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IMPROVING TRUCK SERVICE PERFORMANCE IN TRANSPORTING ROCK AGGREGATE USING GENETIC ANT COLONY ALGORITHM

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Inter-island shipment requests for rock aggregate products are served through the terminal for their own needs (TFON). The high demand for rock aggregate products causes many ships to queue up to be loaded. However, this condition is not comparable to the availability of dump trucks used to serve loading and unloading activities. This study aims to improve the performance of dump truck service in transporting rock aggregate so that the number of dump truck vehicles and optimal loading and unloading service times from the stockpile to ship at TFON are obtained. The research location was carried out at active rock mining companies in the Central Sulawesi region. The data collection method is carried out using field surveys (observations) using a time recording device by recording the process of transporting rock aggregates from the stockpile location to the ship in TFON and collecting secondary data on the demand for rock aggregates to be transported. The analysis method uses the hybrid Genetic Ant Colony Algorithm (ACO-GA) method namely a combination method between the Ant Colony Optimization algorithm and the Genetic Algorithm which aims to maximize the optimal number of trucks used in the transportation process and minimize the time in the loading and unloading process. The results showed that there had been an increase in service performance of the dump truck used in transporting rock aggregate with the longest distance of 2.3 km with a total of 5 dump trucks. The number of dump trucks of 5 units was selected because it falls within the fitness value criteria which is closest to the optimum value or equal to the value of the resources owned. Meanwhile, the optimal loading and unloading process time is in the range of 1.81–3.34 working days

Keywords: service performance, transportation, rock aggregate, terminal for their own needs

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1. Introduction

Ports are transportation connectivity nodes between sea and land modes that are connected through a transportation infrastructure network. As a maritime country, Indonesia is highly dependent on sea transportation in distributing production in various sectors, especially in logistics services at ports [1]. One of the logistics products that require service services at the port is products in the rock industry sector such as foundation stones, gravel, broken stone, stone ash, and sand. This type of rock product is found in various countries including Indonesia, one of which is in the province of Central Sulawesi which has considerable resource potential and meets the quality standards of construction materials. The shipment of this rock aggregate product continues to increase in number every year reaching 3.34 million m^3 per year [2]. According to data from the Port Authority (KSOP) Class II Teluk Palu, Central Sulawesi has become the largest producer until 2021 for the Kalimantan region with a supply value of 90 % [3] and several other areas in the Eastern Region of Indonesia. With the increasing demand for this rock aggregate product from year to year, it has an impact on the level of busyness at the port. Thus, improving a reliable transportation infrastructure network is important to improve the accessibility of rock aggregate transportation.

So far, inter-island shipments of all demand for rock aggregate products has been served through the terminal for self-interest (TFON). The high demand for this rock aggregate product causes many ships to queue up to be loaded. However, this condition is not comparable to the availability of equipment used to serve loading and unloading activities at TFON so that it has an impact on ships that stay at the port for too long [4]. In fact, equipment components have an important role in port operations to speed up the loading and unloading process. In real conditions today, rock aggregates are transported from the stockpile location to the ship using a dump truck with a maximum mileage of 2.3 km. In the process of transporting this rock aggregate product, there are many obstacles faced on the way in the form of traffic constraints, road infrastructure constraints, and road geometric conditions that have an impact on the travel time of dump trucks. In addition, the number of dump trucks used in transportation is only 3 units, not proportional to the total rock aggregate that will be transported to the ship, so the completion time of transportation is long. In fact, based on regulations issued by the Government, the time needed for the loading and unloading process at the port is a maximum of 4 days. However, the completion of loading and unloading is often carried out in the range of 7 days.

By looking at the problems that occur as described above, if left unchecked, it will certainly have an impact on the losses experienced by consumers as service users because they will incur additional costs while at the port. Therefore, studies that are devoted which aims to improve the performance of dump truck (DT) services in transporting rock aggregate at TFON are scientific relevance.

2. Literature review and problem statement

According to [5] one of the fundamental approaches to minimize transportation time is the tactical logistics operations based on optimizing vehicle routing. Route optimization here is meant as increasing the number of vehicles used for transportation. However, this has an impact on increasing operational costs. Cheap logistics is a concept related to the production and distribution of industrial goods, taking into account economic factors. Therefore, the goal is not only related to the economic impact of an organization's logistics but also to broader implications for consumers. The scope of low-cost logistics activities includes measuring the economic impact of different distribution strategies, reducing operational costs on land, and reducing operational costs on ships [6]. According to [1], optimal fleet management can minimize transportation time. Many researchers have recently conducted route optimization to determine the importance of implementing vehicle route problems (VRPs) to consider economic aspects, such as minimizing transportation time, and the results have been found to be closely related to vehicle allocation [7]. [8] using the VRP model in developing a vehicle routing system for reverse logistics operations to address and model waste logistics challenges, then [9] developed the green vehicle routing problem (GVRP), which includes electric trucks and conventional trucks aimed at minimizing the cost and total greenhouse gas emissions. This is in line with research [1] that developed a green vehicle routing problem model (GVRP), which includes electric trucks and conventional trucks aimed at minimizing the cost and total emissions of crude oil product transportation by sea.

Solving vehicle routing problems has been done by many previous researchers using the Ant Colony Optimization method. Researchers found that individual ants transfer information through substances called pheromones. On its way, ants can leave pheromones in their path and tend to move towards pheromones with high intensity. Based on the principles of the ant colony algorithm and ideas so this method is appropriate to use in solving vehicle routing problems (VRP) [10].

Transportation time is an important factor in transportation operations or TFON. In classical form, the transportation problem is multi-objective has been studied by several previous researchers. Many researchers focus more on minimizing time and costs simultaneously to find optimal transportation solutions, for example [11] produced new work on alternative algorithms that use geometric methods along with penalty techniques to solve multi-objective transportation problems namely minimizing transportation time and costs; [12] solving multi-dimensional and multi-objectives transportation problems using goal programming problems so that optimal cost and time values can be determined; [13] build two models to solve transportation problems with two uncertain goals, namely expected value goal programming model and chance-constrained goal programming model so that it can solve transportation problems, namely minimizing transportation costs and transportation time; [14] solving multi-objectives transportation problems with the help of soft computing methods using three different techniques, namely:

1) fuzzy interactive satisficing method;

2) global criterion method;

3) convex combination method. The objectives are to minimize both total cost and time for transportation. Meanwhile, [7] proposed minimizing transportation time and reducing fuel consumption costs in transportation problems. [15] studied the optimization of transportation problems with several conflicting objectives using a Multi-Item Just in Time approach. [16] developed an algorithm to identify practical vehicle routing problems in small and medium cities aimed at minimizing fuel consumption based on time-dependent speed.

Apart from that, some researchers also build algorithms with more than two objectives, for example [17] developed a planning model built with three transportation problem objectives, namely minimizing total transportation costs, transportation time, and carbon emissions on new transportation corridors that provide more comfortable transportation conditions in port hinterlands. Currently, the most important challenge faced by rock aggregate producers as TFON managers are managing transportation problems from inland areas to ports by optimizing the use of transport vehicles so that transportation time can be minimized. Several previous researchers have conducted research related to transportation time optimization using various approaches, including [18] researching transportation problems using methods using Fuzzy Particle Swam Optimization (FPSO) to minimize logistics transportation time. Meanwhile [19] in its research examined logistics problems using Mixed Integer Non-linear Programming (MINLP) methods to minimize actual time in transport. Meanwhile, [7] explored the best solution to transportation problems by utilizing three multi-objective approaches, namely the Zimmermann Programming Technique, Global Criteria Method, and Minimum Distance Method in minimizing transportation time in the Egyptian region so as to determine the ideal truck fleet allocation.

In real life, the optimal use of vehicle dump trucks in transporting goods and people is an important decision in solving transportation problem. One good method to used is the Ant Colony Algorithm method. Many researchers use the Ant Colony Optimization (ACO) method, some of which [20] used the Ant Colony Algorithm method to optimize the change propagation path thereby reducing transport time. [21] apply the Ant Colony Algorithm to find the shortest route so as to minimize operational costs. [22] presented the Hierarchical Multi-Switch Multi-Echelon Vehicle Routing Problem-Service Time (HMSME-VRP-ST) mathematical model by proposing a Hybrid Clustered Ant Colony Optimization (HCACO) algorithm approach to solve vehicle routing problems with the aim of minimizing fixed costs and variables of the vehicle fleet.

Given the above, there is a need to expand research on transportation issues. Although in recent years, there have been many studies on transportation problems that consider the transportation time factor, this study focuses more on the multi-purpose transportation problem of logistics of rock aggregate products by considering the aspect of resources with infrastructure network systems, one type of product, and homogeneous truck transportation.

3. The aim and objectives of the study

The aim of the study is to identifying the possibility of improvement in service performance of dump trucks in transporting rock aggregate from the stockpile area to ships at TFON using the Hybrid Genetic Ant Colony Algorithm (ACO-GA) method.

To achieve this aim, the following objectives are to be achieved, namely:

– to maximize the number of dump trucks used in transporting rock aggregate from the stockpile to the ship;

– to minimize the completion time for loading and unloading rock aggregates so that the time limit set by the government is achieved.

4. Materials and methods

4. 1. Object and hypothesis of the study

The object of the study is the level of truck service in transporting rock aggregate from the stockpile location to the ship by reviewing the number of truck vehicles used and the completion time of loading and unloading.

The main hypothesis of the study is that if the number of truck vehicles used in transportation is maximized, the loading and unloading completion time can be minimized.

The assumptions made in this study are:

a) trucks have the same type and capacity;

b) trucks have working hours of 8 hours per day;

c) each truck only transports rock aggregate products according to the number of requests;

d) consumer demands are fulfilled in one loading per 1 ship;

e) truck speed when loading is constant.

Simplifications adopted in the study are to build an optimization model to achieve two objective functions, namely maximizing the number of dump trucks (Z_1) and minimizing the completion time of loading and unloading (Z_2).

This research is through a hybrid method approach of the Genetic Ant Colony Algorithm (ACO-GA) method which aims to maximize the number of trucks and minimize the completion time of loading and unloading by considering the infrastructure network system, one type of product and homogeneous truck transportation. The case of logistics distribution of rock aggregate products for the Kalimantan region and the Eastern Region of Indonesia supplied by producers in Central Sulawesi is considered.

4. 2. Conceptual framework of rock aggregate transportation systems

The transportation of rock aggregate products at the source location uses a dump truck with a capacity of 22 tons. Rock aggregate products are transported from producer areas located on land (hinterland) to ships to meet consumer demand. The rock products transported to the ship depend on the volume of demand. The self-interest terminal (TFON) is used as an infrastructure node to meet the needs of Kalimantan and several other regions in Eastern Indonesia.

Transportation of rock aggregate products from production areas located on land (hinterland) using 3 units of dump trucks, and the infrastructure network is integrated with TFON. Distance, vehicle size, and vehicle speed are considered as obstacles in transporting rock aggregate products. All vehicles used in the transportation process are considered to be self-owned fleets in the rock logistics industry.

The assumptions used to optimize are as follows: (a) trucks have the same type and capacity, (b) trucks have working hours of 8 hours per day, (c) each truck only transports rock aggregate products according to the number of requests, (d) consumer demands are met in one loading per 1 ship, (e) truck speed when loading is constant.

All processes of transporting rock aggregate from the stockpile location to the ship at TFON can be described based on actual conditions, including working equipment components, TFON components and the position of the ship when moored at the pier. This can be seen in Fig. 1.

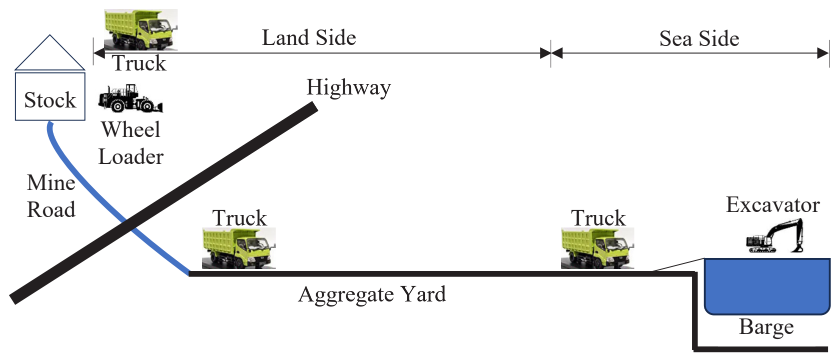

Fig. 1. Conceptual framework of rock aggregate transportation system

Fig. 1 depicts the conceptual framework for a schematic representation of operations and equipment at TFON, including equipment for loading and unloading from ships to the dock or vice versa and trucks for carrying rock aggregate within the terminal area.

4. 3. Data collection method

In this research, data collection techniques were carried out in two ways, namely primary data sources including direct observation, and secondary data sources including documentation studies. The observation technique is carried out by making direct observations of the variables needed to assess more deeply the process of transporting rock aggregates from the stockpile to the ship at TFON based on the actual data requirements of the dump truck transportation process.

Meanwhile, documentation studies are a way of collecting data and information by collecting supporting data in the form of books, archives, documents, written numbers, and pictures in the form of reports and information that supports research [23]. In this research, documentation studies were obtained from authorized institutions such as the Harbor Master's Office and Class II Port Authority of Palu Bay, Palu City Regional Revenue Agency, Donggala Regency Regional Revenue Agency, Central Sulawesi Provincial Energy and Mineral Resources Service, Central Sulawesi Mining Inspector, Companies Mining and literature books that support this research, regulations related to the research topic and data in the form of field photos and videos. This location was chosen as a research object because this location has many abundant rock mines with good quality material.

4. 4. Method of analysis

The approach used in analyzing dump truck performance improvement is Genetic Ant Colony Optimization (ACO-GA), which is a method that uses artificial intelligence (AI) to complete optimization. One of the advantages of this method is that it does not require too many mathematical requirements to complete the optimization process. The best analysis results for each generation can be used as an alternative decision support system. In general, the flow diagram of the optimization completion process with the help of ACO-GA can be seen in Fig. 2.

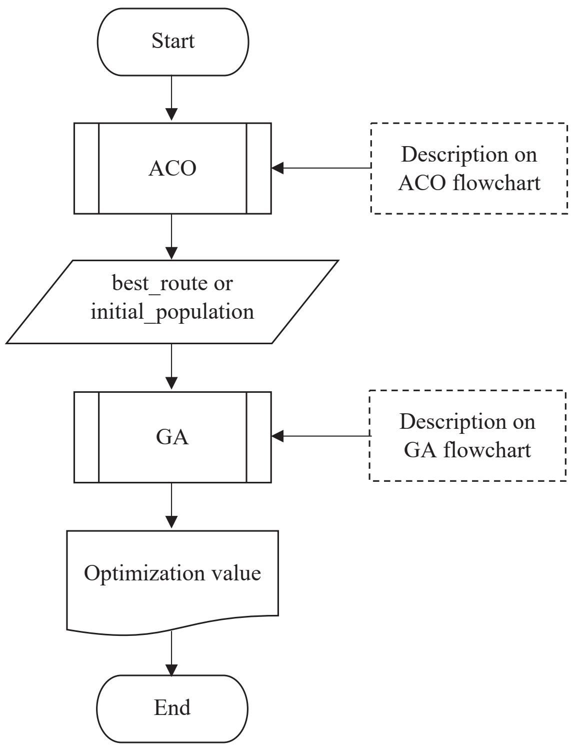

Fig. 2. Optimization process using Hybrid ACO-GA

Improving dump truck service performance is the object of this research. In general, to optimize the transportation of rock aggregate from the stockpile to the ship with two objectives, namely to maximize the number of dump trucks and minimize the completion time for loading and unloading are carried out by considering various variables and constraints which affects the transportation process.

Completion of the optimization of rock aggregates transportation is carried out in stages starting from identifying variables and parameters, creating a linear optimization model, and formulating linear programming. Create a optimization model with two objective functions, Z1 and Z2 which are related to maximizing the number of dump trucks (1) and minimizing the loading and unloading completion time (3).

Constraints on total demand, number of trucks, truck capacity, operating time and effective time are calculated based on (2). The total load constraint is based on the assumption that all aggregates must be transported by available trucks and is calculated based on (4). Travel and loading and unloading time constraints are based on the assumed sum of travel time, loading time, and unloading time for all trucks taking into account constraints, and are calculated based on (5). Meanwhile, road capacity constraints are based on the assumption that the number of trucks moving on the road must not exceed the capacity of the road, and is calculated based on (6):

$$\max Z_1 = N_{truck}, \quad (1)$$

$$\frac{V_{ship}}{N_{truck} \cdot C_{truck} \left(\dfrac{T_{ops}}{t_{load} + t_{dump} + t_{travel}} \right)} < T_{\max}, \quad (2)$$

$$\min Z_2 = Teff \cdot N_{truck}, \quad (3)$$

$$N_{truck} \cdot C_{truck} \geq V_{ship}, \quad (4)$$

$$T_{eff} \geq t_{travel} + t_{load-unload}, \quad (5)$$

$$N_{truck} \leq N_{truck\max}, \quad (6)$$

where N_{truck} – number of trucks (units); T – effective turnaround time based on the number of trucks (hours); $T_{\max}$ – maximum time set by the government (days); T_{eff} – effective completion time (hours); $N_{truck\max}$ – total truck units owned (truck units); C_{truck} – load capacity of each truck (m^3/truck); V_{ship} – total amount of aggregate that needs to be transported (m^3); t_{load} – time required to load aggregate into the truck (hours); t_{unload} – time taken to unload aggregate from truck to ship (hours); t_{travel} – the time it takes for a truck to travel from stockpile to ship (hours); $T_{operation}$ – daily operational time in hours; R_{lalin} – traffic ratio; R_{infra} – road condition ratio; $R_{load\text{-}unload}$ – loading and unloading ratio; $R_{v\_load\text{-}v\_unload}$ – ratio of truck speed to load and no load.

5. Results of research improving truck service performance in transporting rock aggregate using genetic ant colony algorithm

5. 1. Maximizing of the number of dump trucks

The algorithm used in the analysis of optimizing the number of dump trucks is Ant Colony Optimization (ACO). In this analysis, the first thing to do is provide initial initialization regarding the maximum number of ants, maximum number of iterations, number of objectives, evaporation value, alpha value, and beta value needed as a stopping condition to create new generations. Stopping conditions are needed to set the optimization achievement limit values, as shown in Tables 1, 2. The initial condition table is needed to determine the maximum number of iterations required to create a new generation. In creating a new generation, other supporting variables are also needed with certain limitations.

Table 1

The initial condition of ACO

Variable	Value
Number of ants	5
Number of iterations	10
Total evaporation value	0.3
Max. generation	20
Alpha	1
Beta	1

Table 2

The initial condition of GA

Variable	Value
Max. Gen	10
Gen	20
Population	10
Probability of crossover (pc)	0.3
Probability of mutation (pm)	0

The next stage is to determine the variables and parameters used in the dump truck optimization process using actual data obtained during the primary survey. The actual data obtained was 10 sets, which later this data will be processed algorithmically to produce the best solution in the process of transporting rock aggregate using a dump truck from the stockpile location to the ship. Actual data can be displayed in Table 3.

Table 3

Actual data of aggregate transportation process

Variable	Value (period)									
	1	2	3	4	5	6	7	8	9	10
Transport distance from stockpile – ship (*D*), km	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Average speed (v), km/hours	10	10	10	10	10	10	10	10	10	10
Average speed of damaged roads (v_{infra}), km/hours	10	10	10	10	10	10	10	10	10	10
Average speed of empty load (v_{empty}), km/hours	11	11	11	11	11	11	11	11	11	11
Maximum speed on road conditions ($v_{\max}$), km/hours	11	11	11	11	11	11	11	11	11	11
Dump truck load capacity (*L*), m^3/truck	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
Total amount of rock aggregate transported (*Q*), m^3	2297	3093	2799	3208	3116	2995	4193	3811	3148	5164
Loading time (*t_load*), hours	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
Unloading time (*t_unload*) hours	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Ideal loading time (*t_ideal load*), hours	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Ideal time to unload (*t_ideal unload*), hours	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Number of dump trucks used (*x*_max), units	3	3	3	3	3	3	3	3	3	3
Operation time (*t_operation*), hours	8	8	8	8	8	8	8	8	8	8

The next stage is carrying out the Ant Colony Optimization (ACO) algorithm process with steps consisting of initializing pheromone, initial placement of ants, carrying out ACO iterations, and updating the minimum value. At each iteration, the minimum value is chosen from the new ant position, and the pheromone is updated according to the newly calculated objective function value. So, the final results of the Ant Colony Optimization (ACO) carried out obtained a solution as shown in Table 4.

Table 4

Initial selection solution based on Ant Colony Optimization (ACO)

Iteration	Minimum Value
1	4
2	44
3	35
4	17
5	5
6	5
7	50
8	5
9	4
10	4

From the process of initializing and updating the pheromone value to obtain the minimum value as in Table 4 above, the analysis process using the Ant Colony Optimization (ACO) algorithm method has been completed with the initial conclusion that the value in the 5^{th}, 6^{th} and 8^{th} iterations has a minimum value of 5 selected because it falls within the fitness value criteria which is closest to the optimum value or equal to the value of the resources owned. Furthermore, these results will be used again in the Genetic Algorithm (GA) process.

The second stage is carrying out analysis using the Genetic Algorithm (GA) algorithm method. This GA analysis is carried out in the following stages:

1. Selection.

The selection process is selecting the parents that will be subjected to the crossover process. These selected parents are parents who have the power to influence the value of the genes on the chromosomes selected through this selection process. The selection method in the Genetic Algorithm that is most widely used is the Roulette Wheel Method or known as stochastic sampling with replacement. The roulette Wheel Method is where individuals are mapped onto line segments sequentially so that each individual segment has the same size as the fitness size.

The flow of the Roulette Wheel Method sequence can be explained as follows: calculating total fitness, calculating the selection probability for each individual, and calculating cumulative probability. The next stage is determining random numbers, random numbers between 0 and 1, and selecting individuals based on selection probability. The provisional results on stage 3 of the random selection process obtained from the ACO results can be seen in Table 5.

Table 5

Provisional results after selection on stage-3

Chromosome	Fitness (x)
2	44
3	35
4	17
7	50
7	50
2	40
3	35
7	50
8	5
2	44

2. Crossover.

Crossover is crossing selected parents (parents) to produce children (offspring). Offspring is formed from the combination of 2 chromosomes of the current generation/iteration which act as parents using a crossover operator. Crossing is carried out on parents selected from the crossover probability (*pc*). The results of crossbreeding between chromosomes can be seen in Table 6.

Table 6

Results of crossover uniform

Crossover $R \leq 0.3$		
Chromosome	Random	Parent selection
2	0.35	35
3	0.45	44
4	0.25	50
7	0.50	17
7	0.55	44
2	0.35	50
3	0.25	50
7	0.40	35
8	0.20	44
2	0.30	5

The next step is the mutation process, namely the operator to modify the chromosome selected from the mutation probability (Pm). With the mutation process, the process of selecting the parent affected by the mutation is carried out with the results in Table 7. Meanwhile, the results of the new population can be seen in Table 8.

Table 7

Mutation process of chromosome

$Pm=0.1$			
Chromosome	Initial fitness	Random value	Fitness after mutation
2	35	0.05	36
3	44	0.15	44
4	50	0.40	50
7	17	0.10	18
7	44	0.50	44
2	50	0.30	50
3	50	0.20	50
7	35	0.25	35
8	44	0.45	44
2	5	0.35	5

Table 8

New population results

Population	Fitness (x)
1	36
2	44
3	50
4	18
5	44
6	50
7	50
8	35
9	44
10	5

From the mutation process carried out as shown in the Table 8 above, the iteration process of the Genetic Algorithm (GA) has been completed. For greater clarity, the ACO-GA optimization results for DT can be depicted in a graph like Fig. 3.

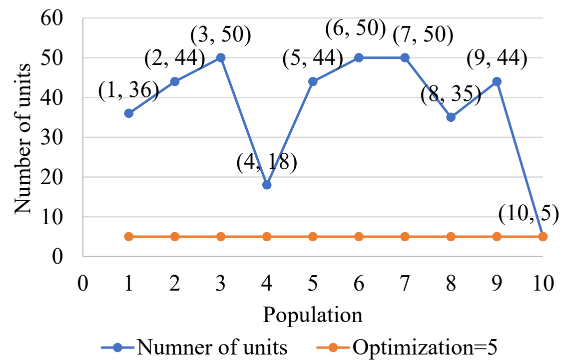

Fig. 3. Optimization of DT number using ACO-GA method

Based on Fig. 3 it can be explained that the resulting new populations have different fitness values (x). However, only the population (10) produces a fitness value (x)=5. The fitness value (x)=5 is the optimum value for the number of dump trucks needed and this value is in accordance with the number of existing resources. The red dotted line is the optimization line.

5. 2. Minimizing of total transport time

After obtaining a fit value (x) of 5 dump trucks, the optimal time value (T) will be found using the formula (3) minimize T, then the calculation of the optimal number of trucks has been obtained through the ACO-GA calculation and calculate the obstacle ratio. The next step is to calculate the travel time by taking into account traffic constraints and road damage and loading and unloading times by considering constraints and calculating effective time. The final result is the calculation of the total effective turnaround time based on the number of trucks and obtained 27.48 work hours or 3.44 work days. Perform the above calculation with other data sets, for a total of 10 data sets, with the results obtained shown in Table 9.

Table 9

Optimization results of DT number and transportation time

Period	Q (m^3)	Optimization unit (Unit)	Optimization time (Hari)
1	2297	5	1.92
2	3093	5	2.53
3	2794	5	2.38
4	3208	5	2.48
5	3116	5	2.16
6	2995	5	2.39
7	4193	5	3.34
8	3811	5	2.54
9	3148	5	1.81
10	5164	5	3.44

The final result of calculating the total effective completion time and based on the number of trucks based on the ACO-GA calculation steps for x is 5 units, 27.48 working hours are obtained. If the settlement time is converted into working days, where there are 8 working hours in a day, let's get 3.44 working days. Optimization results of DT number and transportation time with other data sets so that the total becomes 10 data sets with the results obtained shown in Table 9.

The results of the comparison of ACO and ACO-GA are graphically shown in Fig. 4. From the graphic results, it can be explained that there is data on the number of trucks which varies between 4 to 291. The red dotted line in the figure shows that the ideal number of trucks used in the transportation process of 5 units. From the optimization results, the recommended optimization value to obtain the ideal number of trucks is 5 units with a work completion time of 27.52 working hours or 3.44 working days.

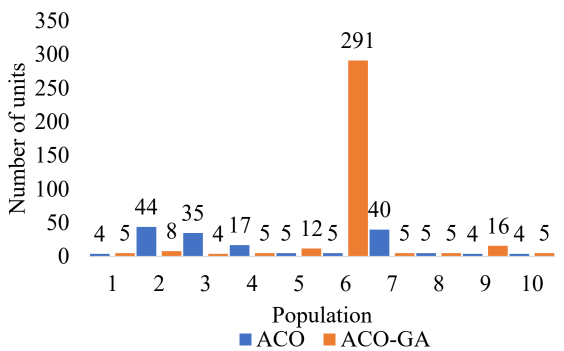

Fig. 4. Comparison results of ACO and Hybrid ACO-GA

Comparing the results of the Ant Colony Optimization (ACO) analysis with the hybrid Ant Colony Optimization Genetic Algorithm (ACO-GA) based on field conditions, for the DT case chosen is the result at an optimization value of 5, where the productivity of the tool can reach 243 m^3/hour provided it is repaired. road conditions and the number of dump trucks operated are 5 units.

6. Discussion of results improving truck service performance

This paper presents an analysis framework for the transportation of rock aggregates that describes the factors that influence service performance in the transportation sector, especially for transportation in the rock mining industry which has long distances between production locations and ports. Various stages of analysis have been carried out to provide optimal results on dump truck service performance.

The first step of optimization is to find a route to improve the performance of truck services in transporting rock aggregate with the aim of maximizing the number of trucks (Z_1). Furthermore, minimize the completion time of loading and unloading (Z_2) by using the same method used for (Z_1) optimization.

Based on the initial step of optimization using the Ant Colony Optimization (ACO) method, the maximum value of the number of trucks is obtained as shown in Table 4. At this stage, the ACO analysis process has been completed with the initial conclusion that the maximum value in the 5^{th}, 6^{th} and 8^{th} iterations has a maximum value of 5 which is selected because it is included in the conformity value criterion that is closest to the optimal value or equal to the value of the resource owned. Then the next optimization step is carried out using the Genetic Algorithm (GA) method.

The next optimization results using the Genetic Algorithm (GA) method, are carried out in several stages consisting of selection, crossover and mutation. The optimization results obtained from the ACO method are then used as the parent selection of iteration 1 where the maximum value obtained is used as the fitness function (x). Then the selection steps were carried out using the Roulette Wheel Method by calculating total fitness, calculating the selection probability for each individual, calculating the cumulative probability, randomizing with random numbers 0 and 1, and selecting individuals based on the selection probability. From the calculation steps that have been carried out, the provisional results of the selection are obtained as shown in Table 5.

The stages after obtaining the provisional results of the parent selection are then carried out a crossover by crossing the selected parents to produce offspring. Crossover is carried out on the selected parent from the crossover probability (pc) with the stage of generating a random number, selecting the chromosomes to be crossed with the limit of the crossover probability (pc) where the randomy $\leq pc$, randomly crossing the selected chromosomes by making a parent pair for the crossover. The results of crossbreeding between chromosomes can be seen in Table 6.

To modify the selected chromosomes from the mutation probability is done using a mutation operator. The mutation will change each fitness value by 1 if it is affected by the mutation. The Random Values used in the mutation process are [0.05, 0.15, 0.40, 0.10, 0.50, 0.30, 0.20, 0.25, 0.45, 0.35]. Chromosomes that have undergone mutations can be seen as shown in Table 7. Thus, the results of the new population after the mutation process can be seen in Table 8.

Based on the results of the mutation carried out as shown in Table 8, the optimization of the number of dump trucks has been obtained with different fitness values in each population. Population 1 gets a fitness score (36), population 2 gets a fitness score (44), population 3 has a fitness score (50), population 4 has a fitness score (18), population 5 has a fitness score (44), population 6 has a fitness score (50), population 7 has a fitness score (50), population 8 has a fitness score (35), population 9 has a fitness score (44), and population (10) has a fitness score (5). From the fitness value in the 10 populations, which had a fitness value (5) was selected because it met the criteria for the fitness value closest to the optimum value or in accordance with the number of available resources. Based on the results of this optimization the number of dump trucks used in each rock aggregate transportation is as many as 5 units.

The description of the results of dump truck optimization based on the ACO-GA hybrid method as shown in Table 8 can be seen in Fig. 3. Fig. 3 explains that the red dotted line is the optimum value or value of the resources owned by the producer. The new population produced has different fitness (x) values. Of the 10 existing populations, only population 10 has a fitness value (5) equal to the fitness value or equal to the resource value.

Then from the selected fitness value (5), then by using the same method and stages as in maximizing the number of dump trucks (Z_1), then the optimization of the loading and unloading completion time (Z_2) will be carried out. The loading and unloading completion time is calculated using the model that has been made in equation (3) which aims to minimize the loading and unloading completion time. The completion of the calculation is done with the help of the Google Colaboratory application. Of course, the model contains constraints according to field conditions and other constraints. This optimization model only makes a prediction about the optimal loading and unloading completion time. The Z_2 minimization scenario results in the smallest loading and unloading completion time in the range of 1.81 days or 14.48 hours and the largest in the range of 3.44 days or 27.52 hours, with a maximum number of dump trucks used as many as 5 units. The completion time for loading and unloading is lower than the reference set by the government, which is 4 days. However, the number of dump trucks used is maximized, increasing operational costs. In summary, the results of Z_2 minimization, as presented in Table 9, show that although the completion time of loading and unloading can be minimized through distribution route optimization, there is an increase in the number of dump truck vehicles and the number of demand.

Comparing the results of the Ant Colony Optimization (ACO) analysis with the hybrid Ant Colony Optimization Genetic Algorithm (ACO-GA) based on field conditions, there was a significant difference in the results obtained. From the results of the graph in Fig. 4, it can be explained that there is data on the number of trucks that vary between 4 to 291 units in the ACO-GA method, while with the ACO method, the number of dump trucks is in the range of 4 to 44 units. However, all of this depends on the ability of producers to prepare resources, so in this study there is an ideal limit set as the optimum value.

The analysis approach used in this research is the Hybrid Genetic Ant Colony Algorithm (ACO-GA) with two objective functions, namely maximizing the number of dump trucks and minimizing transportation time. This analysis method is a combination of the Ant Colony Optimization method and Genetic Algorithm. The analysis was carried out in stages, starting from analysis using the ACO method. The results obtained from the ACO analysis are then used in further analysis using the GA method until optimal results are obtained based on the number of iterations that have been previously determined. The analysis results show that this analysis method can provide a solution regarding the optimal number of dump trucks used in transporting rock aggregate from the stockpile to the ship and the optimal transportation time.

A detailed comparison of several attributes is presented to highlight research gaps and the need for this research. Some of the main contributions of our approach can be explained as follows. When compared with existing literature on single-objective transportation problems [19, 20] and the references cited therein, this work extends the literature to multi-purpose transportation problems in an integrated framework.

When compared with the literature on transportation optimization problems [20–22] as well as the references cited therein, this research extends the literature by using the behavior of ants in searching for food through the hybrid Ant Colony Optimization and Genetic Algorithm (ACO-GA) method in an integrated multi-objective optimization model of the transportation system in TFON.

When compared with existing research on multi-objectives transportation problems [7, 11–16], the proposed integrated model provides a solution to real-world goals, namely to maximize the use of the number of vehicles used in transportation and minimize transportation time. To our knowledge, these goals have not been analyzed together comprehensively in previous research.

7. Conclusions

1. The calculation results for the optimal number of dump trucks required for the process of transporting rock aggregate from the stockpile to the ship are 5 units. This amount is an ideal value in the process of transporting rock aggregates in mining areas because it is in accordance with existing resource conditions.

2. With the optimal number of dump truck vehicles obtained as 5 units, the optimal total transportation time has also been produced. The total transportation time varies based on the amount of rock aggregate transported to the ship, ranging from 1.81 to 3.34 days.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has associated data in a data repository.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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