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Application of Particle Optimization and Genetic Algorithms (GA) Method in Fleet Transportation Systems of two-wheeled automotive industry

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Abstrak. Salah satu aktifitas pada Industri otomotif roda dua adalah proses pengiriman komponen atau part dari Suplier ke pabrik perakitan sepeda motor. Pengiriman part menggunakan armada dari masing masing suplier. Seiring dengan peningkatan permintaan pasar, maka permintaan komponen ke suplier semakin bertambah. Hal ini berdampak pada peningkatan jumlah dan frekuensi armada yang masuk ke area pabrik, selain itu juga ada peningkatan biaya transportasi. Penelitian ini bertujuan melakukan efisiensi jumlah, frekuensi dan biaya transportasi armada dengan menggunakan pendekatan Milkrun dan VRP (Vehicle Routing Problem). Untuk mendapatkan hasil yang optimal, maka digunakan metode PSO (Particle Swarm Optimization) dan GA (Genetic Algorithm) dengan memanfaatkan software Matlab 2022. Penelitian ini melibatkan 40 suplier, Logistic Partner dan pabrik perakitan sepeda motor. Hasil penelitian ini menunjukkan hasil yang lebih baik yaitu sebelum penelitian Jumlah armada 40unit dan frekuensi 40 kali pengiriman dengan total biaya pengiriman sebesar Rp 2,769,330, sedangkan sesudah penelitian dengan metode optimasi PSO jumlah armada 5unit dan frekuensi 8 kali pengiriman dengan total biaya pengiriman sebesar Rp 2,679,113. Untuk optimasi GA jumlah armada 4unit dan frekuensi 8 kali pengiriman dengan total biaya pengiriman sebesar Rp 2,000,058.

Kata kunci: Sistim Transportasi armada, Milkrun, VRP, PSO, GA

Abstract *One of the activities in the two-wheeled automotive industry is the process of sending components or parts from suppliers to motorcycle assembly plants. Delivery of parts using the fleet of each supplier. Along with the increase in market demand, the demand for components to suppliers is also increasing. This has an impact on increasing the number and frequency of fleets entering the factory area, besides that there is also an increase in transportation costs. This study aims to make the efficiency of the number, frequency and cost of fleet transportation by using the Milkrun approach and VRP (Vehicle Routing Problem). To get optimal results, the PSO (Particle Swarm Optimization) and GA (Genetic Algorithm) methods are used by utilizing the Matlab 2022 software. This research involved 40 suppliers, Logistic Partners and motorcycle assembly factories. The results of this study showed better results, namely before the research the number of fleets was 40 units and the frequency of 40 shipments with a total shipping cost of IDR 2,769,330, while after the research with the PSO optimization method the fleet number was 5 units and the frequency of 8 shipments with a total shipping cost of IDR 2,679,113. For GA optimization, the number of fleets is 4 units and the frequency is 8 times of delivery with a total shipping cost of IDR 2,000,058.*

Keywords: Fleet Transport Systems, Milkrun, VRP, PSO, GA

1. INTRODUCTION

Indonesia is a country with a rapidly growing economy in the Southeast Asia region. This cannot be separated from the many companies/industry that see the market in Indonesia as quite promising. Besides that, Indonesia also plays an active role in supporting the movement of domestic industry. One industry that continues to grow today is the automotive manufacturing industry. This development makes business processes compete with each other to achieve competition. Based on data from the Indonesian Motorcycle Association (AISI), the average sales of motorcycles for domestic and export from 2017 - 2021 is 6,170,334 units. The motorcycle manufacturing industry in Indonesia has activities to process raw materials into finished goods in the form of motorcycles that are ready to be marketed throughout Indonesia and overseas. One of the motorcycle manufacturers in Indonesia certainly has vendors supplying raw materials((Cui et al., 2019)et al., 2019). In the delivery process, suppliers or suppliers require transportation facilities in the form of a fleet of trucks of various types and models(Eltoukhy et al., 2018). (Norouzi et al., 2017). According to (Purba et al., 2019) there are two kinds of transportation models at the factory, the direct delivery model and the consolidated model.

Transportation in the supply chain system in the motorcycle manufacturing industry has a very important function because it plays the role of carrying out the movement of goods, both goods in the form of raw materials, components, semi-finished goods and finished goods(Safaei & Jardine, 2018). The economic value of transportation in carrying out this role is to carry out the movement of inventory from the location of origin to a certain destination location in the supply chain management system. Transportation performance will determine the performance of procurement, production and customer relationship management. Transport also takes into account many conditions, including heterogeneous fleets, optimization of load-on-vehicle to address vehicle capacity, in-vehicle order fit, return of empty pallets from assembly plants to suppliers, and delivery time considerations. Without reliable transportation performance, it is certain that almost all of the main supply chain activities will not run properly.

Based on initial observations in one of the two-wheeled automotive industries, that the system for sending components from suppliers to factories is all done by direct delivery. Suppliers use the supplier's own transportation fleet or rent a fleet. The number of suppliers who send components and materials to the factory is 140 companies and the locations of the suppliers or suppliers are within a radius of 100 km from the factory location. One of the problems related to the supplier fleet is the level of load or utilization of the average fleet of only 55%. In addition to the fleet originating from suppliers of plastic painting components, this causes waste in terms of truck capacity and other costs. Another problem is that there is a buildup or queue in the Warehouse receiving area. This is due to the ever-increasing production needs causing the frequency of component delivery to also increase (Normasari et al. 2019). Besides that, the problem is also the existence of rules that limit the time of receipt at the warehouse at a certain time(Eydi & Alavi, 2019) (Rahman & Asih, 2020).

Some of the previous research strategies carried out to obtain effective and efficient transportation were optimizing milk-run routes with mixed integer linear programming models, container loading heuristics to increase the utilization of milk-run vehicles(Gad, 2022). Designing a "Smart Decision" method using the internet of things and Big Data to optimize milk run logistics and reduce transportation costs (Karouani & Elgarej, 2022). Application of the “Mix Integer Linear Programming (MILP)” mathematical model in the operational planning of distribution networks for the automotive industry(Ranjbaran et al., 2020). Use of the Ant Colony Algorithm method to optimize distribution routes by considering carbon emissions so as to reduce distribution costs for logistics companies(Allaoui et al., 2018). Develops a mathematical model and proposes a Swarm Optimization (SSO) heuristic for the Heterogeneous Fleet Vehicle Routing Problem (HFVRP) with the aim of minimizing distribution costs, which consist of fixed acquisition costs and variable fuel costs(Gao & Lu, 2021). Genetic Algorithm (GA) to solve the Green Vehicle Routing Problem (G-VRP) Routing Problem with Tabu Search (Eltoukhy et al., 2018). A Simulated Annealing Heuristic for the Capacitated Green Vehicle Routing Problem(Normasari et al., 2019). A Fuel Efficient Green Vehicle Routing Problem with Varying Speed Constraint (F-GVRP)(Poonthalir & Nadarajan, 2018)(Karami, 2022). The Green Vehicle Routing Problem (Moghdani et al., 2021) A New Hybrid Whale Optimization Algorithm for Green Vehicle Routing Problem(Dewi & Utama, 2021). Completion of FCVRP Using Hybrid Particle Swarm Optimization Algorithm(Ali & Farida, 2021)

Based on previous research, the problem analysis in this study uses alternative solutions to the supplier fleet transportation system. Based on the Gap, the method used is the milk run approach with the Vehicle Routing Problem (VRP) method through two Particle Swarm Optimization (PSO) methods and Genetic Algorithm. The purpose of this research is to reduce the number of frequency of delivery supplier fleets through the Milkrun approach and reduce the total cost of fleet transportation

2. METHOD

This research was conducted in the automotive industry for two-wheeled vehicles in Indonesia. Research focuses on reducing the number of fleets and shipping transportation costs. This research is supported by primary data obtained from observations in the field. In addition, secondary data is also needed through company reports, supporting articles and institutional data related to the automotive industry. The research uses systematic stages to obtain the desired objective function as depicted in Figure 1

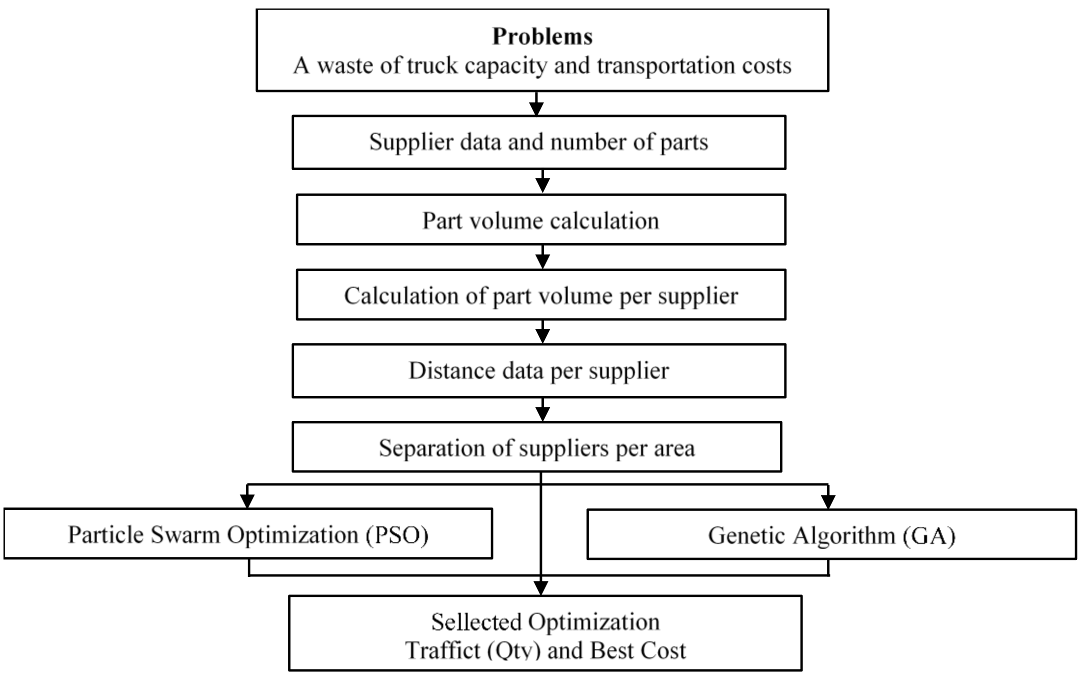

Figure 1 – Research Framework

2.1. Calculation of Area and Volume of Polybox per Part

$$TP = \sum_{i=1}^{N_t} D_t * OP_t * Pr_t \quad (1)$$

$$P_{Qty} = \frac{TP * OP_t}{P_c} \quad (2)$$

$$P_V = P_{s(p)} * P_{s(l)} * P_{s(t)} \quad (3)$$

$$P_{QV} = P_{Qty} * P_v \quad (4)$$

Remark:

N_t : Number of types
D_t : Request Per type
OP_t : Percentage of orders
Pr_t : Product per type
TP : Total parts per type
P_{Qty} : Part Qty
P_C : Packing Content
P_v : Volume Part
P_{QV} : Part Qty Volume
$Ps_{v(p)}$: Long Part
$Ps_{v(l)}$: Wide Parts
$Ps_{v(t)}$: High Part

2.2. Calculation of Polybox Needs per Day (Amount, Area and Volume) per Supplier

$$V_s = \sum_{i=1}^{N_t} P_{Qv} \quad (5)$$

Remark:

V_s : Volume Supplier
P_{Qv} : Part Qty Volume

2.3. Fleet Capacity Calculation

$$V_a = \sum_{k=1}^{N_s} \left(\sum (V_s < C_9) + (V_s < C_7) \right) \qquad k = 1,2, \ldots\ldots\ldots\ldots N_s \quad (6)$$

Remark:

V_a : Fleet Volumes
C_9 : Maximum Vehicle Capacity 9 meters
C_7 : Maximum Vehicle Capacity is 7 meters
N_s : Number of Suppliers

2.4. Distance Calculation (Pool1/2, Supplier, Factory)

$$J_{a9} = \sum \sum ecludean\left(Jarak(R_a)\right) \quad (7)$$

$$J_{a7} = \sum \sum ecludean\left(Jarak(R_a)\right) \quad (8)$$

$JC_{a9} = J_{a9} * C_{a9}$

$JC_{a7} = J_{a7} * C_{a7}$

Remark:

Distance : Distance Matrix (Distance between points using Google Map)

J_{a9} : Fleet Distance 9
J_{a7} : Fleet Distance 7
C_{a9} : 9M Operating Costs
C_{a7} : 7M Operating Costs
JC_{a9} : Fleet Cost 9M
JC_{a7} : Fleet Cost 7M
R_a : Fleet Route

2.5. Time Calculation

$W_{a9} = JC_{a9}/$ Fleet speed (9)
$W_{a7} = JC_{a7}/$ Fleet speed (10)
Remark:
W_{a9} : Fleet Time 9M
W_{a7} : Fleet Time 7M

2.6. Calculation of Fitness (Objective Function)

Cost = $(JC_{a9} * J_9) + (JC_{a7} * J_7)$ (11)
Minimize f = $\sum Cost$ (12)
Remark:
JC_{a9} : Fleet Cost 9M
JC_{a7} : Fleet Cost 7M
J_9 : Number of vehicles 9M
J_7 : Number of vehicles 7M
Cost : Cost function
f : Fitness function

2.7. Collect Data

The first part of the analysis phase is to collect some of the data needed for PSO and GA analysis. These data include production requirement data/day, data on the need for parts per type, truck fleet capacity data and distance matrix. The data can be seen in Table 1, Table 2. Table 3 and Table 4.

Table 1 – Production Requirement Data/Day

Engine production (type per day) (A)						
Type A	Type B	Type C	Type D	Type E	Type F	Total
4,100	1,150	1,900	350	250	2,100	9,850

Table 2 – Data on the Need for Parts Per Type

SUPLIER	PART NAME	Standard using part per tipe (B)						% ORDER (C)	Requirement Part per Tipe A*B*C)						
		A	B	C	D	E	F		A	B	C	D	E	F	Total
ADI	SW ASSY, START IDLE	0	0	1	0	0	0	100 %	-	-	1,900	-	-	-	1,900
ADI	SW ASSY, DIM HORN WINKER	0	0	1	0	0	0	100 %	-	-	1,900	-	-	-	1,900
ADI	COVER, CABLE	0	0	0	0	1	0	100 %	-	-	-	-	250	-	250
ADI	KEY SET	0	0	0	0	1	0	100 %	-	-	-	-	250	-	250
ADI	SW ASSY, SEAT OPENER	0	0	0	0	1	0	100 %	-	-	-	-	250	-	250
ADI	SW ASSY, START	0	0	0	0	1	0	100 %	-	-	-	-	250	-	250

Table 3 – Truck Fleet Capacity Data

	Long	Wide	High	Square	Content
Pallet	110	110	12	12,100	145,200
Stack of polyboxes	100	100	100	10,000	1,000,000
Truck 9 meter	940	240	250	225,600	56,400,000
Truck 7 meter	750	240	245	180,000	44,100,000

	Fleet 9 Meter	Fleet 7 Meter
Available capacity (cm^3)	56,400,000	44,100,000
Maximum Palet (cm^3)	4,320,000	3,360,000
Truck Effective Capacity (cm^3)	52,080,000	40,740,000

Calculation of the distance between the Pool as many as 40 Suppliers. Factory location determination based on Google Map. The following recapitulation of the distance between the 40 pools can be seen in Table 4.

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UJoST

Universal Journal of Science and Technology

Vol. 2 No. 1 (2023) March 2023

Table 4 – Distance Matrix

	Pool1	Pool2	AHM	ADI	FNI	HLI	JVIC	NOK	NSK	SHI	SKI	SST1	SSY
Pool1		41.40	14.60	13.50	15.90	13.40	10.00	13.40	15.70	17.60	15.40	13.30	82.70
Pool2	41.40		37.90	40.90	38.70	41.50	34.40	38.20	40.00	41.70	39.90	37.60	61.90
AHM	14.6	37.90		3.70	2.70	3.90	4.40	1.70	3.60	5.40	3.30	1.60	72.90
ADI	13.5	40.90	3.7		2.70	0.80	10.50	5.40	2.00	1.70	2.80	3.80	74.40
FNI	15.9	38.70	2.7	2.7		2.70	9.60	4.00	2.40	3.70	2.90	3.90	73.70
HLI	13.4	41.50	3.9	0.8	2.70		11.50	5.20	3.00	2.80	3.70	5.20	75.60
JVIC	10	34.40	4.4	10.5	9.60	11.50		4.10	6.00	7.60	5.80	4.10	75.30
NOK	13.4	38.20	1.7	5.4	4.00	5.20	4.10		2.40	4.00	2.20	0.13	73.00
NSK	15.7	40.00	3.6	2	2.40	3.00	6.00	2.40		2.40	0.95	2.30	73.00
SHI	17.6	41.70	5.4	1.7	3.70	2.80	7.60	4.00	2.40		2.90	4.30	74.90
SKI	15.4	39.90	3.3	2.8	2.90	3.70	5.80	2.20	0.95	2.90		2.10	72.10
SST1	13.3	37.60	1.6	3.8	3.90	5.20	4.10	0.13	2.30	4.30	2.10		73.00
SSY	82.7	61.90	72.9	74.4	73.70	75.60	75.30	73.00	73.00	74.90	72.10	73.00	

Supplier Grouping

Formula:

$$\sum_{k=1}^{Ns} J_{k1} < J_{k2}, \Sigma P_{1}, \Sigma P_{2} \quad (13)$$

Remark:

K : Number of Suppliers 1,2,3, ………N_s

J_{k1} : Supplier Distance -k to Pool-1

J_{k2} : Supplier Distance -k to Pool-2

P_1 : Pool-1

P_2 : Pool-2

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Vol. 2 No. 1 (2023) March 2023

Table 5 – Supplier Grouping

Group	Suplier*
Pool 1	1,2,3,4,5,6,7,8,10,12,18,19,20,21,22,23,24,26,28,29,30,31,32,33,34,35,36,37,38,39,40
Pool 2	9,11,13,14,15,16,17,25,27

3. RESULT AND DISCUSSION

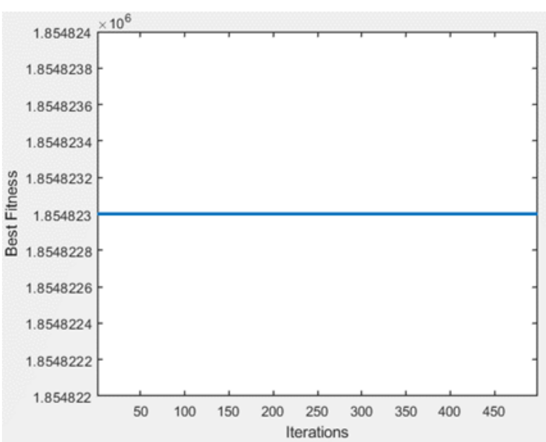
3.1. RESULT

1. Analysis with the Particle Swarm Optimization (PSO) Method

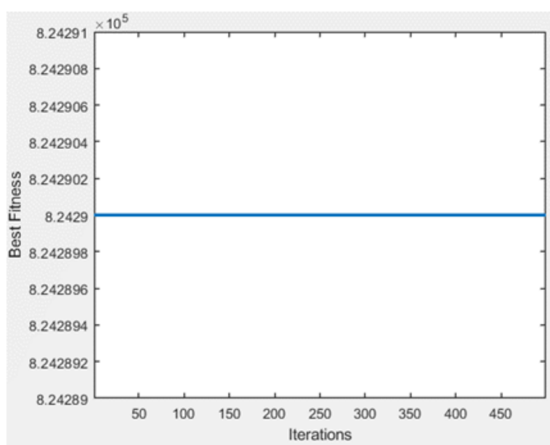
Calculations with the PSO optimization method with 500 iterations. Each iteration determines the optimal result. Following are the results of analysis with PSO Algorithm

Table 6 – Result PSO

		Pool 1	Pool 2	Total
Cost Minimum (Rp)		1,854,823	824,290	2,679,113
Truck fleet requirements	9meter	4	1	5
	7meter	0	0	-
Number of Traffic (Frequency)		7	1	8



Iteration Pool 1



Iteration Pool 2

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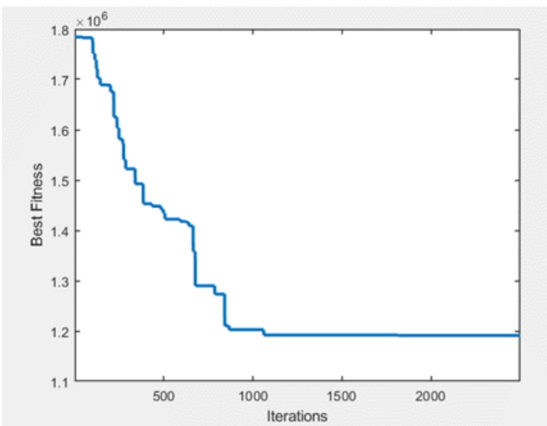
Vol. 2 No. 1 (2023) March 2023

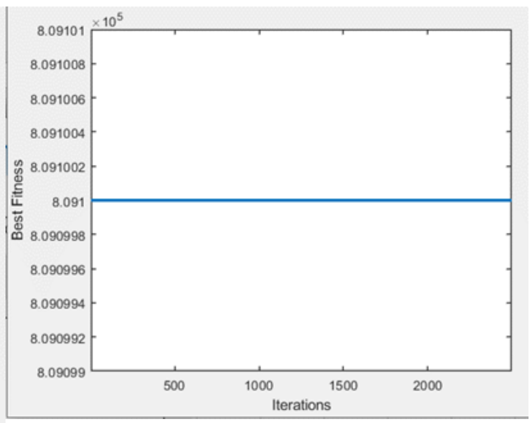
2. Analysis with Genetic Algorithm Method (GA)

Calculations with the GA optimization method with 2500 iterations. Each iteration determines the optimal result. Following are the results of analysis with GA:

Table 6 – Result GA

		Pool 1	Pool 2	Total
Cost Minimum (Rp)		1,190,958	809,100	2,000,058
Truck fleet requirements	9meter	3	1	4
	7meter	0	0	0
Number of Traffic (Frequency)		7	1	8





Iteration Pool 1 Iteration Pool 2

Based on the analysis of the PSO and GA optimization methods, optimal results are obtained. This analysis yields lower results in cost usage and the number of truck fleets required. The following is a comparison of total fleet traffic and operational costs per day for 40 Suppliers can be seen in Table 7

Table 7. Comparison of results before and after the study

	Preliminary data	PSO	GA
Cost Minimum (Rp)	2,769,330	2,679,113	2,000,058
Truck fleet requirements (Unit)	40	5	4
Number of Traffic (Frequency)	40	8	8

The results of the analysis with PSO and GA show the number of trucks needed, the amount of traffic and transportation costs. Results of the analysis show that GA is more efficient in producing the required number of truck fleets and transportation costs than PSO

3.2. DISCUSSION

The results after the research show a decrease in the amount of traffic, the number of fleet needs and transportation costs. However, this research can still be developed with an IoT approach as was done by (Karouani & Elgarej, 2022)to monitor fleet movement communications. Based on the results of this study, there are several benefits that can be obtained, including for researchers to be used as a reference for further research related to route optimization, capacity and number of fleets using the(Ramadhani & Garside, 2021) combination method. For industrial players, it can be used as a step to fix supply chain problems with reference to determining routes, capacity and fleet numbers quickly.

4. CONCLUSION

Based on the analysis using the PSO and GA methods, an efficient number of fleets and costs are obtained. Both of these methods can be said to be successful in finding optimal solutions to problems in the supply chain. This can be seen from the results of the PSO and GA algorithms which both provide significant results in the form of a lower amount of traffic. The GA method results in fewer fleets and costs compared to the PSO method. This study has several limitations that need to be developed for further research, namely not conducting an analysis related to reducing CO_2 emissions. This is intended to get a sustainable green industry in the supply chain.

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