
      $f(x_{i,d}(t)) = \sum x_i d_{ij}$
      Update $pbest$, $gbest$
    end for
  end for
end for

Fig. 1. Particle swarm optimization algorithm

2.2.2 PSO flowchart

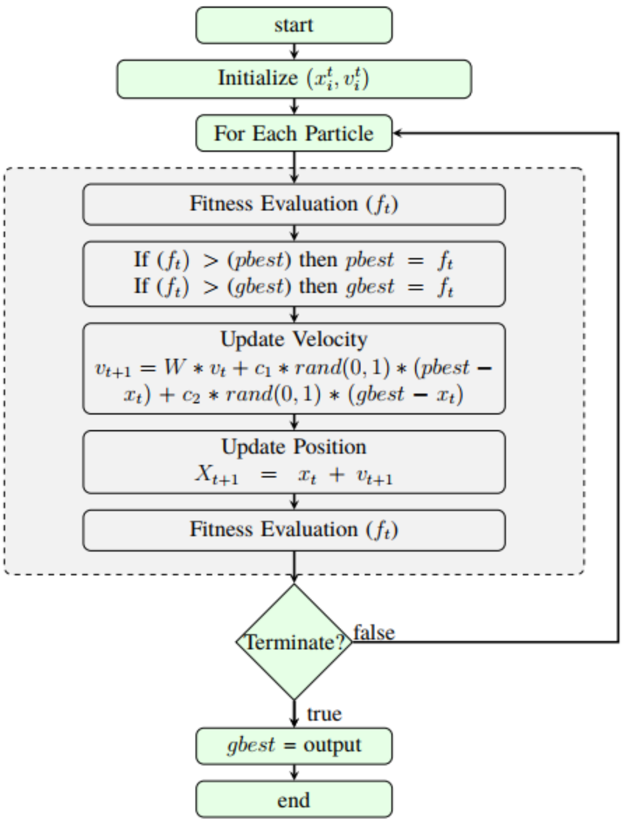

Fig. 2. Particle swarm optimization flowchart

Fig. 2 shows the flowchart of Particle Swarm Optimization. The process begins by initializing the position and velocity of each particle. It then evaluates the fitness of each particle before the updates of position and velocity. During iterations, each particle keeps records of its local and global best performance. The model terminates when defined stopping criteria is met.

The simplified equation for updating a particle's velocity and position respectively, according to [14], are:

$$v_i^1 = \omega^0 v_i^0 + \varphi_1 \beta_1 (pbest_i^0 - x_i^0) + \varphi_2 \beta_2 (gbest_i^0 - x_i^0) \quad (4)$$

$$x_i^1 = x_i^0 + v_i^1 \quad (5)$$

2.3 Genetic algorithms

Genetic algorithm is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation [14].

The process of natural selection starts with the selection of fittest individuals from a population. They produce offspring which inherit the characteristics of the parents and will be added to the next generation. If parents have better fitness, their offspring will be better than parents and have a better chance at surviving [8]. GA goes through five phases: Initialization, Fitness evaluation, Selection, Crossover and Mutation.

The following assumptions guides the implementation of Genetic Algorithm according to [9]:

i. Offspring are better fit than parent chromosomes
ii. Offspring's have traits of the mating parents
iii. Selection of offspring are based on survival of the fittest

Genetic Algorithm has various advantages, these include:

i. Is faster and more efficient as compared to other traditional methods.
ii. Has very good parallel capabilities.
iii. Optimizes continuous and discrete functions and also multi-objective problems.
iv. Provides a list of "good" solutions and not just a single solution.
v. Always gets an answer to the problem, which gets better over the time.
vi. Useful when the search space is very large and involves large number of parameters.

On the other hand, Genetic Algorithm suffer some few limitations.

1. GA is not suited for all problems, especially problems which are simple and for which derivative information is available.
2. Fitness value is calculated repeatedly which might be computationally expensive for some problems.
3. Being stochastic, there are no guarantees on the optimality or the quality of the solution.
4. If not implemented properly, the GA may not converge to the optimal solution.

The following assumptions are required in Genetic Algorithm:

i. Np : Population size of each iteration
ii. Ng : Number of generation(iterations) required
iii. Pc : Crossover Rate. ((Pc%) chromosomes undergoes crossover at each iteration)
iv. Pm : Mutation Rate. ((Pm%) of genes undergoes mutation)

2.3.1 GA algorithm

```
Generate initial population X^k = {x_1^k, x_2^k, ..., x_n^k}
Fitness evaluation x_i^k, for i = 1, 2, .., k
for k = k + 1 do
    Parent selection {x_i1, x_i2, ..., x_in} from X^(k+1) based on fitness
    Crossover on {x_i1^new, x_i2^new, ..., x_in^new} at P(c)
    Mutation on {x_i1^new, x_i2^new, ..., x_in^new} at P(m)
    Offspring fitness {x_i1^new, x_i2^new, ..., x_in^new}
    Insert x_p^new and x_q^new into X^new
    Best Fittest Selection from X^(k-1) and X^new to form X^k
end for
x* = best chromosome in X^k
```

Fig. 3. Genetic algorithm

Fig/ 3 shows the implementation steps for Genetic Algorithm. The algorithm begins with an initially generated population (which may be generated randomly or seeded by other heuristics). After which parents' chromosomes are selected based on fitness for mating to produce offspring's for crossover and mutation. These offspring's contain characteristics of the parents. Crossover and mutation are then applied on the selected offspring's for final fitness evaluation and optimality test

2.3.2 GA flowchart

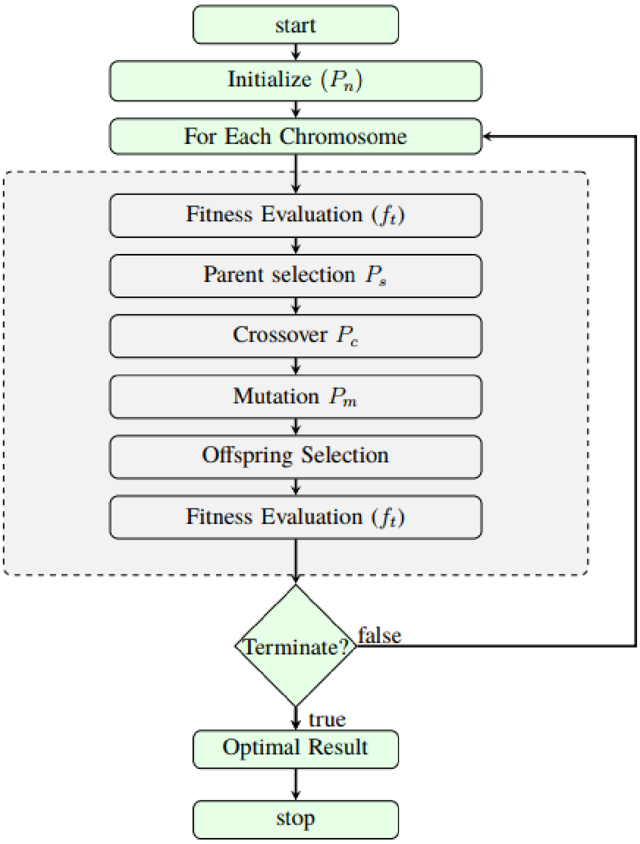

Fig. 4. The flowchart of genetic algorithm

Fig. 4 shows the flowchart of Genetic Algorithm. Crossover and Mutation play a very important role in this algorithm. They help in producing the best and fittest offsprings for subsequent generation creation.

2.4 Hybrid model

The hybrid algorithms combine Crossover and Mutation operators of GA with PSO. This was the algorithm used in this paper. The routes were converted into arrays and simulation was run with MATLAB. The hybrid algorithms follow the following steps: Initialization, Fitness calculation, Update of a particle's velocity and position, Crossover and Mutation [6].

The hybrid algorithms eliminate Particle Swarm Optimization's drawback of premature convergence. It also eliminates the fast rate of information flow between particles which usually results in the creation of similar particles that increases the probability of being trapped in local optima. HPSO also ensures that the problem dependency associated with the stochastic approach of PSO is eliminated [13,15,16].

The hybrid model merges crossover and mutation of Genetic Algorithm with Particle Swarm Optimization. This merge avoids premature convergence and avoid trapping in local minima by the presence of operators: crossover and mutation. The hybrid is also expected to enhance the speed of iteration and simulation

2.4.1 Hybrid model algorithm

Require: Initialize x_i, v_i, $iteration(t)$, $pbest(p_i)$, $gbest(p_g)$, p_c, P_m

Generate n random particles (i)
for $t = 1 : Max_{it}$ **do**
  for $i = 1 : n$ **do**
    $f(x_{i,t}(t) = \sum x_i d_{ij}$
    if $f(x_{i,d}(t)) < f(p_i(t))$ **then** $p_i(t) = x_{i,d}(t)$
      $f(p_g(t)) = \min_t(f(p_i(t))$
    end if
    Update $pbest$, $gbest$
    for $i = 1 : n$ **do**
      $v_{i,d}(t+1) = wv_{i,d}(t) + c_1 r_1(p_i - x_{i,d}(t)) + c_2 r_2(p_g - x_{i,d}(t))$
      $v_{i,d}(t+1) = x_{i,d}(t) + v_{i,d}(t+1)$
      if $v_{i,d}(t+1) > v_{max}$ **then** $v_{i,d}(t+1) = v_{max}$
      else if $v_{i,d}(t+1) < v_{min}$ **then** $v_{i,d}(t+1) = v_{min}$
      end if
      if $x_{i,d}(t+1) > x_{max}$ **then** $x_{i,d}(t+1) = x_{max}$
      else if $x_{i,d}(t+1) < x_{min}$ **then** $x_{i,d}(t+1) = x_{min}$
      end if
      $P_c(x_{i,d}(t+1))$
      $P_m(x_{i,d}(t+1))$
      $f(x_{i,t}(t) = \sum x_i d_{ij}$
      Update $pbest$, $gbest$
    end for
  end for
end for

Fig. 5. The hybrid model algorithm

The hybrid model goes through the initialization stage, fitness evaluation, update of velocity and position of PSO after which the best result is taken through the crossover and mutation stages of GA The least among the fitness values determines the personal best fit or estimate of each particle and the least among all personal best is the global best fit or estimate. After updating the velocity and position of the particles, if the updated velocity is greater than the generated velocity, then the generated velocity replaces the velocity

2.4.2 Hybrid model flowchart

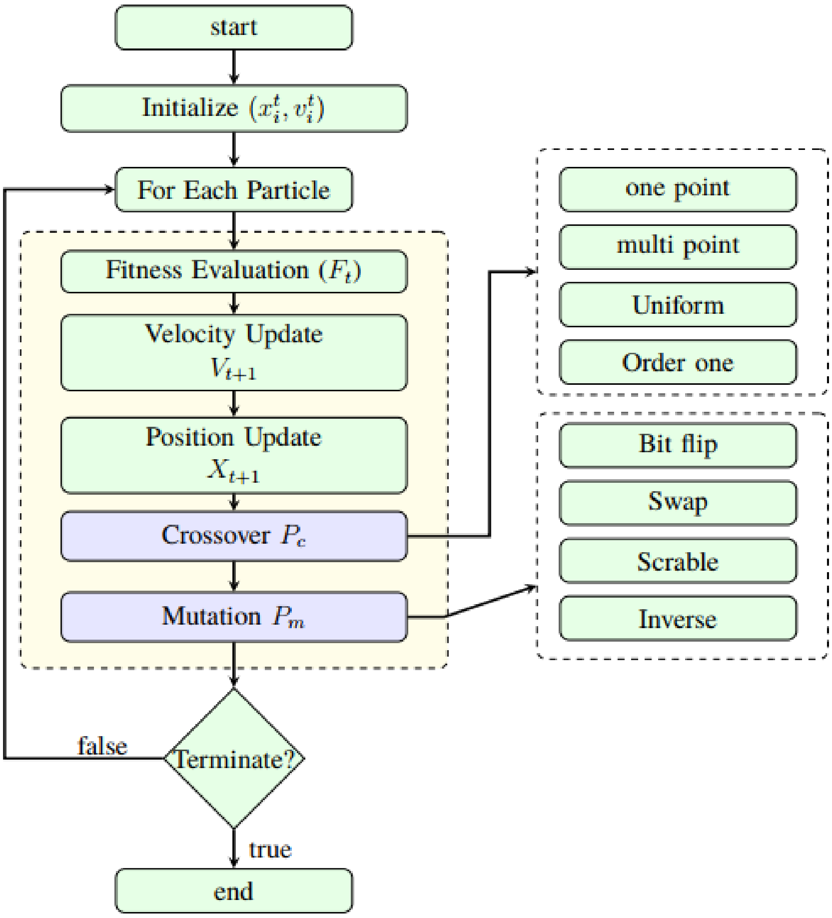

Fig. 6. Hybrid model flowchart

3 Results and Discussion

A maximum of 10,000 iterations was set to test the model. Other defined parameters of PSO and GA was maintained. The result obtained with the proposed model after applying it to the problem identified is compared with the results obtained from a separately implemented PSO and GA algorithms as well as other hybrid models. A stopping criterion of 10,000 iterations was set for all algorithms. The results for each model are presented below:

3.1 Result of particle swarm optimization

After 10,000 continuous iterations, PSO reduced the field distance from 1700km to 1160.6km at a difference of 539.4km which represent a reduction percentage of 31.73%. This improvement in route reduction occurred within 780.4098 seconds. Fig. 7 shows the resulting graph of PSO. The cost (route distance) started from 1800 at iteration 0. At iteration 1000, the route distance had reduced to 1290. From iterations 3000 to 10,000, the route distance was fixed at 1160.6km, which means there was no improvement till the end of the iterations.

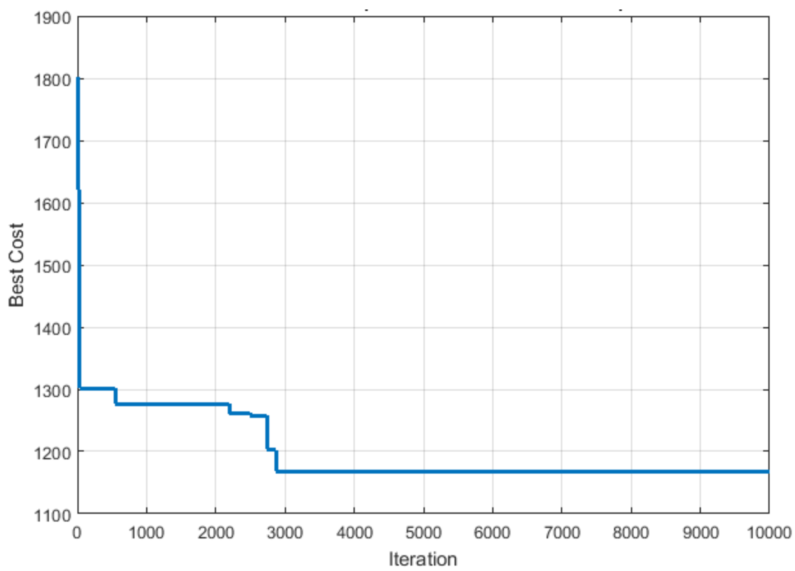

Fig. 7. PSO results after 10,000 iterations

3.2 Result of genetic algorithm

After 10,000 iterations, GA reduced the field distance from 1700km to 1190.3km at a difference of 509.7km which represent a reduction percentage of 29.98%. This improvement in route reduction occurred within 397.3308 seconds. Fig. 8, the best cost (route distance) started from 1800 at iteration 0. At iteration 800, the route distance had reduced to 1290. From iterations 2800 to 10,000, the route distance was fixed at 1190.3km, which means there was no improvement till the end of the iterations.

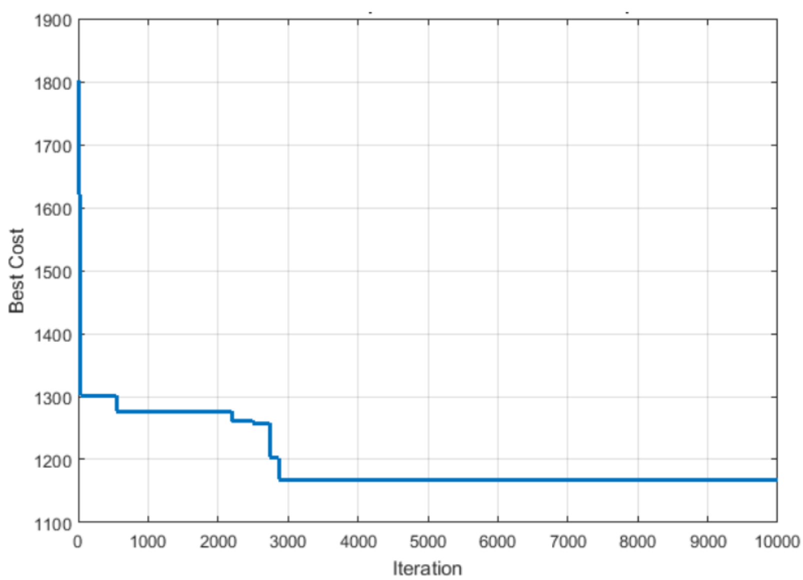

Fig. 8. GA results after 10,000 iterations

3.3 Result of hybrid algorithm

After 10,000 iterations, the proposed hybrid reduced the field distance from 1700km to 1132.3km at a difference of 567.7km which represent a reduction percentage of 33.39%. This improvement in route reduction occurred within 609.2527 seconds. Fig. 9, the best cost (route distance) reduced from 1350 to 1240 at iteration 0. At iteration 550, the route distance 106 reduced from 1240 to 1980. From iterations 3000 to 10,000, the route distance was fixed at 1132.3km, which means there was no improvement till the end of the iterations.

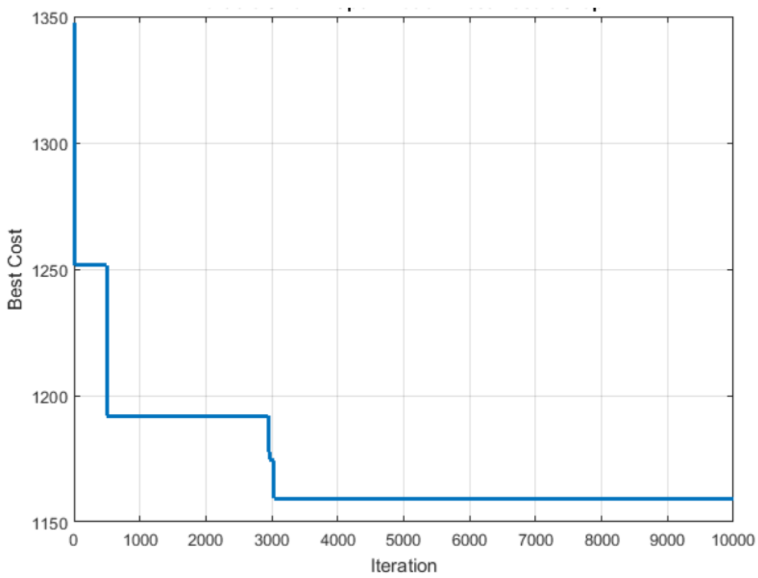

Fig. 9. GA results after 10,000 iterations

3.4 Discussion

Table 1 shows the summary of the algorithms, iterations, durations and optimal route results of the simulation. Even though PSO is easy to implement as compared with GA, it is known to converge prematurely to local optimal. After 10,000 iterations, an optimal distance of 1160.6 km was achieved within 780.4098 seconds. In the same number of iterations, GA produced 1190.3 km within 397.3308 seconds. This confirms that the crossover and mutation operators in GA makes the algorithm run faster as compared to PSO but PSO is much optimal in result than GA. The hybrid algorithm which combines crossover and mutation with PSO produced a minimal optimal result of 1132.3 km after 10,000 iterations within 550.2527 seconds. It is evident that, merging the two operators increases that duration of iterations but it produced the best result as compared to PSO and GA separately.

Table 1. Summary of algorithms, iterations, best results and durations

Algorithm	Iterations	Best results	Duration
PSO	10,000	1160.6 km	780.4098 secs
GA	10,000	1190.3 km	397.3308 secs
Hybrid	10,000	1132.3 km	550.2527 secs

From Table 1, the optimal result was achieved by the new hybrid model since that model lasted for 550.2527 seconds producing the best reduced distance of 1132.3 km. this is an indication that the direct application of crossover and mutation in PSO has greatly enhanced the performance of the proposed model.

4 Conclusion

In conclusion, a hybrid algorithm that merges crossover and mutation parameters of GA with PSO has been developed and implemented. The model was tested on data and compared with existing models in use and it was deem fit. The error estimation shows that it performs equally better and can be used to solve the problem of Zoomlion Ghana Limited. The hybrid model's results proved better and optimal as compared to other existing hybrid models.

Acknowledgement

We are very much grateful to God for making this article a success. Special appreciation to the authors (Justice kangah, Henry Otoo and Joseph Acquah) who contributed greatly towards the success completion of this work.

Competing Interests

Authors have declared that no competing interests exist.

References

[1] Desaulniers G, Errico F, Irnich S, Schneider M. Exact algorithms for electric vehicle-routing problems with time windows. Operations Research. 2016;64(6):1388-1405.

[2] Albayrak M, Allahverdi N. Development a new mutation operator to solve the traveling salesman problem by aid of genetic algorithms. Expert Systems with Applications. 2011;38(3):1313–1320.

[3] Aguiar BdCXC, Siqueira PH, de França Aguiar G, de Souza LV. Particle swarm optimization for vehicle routing problem with fleet heterogeneous and simultaneous collection and delivery. Applied Mathematical Sciences. 2014;8(77):3833–3849.

[4] Belfiore P, Tsugunobu H, Yoshizaki Y. Scatter search for vehicle routing problem with time windows and split deliveries. In Vehicle Routing Problem. InTech; 2013.

[5] Akaateba MA, Yakubu I. Householders' satisfaction towards solid waste collection services of zoomlion ghana ltd in wa,ghana. European Scientific Journal. 2013;9(32).

[6] Belenguer JM, Benavent E, Lacomme P, Prins C. Lower and upper bounds for the mixed capacitated arc routing problem. Computers & Operations Research. 2016;33(12):3363–3383.

[7] Bhattacharjya RK, Datta B. Optimal management of coastal aquifers using linked simulation optimization approach. Water Resources Management. 2005;19(3):295–320.

[8] Bishop BA, Anderson CW. Student conceptions of natural selection and its role in evolution. Journal of Research in Science Teaching. 1990;27(5):415–427.

[9] Blickle T. Tournament selection. Evolutionary Computation. 2000;1:181–186.

[10] Cohen B. Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technology in Society. 2006;28(1-2):63–80.

[11] Chu F, Labadi N, Prins C. Lower bounds for the periodic capacitated arc routing problem. In The Odysseus 2013 conference; 2013.

[12] Das S, Bhattacharyya BK. Estimation of municipal solid waste generation and future trends in greater metropolitan regions of kolkata, india. Journal of Industrial Engineering and Management Innovation. 2014;1(1):31–38.

[13] Chen B, Zhang R, Chen L, Long S. Adaptive particle swarm optimization with gaussian perturbation and mutation. Scientific Programming; 2021.

[14] Belmecheri F, Prins C, Yalaoui F, Amodeo L. Particle swarm optimization algorithm for a vehicle routing problem with heterogeneous fleet, mixed backhauls, and time windows. Journal of Intelligent Manufacturing. 2013;24(4):775–789.

[15] Brandao J. A new tabu search algorithm for the vehicle routing problem with backhauls. European Journal of Operational Research. 2016;173(2):540–555.
Carić T, Galić A, Fosin J, Gold H, Reinholz A. A modelling and optimization framework for real-world vehicle routing problems. In Vehicle Routing Problem. InTech; 2012.

[16] Clerc M, Kennedy J. The particle swarm-explosion, stability, and convergence in a multidimensional complex space. IEEE transactions on Evolutionary Computation. 2002;6(1):58–73.

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