Manpower Planning and Allocation in Warehousing Area: A Multi-Objective Optimization Approach using Goal Programming and Particle Swarm Optimization Methods

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Abstract

The shortage of warehouse labor has long been a thorn in the global supply chain, and it impacts the entire company as well as its customers. To meet unpredictable demand, companies have been heavily reliant on daily workers, but the high percentage of their use need to calculate again because of the difference skill with contractual worker. This research aims to create an optimization model using goal programming and particle swarm optimization (PSO) approach that can determine the required number of contract and daily workers and optimize the cost of labor, while ensuring that the number of daily workers does not exceed 10% of the total number of contract workers also to improve productivity and optimize resources in the warehouse. The results show that the model can significantly reduce the use of daily workers and optimize the distribution of manpower, resulting in a reduction of total manpower needed in the warehouse by around 25%. Moreover, the model optimization also leads to a cost savings of approximately 19% compared to the previous labor allocation system.

Keywords
Optimization, daily worker, contract worker, goal programming, particle swarm optimization.

1. Introduction
Warehouse operations refer to the processes involved in the handling, storage, and movement of goods within a warehouse facility. These operations can be performed by both contract workers and daily workers, depending on the specific needs of the warehouse. According to Porter (2011), a warehouse or warehousing is a place for storing goods that has other functions related to a series of supply activities such as sorting and packing goods before entering the distribution process.

Warehouse manpower shortages have long been a thorn in the global supply chain, when there is a shortage of personnel, the repercussions are felt across the company and also to customers. Labor shortages make warehouse work difficult, especially amidst the growing demand for warehouse workers. Companies looking to grow should re-examine their operations and see how to reduce the impact of labor shortages on operations by optimizing the company's workforce.

Currently, most of the company's warehouses still require workers in large numbers to carry out tasks and carry out operations in the warehouse area. This is because warehouses still do not have access to the technology and robotics needed to automate their operations. In order to deal with unpredictable demand, companies utilize temporary workers (daily workers) to carry out their operations. Temporary workers or casual daily workers have become key players in the warehouse and fulfillment sectors. Hiring freelance daily workers for different seasons or loads is a popular choice. Most companies choose to work on a day labor force instead of hiring full time employees as permanent employees are harder to find in these uncertain times during and after the pandemic (Space, 2022).

This research was conducted at a logistics company and the warehouse was carried out in two Cikarang site areas, where there were 6 warehouses. Then data is collected for workers who are directly related to warehousing operations and segregation of workers is carried out according to their status, namely, contract workers and daily workers (DW). From there we got the usage with the largest data on one of the warehouses (code W-6) which around 55.74% of daily worker usage in average per day. In more detail, researcher also retrieves data from orders that occur in the warehouse (code W-6), which can be seen in Figure 1. It is known that the actual volume looks more than the target/month set by the customer.

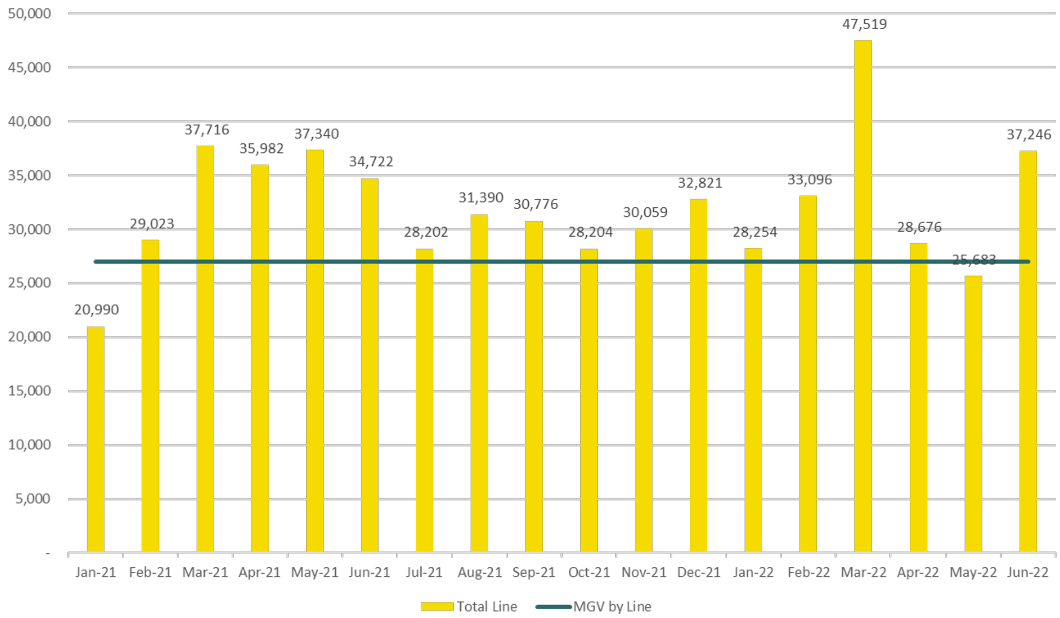


Figure 1. Monthly total volume data compared to targets from customers

With the high use of daily workers and the intensity of their use almost every day, this is not very good for the company because it can have several negative impacts on ongoing warehousing operations. Also, there's a regulation related to daily worker, based on President Regulations No. 35/2021 article 10 paragraph 3, which reads "*The daily work agreement as referred to in paragraph (2) is carried out provided that the Worker/Labour works less than 21 (twenty-one) days in 1 (one) month*". And for other negative impact it can be seen on Figure 2.

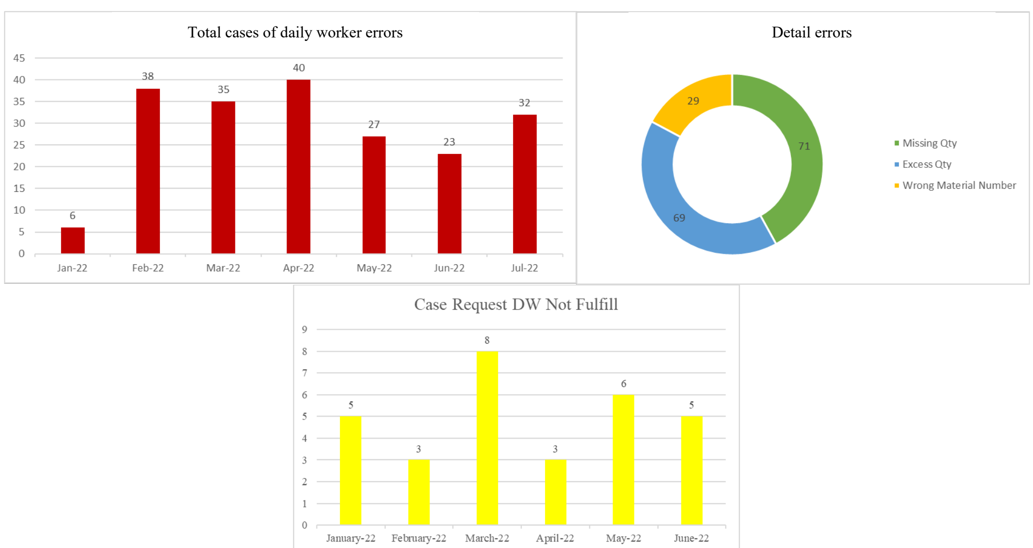


Figure 2. Total cases of daily worker errors and cases of unfulfilled daily worker requests

Regardless of the impact, but from the cost factor, daily workers have a smaller price calculation than contract workers, which the cost are cheaper around 12%. But the very high percentage of daily labor usage is a matter that needs to be fixed. Researchers also benchmarked several other logistics companies and found that daily labor usage in the range of 5-15% and is seasonal not in daily basis.

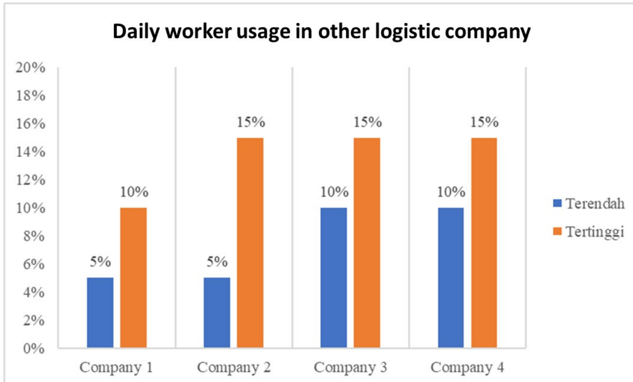


Figure 3. Daily worker usage in other companies

This over dependency on daily workers can have a significant impact on warehouse productivity, as these workers may not have the same level of training or experience as contract worker. This can lead to errors, delays, and increased risk of accidents, which can further impact productivity. To improve warehouse operations and increase productivity, it is crucial to develop more effective manpower planning and allocation strategies.

1.1 Objectives

This study also aims to determine the number of contract workers and daily workers needed and to optimize labor costs, minimize the number of daily workers not to exceed 10% of the total contract workers and enable higher productivity and better optimization of resources in warehouse. So that this research is expected to provide benefits for readers to find out a good optimization model that can minimize daily workers and maximize assignments for contract workers in more economical and profitable for company.

2. Literature Review

2.1 Warehouse

The supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only producers and suppliers, but also transporters, warehouses, retailers and even the customers themselves (Meindl 2016). Warehouses are an essential component of most modern supply chains. They may be involved in various stages of the sourcing, production, and distribution of goods, from handling raw materials and work-in-process to finished products. As delivery points that serve the next customer in the chain, they are critical to the provision of a high level of customer service (Alan Rushton 2014).

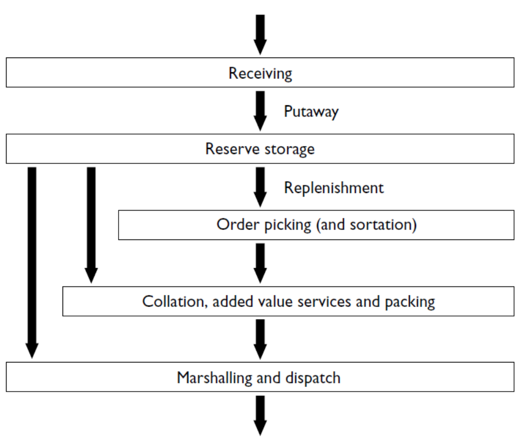


Figure 4. General function and flow process in warehouse

2.2 Manpower Planning

Manpower planning is a process within a company to ensure that the company will have the right number of workers and have the right skills, at the right time and place so that economic value is obtained with maximum utility, according to Obijifo (2012). Basically, manpower planning involves a planning process into human resources in an organization or company. According to Gary (2005), manpower planning is a strategy for the acquisition, utilization, improvement and retention of a company's human resources. The purpose of this manpower planning is to provide continuity of worker efficiency in the overall business process and optimum utilization of manpower resources. The basic components of a manpower system are people, jobs, time and money, according to Grinold (1977) in Holm (2008).

In determining the policy of manpower planning, the interaction between these components must be considered carefully. The essence of manpower planning is providing the right number of workers with the right skills at the right time at the minimum cost. But sometimes there is a condition where the constraints in the system do not have to be fully met.

2.3 Productivity

Work productivity is a comparison between the results that can be achieved with the overall resources used per unit time. Work productivity is a measure of the success of the workforce in producing a product within a certain time (Sumarsono 2015). Productivity is a comparison of the results obtained with the production factors used (Romondor 2012). If employees have encouragement that can increase their ability to increase work productivity, with these abilities, the company's goals will be carried out effectively and efficiently (Huzain 2015).

From these definitions, it shows that work productivity is a mental attitude that always has the view that the quality of life today must be better than yesterday and tomorrow must be better than today. If the employee's work productivity is high, then the employee able to show the same number of results with a larger amount of input producing a larger amount than the amount of input. Conversely, if employee productivity is low, employees are not able to produce the same results or production and are not even able to meet the targets set by the company within a certain time.

2.4 Skill Matrix

The skill matrix is used to see the readiness of employees based on their skills, so a competency map is needed to measure their abilities. This competency map can be used as a material for consideration for the placement of employees based on their expertise, or whether additional training is needed to meet the specified skill qualifications. Skill matrix is a tool to map employee skills based on their jobdesk. Information on the skill matrix can be in the form of tables, grids, icons, alphabets or numbers with conditions that are easy to understand. The purpose of using the skill matrix is to maximize operator utilization and accurately delegate operators to existing operations (Islam M. M. et al. 2015).

2.5 Goal Programming

Goal programming was introduced by Charnes et al. (1955) and Charnes and Cooper (1961). The linear programming model has three main elements, namely the decision variable, the objective function and the constraint function. The basic approach of goal programming is to set a goal which is stated with a certain number for each goal, formulate an objective function, and then look for a solution by minimizing the number of deviations from the objective function (Atmasari 2010). This model allows considering multiple objectives simultaneously while determining the decision to find the best solution from a set of feasible solutions (Liao 2009).

According to Nasendi & Anwar (1985), the Goal Programming Model is divided into two types, namely the general model without priority and the model with priority factors as follows:

- Objective function
  Minimize: $Z = \sum_{i=1}^{m} W_i \left(d_i^+ + d_i^-\right)$
  $Z = \sum_{i=1}^{m} W_i^+ d_i^+ + W_i^- d_i^-$
- Constraint :
  Goal constraint
  $\sum_{i=1}^{m} a_{ij} X_j + d_i^+ - d_i^- = b_i$
  For i = 1, 2,…,m objective
  Constraint function
  $\sum_{j=1}^{n} g_{kj} X_j \leq Ck$

For k = 1, 2,…,p
For j = 1, 2,…,n
And
$X_j, d_i^+, d_i^- \geq 0$
$d_i^+, d_i^- = 0$
Remark
d_i^+ = positive deviational variable from the i goal
d_i^- = negative deviational variable from the i goal
a_{ij} = the coefficient associated with variable j in the i goal
X_j = decision variable
b_i = the associated right hand side value
g_{kj} = the coefficient for constraint
Ck = The number of k resources available.
W_i^+ = weight to be assigned to the respective positive deviation variables.
W_i^- = weight to be assigned to the respective negative deviation variables.

The initial goal programming formulations ordered the unwanted deviations into a number of priority levels, with the minimization of a deviation in a higher priority level being infinitely more important than any deviations in lower priority levels. This is known as lexicographic (preemptive) or non-Archimedean goal programming. Iserman (1982), Sherali (1982) and Ignizio (1983a) stated the lexicographic goal programming model. Lexicographic goal programming should be used when there exists a clear priority ordering amongst the goals to be achieved.

In preemptive goal programming, the objectives can be divided into different priority classes. Here, it is assumed that no two goals have equal priority. The goals are given ordinal ranking and are called preemptive priority factors. These priority factors have the relationship P1 >>> P2 i >>> Pi+1 m where the P1 goal is so much more important than the P2 goal and P2 goal will never be attempted until the P1 goal is achieved to the greatest extent possible.

2.6 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is the brainchild of Eberhart and Kennedy in 1995, which is known as a metaheuristic algorithm. The behavior of a group of birds and fish to maintain their lives is the basis for creating a stochastic optimization technique, namely PSO. One of the evolutionary processing techniques, namely PSO, has a random population (particles) that initiates the disbursement algorithm and forms the basis of the population in PSO (Trelea 2003). According to (Shi, 2001) PSO is similar to that assessed by Genetic Algorithm (GA) by initiating a population of random solutions in the existing system. In multivariable optimization attempts, a group is assumed to have a definite size with the initial position of each particle being at a random location in the multidimensional space. Each particle is considered to have two specific characteristics, namely position and velocity (velocity). The particle moves in a room (space) and then memorizes the best position it has found or passed and has an energy source which is interpreted as the purpose of the function value. This information will be conveyed by each particle to another particle so that the position and speed of each particle can be adjusted.
Each particle is treated like a point in a certain dimension of space. Then there are two factors that characterize the particle status in the search space, namely the particle position and particle velocity (Kennedy and Eberhart 1995). The following is a mathematical formula that describes the position and velocity of a particle in a certain spatial dimension:

$$x_{i(t)} = x_{i(t)}, x_{i(t)}, \dots, x_{iN(t)}$$
$$v_{i(t)} = v_{i(t)}, v_{i(t)}, \dots, v_{iN(t)}$$

Remarks
x = particle position
v = particle velocity
i = Indeks
t = Iteration t-th
N = Room dimensions

The update of the particle velocity at each iteration is described by the following mathematical model (Santosa and Willy 2011):

$$v_{i(t+1)} = wv_{i(t)} + c_1 r_1 \left(P_{best(i)} - x_{i(t)}\right) + c_2 r_2 \left(G_{best(1)} - x_{1(1)}\right)$$
$$x_{i(t+1)} = v_{i(t+1)} + x_{i(t)}$$

Remarks
P_{best} = local best
G_{best} = global best
c = coefficient accelarations
r = random number
w = inertia weight

3. Methods

In this paper, researcher propose a methodology for formulating a mathematical model using goal programming and computing the optimal solution using particle swarm optimization (PSO). Goal programming is a mathematical programming technique used to solve multi-objective problems, where conflicting goals need to be optimized simultaneously. The proposed model is formulated to minimize the deviation between the desired and actual levels of multiple objectives subject to constraints. The PSO algorithm is a population-based optimization technique inspired by the social behavior of bird flocks or fish schools. It is a stochastic optimization method that searches for the optimal solution by iteratively updating the positions of particles based on their own best positions and the best positions found by the entire swarm. The proposed methodology combines the strengths of both goal programming and PSO to provide an effective and efficient approach for solving complex multi-objective problems.

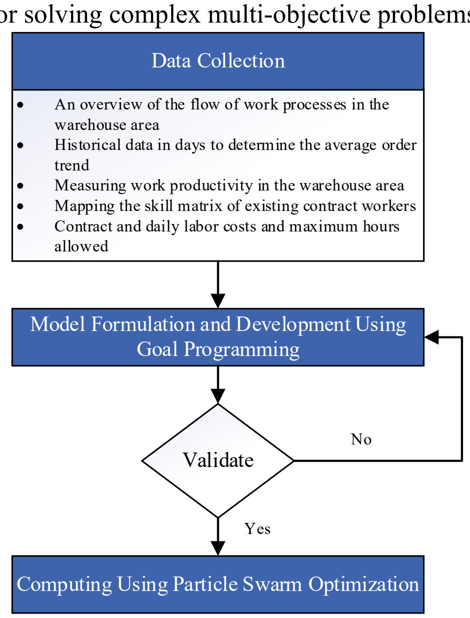


Figure 5. Methodology

4. Data Collection

4.1 Flow Process Warehouse

The warehousing process carried out at this company runs efficiently and effectively with an integrated warehouse management system. The warehousing process carried out at this company includes several stages involving the management of inventory, storage, transfer, collection and delivery of goods. The description of the process flow carried out is as follows.

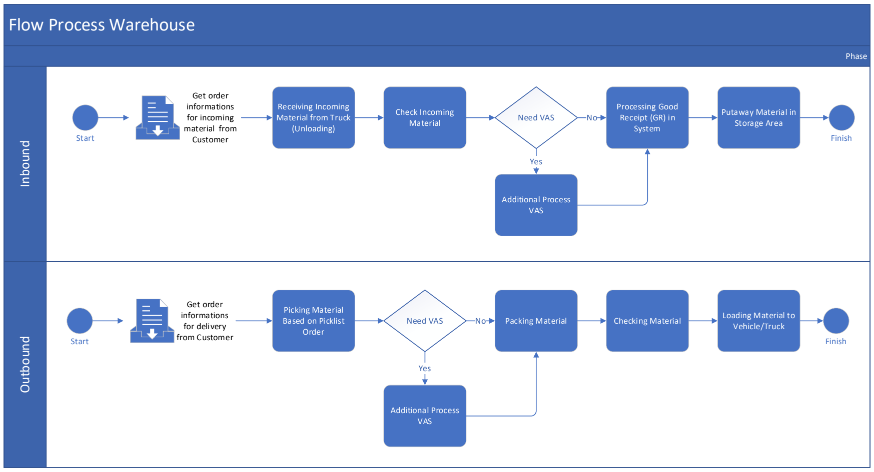


Figure 6. Flow process warehouse

4.2 Salary of worker

Based on the data obtained, there is a significant difference in the number of contract workers and daily workers. The number of contract workers in the warehousing process is 22 people, while the average daily use of labor is approximately 25 people. Apart from differences in numbers, there are significant differences in terms of salary between contract workers and daily workers. As previously mentioned, contract workers are 12% more expensive than daily workers. For current salary that company pay for each month is around IDR 252.834.629.

Table 1. Salary of worker

Description	Salary	
	Month	Daily
Contract worker	IDR 5,737,407	IDR 229,496
Daily worker	IDR 5,064,467	IDR 202,579

4.2 Productivity Measurement

To measure worker productivity, the unit of measure (UOM) per hour is currently used, which indicates the number of lines (orders) or pallets that can be processed by workers in one working hour. Based on the productivity data that collected, the average productivity of workers in the warehouse area is in the range of 6 to 37 UOM per hour.

Table 2. Productivity contract worker

Code	Category	Task	UOM	Productivity (UOM per Hour)	Variance				
					1	2	3	4	5
1	Inbound	Inbound Unloading	Pallet	30	29	28	36	27	28
2	Inbound	Inbound Putaway	Lines	11	8	13	12	16	8
3	Inbound	Inbound Checking MIX	Lines	16	13	24	14	13	16
4	Inbound	Inbound Checking Standard	Pallet	6	7	7	5	8	5
5	Inbound	Inbound Putaway	Pallet	21	17	22	14	28	24
6	Outbound	Outbound Packing	Lines	14	12	18	16	11	11
7	Outbound	Outbound Picking Console	Lines	12	8	14	15	13	12
8	Outbound	Outbound Pick No Console	Lines	15	22	22	8	9	16
9	Outbound	Outbound Checking	Lines	18	19	22	19	16	14
10	Outbound	Dispatch	Lines	37	31	32	46	45	30

Then there is a difference in productivity between contract worker and daily worker. Based on the information that has been obtained, it can be assumed that the average daily worker can only meet around 50% of the productivity standards of contract worker. This may be due to differences in work experience and training received by each worker. Contract workers generally have more work experience and receive more intensive training than daily workers.

4.3 Skill Matrix

In collecting data regarding the skill matrix of workers in the warehouse area, the average contract worker is able to master 4 to 7 skills. To categorize workers' abilities, a standard is established that workers who master more than 60% of the given skill matrix can be categorized as experts or indicator 1, while workers who master less than 60% will be considered as indicator 0. The following table describes the skill matrix.

Table 3. Skill matrix of contract worker

Description	Unloading	Checking	Putaway	Picking	VAS	Packing	Dispatcher	Total
Contract worker 01	1	1	1	1	0	1	0	5
Contract worker 02	0	1	1	1	1	1	0	5
Contract worker 03	0	1	0	1	1	1	0	4
Contract worker 04	1	1	1	1	1	1	0	6
Contract worker 05	1	1	1	1	1	1	1	7
Contract worker 06	1	1	1	1	1	1	0	6
Contract worker 07	1	1	1	1	1	0	0	5
Contract worker 08	1	1	1	1	1	0	0	5
Contract worker 09	1	1	1	1	1	1	0	6
Contract worker 10	1	1	1	1	0	1	0	5
Contract worker 11	1	1	1	1	1	1	1	7
Contract worker 12	0	1	1	1	1	1	1	6
Contract worker 13	0	1	0	1	1	1	1	5
Contract worker 14	0	1	1	1	0	1	1	5
Contract worker 15	1	1	1	1	0	1	1	6
Contract worker 16	1	1	0	1	0	0	1	4
Contract worker 17	0	1	1	1	1	0	0	4
Contract worker 18	1	1	1	1	1	1	1	7
Contract worker 19	0	1	1	1	1	1	0	5
Contract worker 20	0	1	1	1	0	1	1	5
Contract worker 21	1	1	1	1	0	1	1	6
Contract worker 22	0	1	1	1	1	1	1	6

Table 4. Mapping category worker by skill with total additional allowance

Category worker by Skill	Skill Masterin	Total Skill
Contract worker category 1	2,4,5,6	4
Contract worker category 2	1,2,3,7	4
Contract worker category 3	2,3,4,5	4
Contract worker category 4	1,2,3,4,6	5
Contract worker category 5	2,3,4,5,6	5
Contract worker category 6	1,2,3,4,5	5
Contract worker category 7	2,4,5,6,7	5
Contract worker category 8	2,3,4,6,7	5
Contract worker category 9	1,2,3,4,5,6	6
Contract worker category 10	2,3,4,5,6,7	6
Contract worker category 11	1,2,3,4,6,7	6
Contract worker category 12	1,2,3,4,5,6,7	7
Daily Worker	0	0

Total Skill	Allowance
4	100,000.00
5	150,000.00
6	200,000.00
7	250,000.00

Workers are reprocessed based on the number of skills and variations they have mastered. So based on this data it is assumed that each capacity mastered will increase the wage allowance earned. This is used as a differentiator in the calculation of worker in the optimization formulations.

4.4 Order Trend in Warehouse

Historical data collection of inbound and outbound orders from customers within a period of one year starting from July 2021 to June 2022. The data is processed again so that we can find out the trend of average orders in working days, namely Monday to Saturday. Through analysis of trends and patterns identified from this data, companies can anticipate increases in demand and ensure the availability of sufficient resources to meet customer demands.

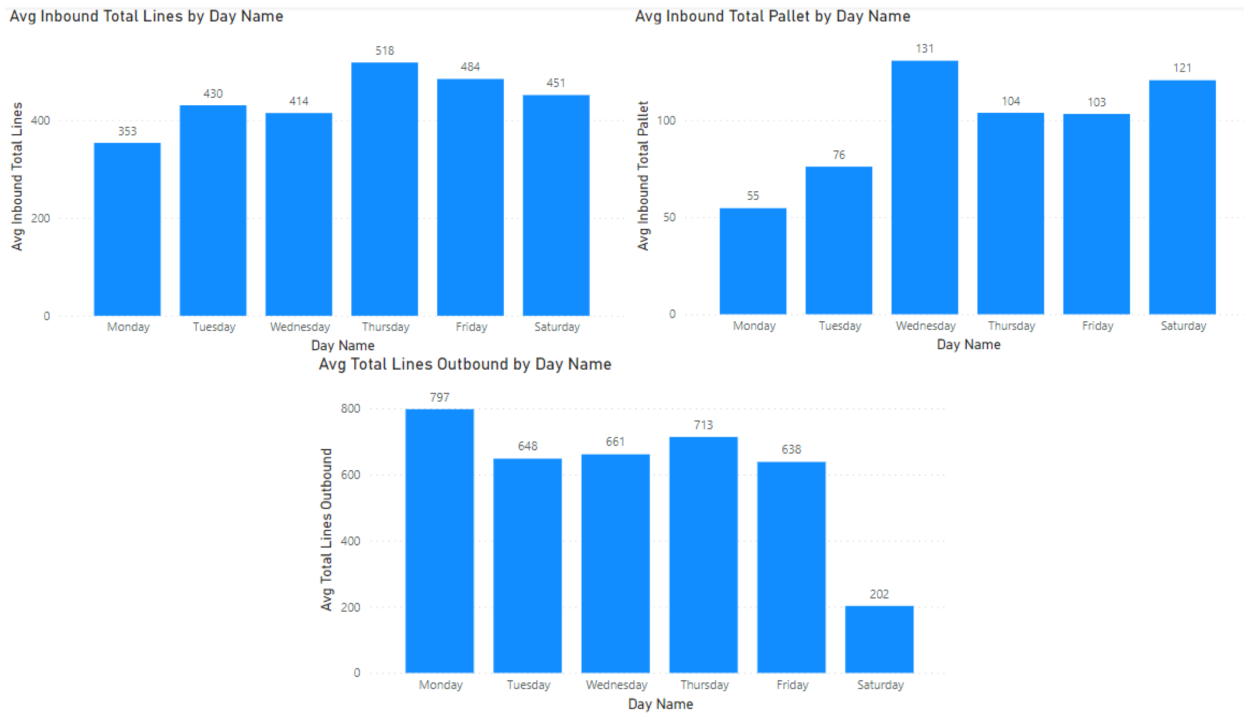


Figure 7. Inbound, outbound trend order in daily basis

From the above data it can be seen that the average inbound lines, inbound pallets and outbound lines are 442 lines, 98 pallets and 610 lines respectively. By understanding patterns and trends in customer demand, companies can make adjustments to capacity and resources, and optimize the efficiency and effectiveness of warehousing operations.

Table 5. Allocated time per day to fulfill order

Tipe order	Average order per day						Allocated time per day					
	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat
Inbound-Lines	353	430	414	518	484	451	2.3	3	2.7	3.1	3.2	4.7
Inbound-Pallets	55	76	131	104	103	121	0.4	0.5	0.9	0.6	0.7	1.3
Outbound-Lines	797	648	661	713	638	202	5.3	4.5	4.4	4.3	4.1	2
Total	1205	1154	1206	1335	1225	774	8	8	8	8	8	8

Average order per day	Average allocated time per day
442	3
98	1
610	4
1150	8

To find out the productivity of each category of workers, a mapping process is carried out which is carried out in accordance with the current description of the process. So that from the data mapping it can be seen the productivity of workers on the type of orders in units of hours in the following table.

Table 6. Productivity worker on the order type

Category worker by Skill	Inbound - Lines	Inbound - Pallet	Outbound - Lines
Contract worker category 1	13	11	19
Contract worker category 2	19	19	17
Contract worker category 3	14	14	18
Contract worker category 4	14	19	16
Contract worker category 5	14	14	18
Contract worker category 6	14	19	19
Contract worker category 7	18	11	23
Contract worker category 8	19	14	20
Contract worker category 9	14	19	19
Contract worker category 10	19	14	23
Contract worker category 11	19	19	20
Contract worker category 12	19	19	23
Daily Worker	10	10	12

4.5 Formulation Model Goal Programming

After collecting data related to the allocation and scheduling of labor in the warehouse area, then the formulation of the goal programming model was carried out. This model aims to solve the problem of workforce allocation and scheduling based on predetermined objectives. Where the formulation of this goal programming model will use several variables such as the number of contract and daily workers, labor productivity, and the cost of using labor. Apart from that, several parameters will also be used such as the number of inbound and outbound orders, and the existing work time limit.

This objective function can be formulated as follows:

$$\begin{aligned}Minimize\ Z = {} & C_{K1}(X_{K1} + X_{K2} + X_{K3}) + C_{K2}(X_{K4} + X_{K5} + X_{K6} + X_{K7} + X_{K8}) + C_{K3}(X_{K9} + X_{K10} + X_{K11}) \\ & + C_{K4}X_{K12} + C_{H1}X_{H1} \leq V_1\end{aligned}$$

$$\begin{aligned}Minimize\ Z = {} & C_{K1}(X_{K1} + X_{K2} + X_{K3}) + C_{K2}(X_{K4} + X_{K5} + X_{K6} + X_{K7} + X_{K8}) + C_{K3}(X_{K9} + X_{K10} + X_{K11}) \\ & + C_{K4}X_{K12} + C_{H1}X_{H1} - (d_1^+ - d_1^-) = V_1\end{aligned}$$

Goal constraint:

1. Constraints on the number of workers

$$X_H \leq 0.1X_K$$
$$X_H - d_2^+ = 0.1X_K$$

2. Constraints on working hours

$$8X_K + 8X_H = JK_1$$
$$8X_K + 8X_H - (d_3^+ - d_3^-) = JK_1$$

3. Constraints on productivity, skill matrix and working hours

a. Each task is carried out by a worker that has the skills and abilities appropriate to the tasks and worker productivity in order to maximize the output generated in inbound (lines)

$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK \geq IL$$
$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK - (d_4^+ - d_4^-) = IL$$

b. Each task is carried out by a worker that has the skills and abilities appropriate to the tasks and worker productivity in order to maximize the output generated in inbound (pallet)

$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK \geq IP$$
$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK - (d_5^+ - d_5^-) = IP$$

c. Each task is carried out by a worker that has the skills and abilities appropriate to the tasks and worker productivity in order to maximize the output generated in outbound (lines)

$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK \geq OL$$
$$X_{(K1-K12)}TP_{(K1-K12)}RJK + X_{(H1)}TP_{(H1)}RJK - (d_6^+ - d_6^-) = OL$$

Remarks:

X_{K1-K12} = Number of contract workers
X_{H1} = Number of daily workers

C_{K1-K4} = Contract worker labor costs plus skills allowance
C_{H1} = Daily worker labor costs
V_1 = Maximum labor cost
JK_1 = Daily working hours
$X_{(K1-K12)}$ = The number of workers allocated to task with skill matrix
$TP_{(K1-K12)}$ = The productivity of contract workers on the type of orders per hour
$TP_{(H1)}$ = The productivity of daily workers on the type of orders per hour
RJK = Average hourly allocation per worker per day
IL_{ij} = Total order *inbound lines*
IP_{ij} = Total order *inbound pallet*
OL_{ij} = Total order *outbound lines*
d_1^+ = Positive deviational variable from goal
d_1^- = Negative deviational variable from goal
d_2^+ = Positive deviational from daily worker provisions
d_3^+ = Positive deviational from working hours
d_3^- = Negative deviational from working hours
d_4^+ = Positive deviational from target *inbound lines*
d_4^- = Negative deviational from target *inbound lines*
d_5^+ = Positive deviational from target *inbound pallet*
d_5^- = Negative deviational from target *inbound pallet*
d_6^+ = Positive deviational from target *outbound lines*
d_6^- = Negative deviational from target *outbound lines*

4.5 Formulation Model Particle Swarm Optimization

Once the goal programming formulation is clear, particle swarm optimization (PSO) is used to find the optimal solution. In this case, each particle in the PSO algorithm represents a potential solution to the goal programming problem, and each iteration of the algorithm is used to evaluate and update this solution. The model can be stated as follows:

$$vXK_{(p,K)} = wvXK_{(p,K)} + c_1 r\left(P_{best}XK_{(p,K)} - XK_{(p,K)}\right) + c_2 r(G_{best}XK_{(K)} - XK_{(p,K)})$$
$$vH_{(p)} = wvH_{(p)} + c_1 r_1\left(P_{best}H_{(p)} - H_{(p)}\right) + c_2 r_2(G_{best}H - H_{(p)})$$
$$XK_{(p,K)} = XK_{(p,K)} + vXK_{(p,K)}$$
$$H_{(p)} = H_{(p)} + vH_{(p)}$$

Remarks:
XK = Number of contract workers
K = Category of contract workers
H = Number of daily workers
p = Particle
c = *coefficient accelarations*
r = random number
w = inertia weight

4.6 Computational Experiments

In this paper, the computational experiment for solving a multi-objective problem using Particle Swarm Optimization (PSO) implemented in Microsoft Excel. The macro-Excel implementation allows for an easy and efficient way to perform PSO optimization, without the need for additional software or programming languages.

Table 7. The algorithm of proposed PSO

Step 01. Initial procedure to define any parameters used

```
Const gajiTAW1 As Double = 5737407 + 100000
Const gajiTAW2 As Double = 5737407 + 150000
Const gajiTAW3 As Double = 5737407 + 200000
Const gajiTAW4 As Double = 5737407 + 250000
Const gajiDW As Double = 5064467
Const maxNumPekerja As Double = 9
Public ProdK(1 To 12, 1 To 3) As Double
Public ProdH(1 To 3) As Double
Public InbLines(1 To 6) As Double
Public InbPallets(1 To 6) As Double
Public OutbLines(1 To 6) As Double

'start of constants and variables for PSO
Const w As Double = 0.75 'w is inertia weight
Const c1 As Double = 1.25 'c1 is constant value for local (particle) best contribution
Const c2 As Double = 1.25 'c2 is constant value for global best contribution
Const maxVel As Double = 1.5 'maximum velocity
Const minVel As Double = -1.5 'minimum velocity
```

Step 02. Define constraint – Regarding the limitation on the number of daily workers not exceeding 10% of the contract workers

```
Function constraint1(pXK() As Double, pH)
    'constraint-1 (Harian should be <= 10% of total K
    isFail = False
    totXK = 0
    For K = 1 To 12:
        totXK = totXK + pXK(K)
    Next K
    If pH > 0.1 * totXK Then isFail = True
    constraint1 = isFail
End Function
```

Step 03. Define constraints – Regarding productivity, matrix skills, total orders and working hours

```
Function constraint2(pXK() As Double, pH)
    'constraint-2 (have to complete 100%)
    Dim capForInbLinesK(12) As Double
    Dim capForInbPalletsK(12) As Double
    Dim capForOutbLinesK(12) As Double

    totForInbLinesK = 0
    For K = 1 To 12
        totForInbLinesK = totForInbLinesK + pXK(K) * ProdK(K, 1) * 3
    Next K
    capForInbLinesH = pH * ProdH(1) * 3

    totForInbPalletsK = 0
    For K = 1 To 12
        totForInbPalletsK = totForInbPalletsK + pXK(K) * ProdK(K, 2) * 1
    Next K
    capForInbPalletsH = pH * ProdH(2) * 1

    totForOutbLinesK = 0
    For K = 1 To 12
        totForOutbLinesK = totForOutbLinesK + pXK(K) * ProdK(K, 3) * 4
    Next K
    capForOutbLinesH = pH * ProdH(3) * 4

    isFail = False

    'check constraint per day
    allowedSisa = 0
    For d = 1 To 6
        sisaInbLines = InbLines(d) - (totForInbLinesK + capForInbLinesH)
        sisaInbPallets = InbPallets(d) - (totForInbPalletsK + capForInbPalletsH)
        sisaOutbLines = OutbLines(d) - (totForOutbLinesK + capForOutbLinesH)
        If (sisaInbLines > allowedSisa) Or (sisaInbPallets > allowedSisa) Or (sisaOutbLines > allowedSisa) Then
            isFail = True
'            MsgBox ("Fail for day " & d)
            d = 7
        End If
    Next d

    constraint2 = isFail
End Function
```

Step 04. Determine fitness value

```
Function fitVal(pXK() As Double, pH)
    If constraint2(pXK, pH) Then
        fitVal = 10 ^ 16
    Else:
          If constraint1(pXK(), pH) Then
            fitVal = 10 ^ 16
          Else:
            fitVal = gajiTAW1 * (pXK(1) + pXK(2) + pXK(3)) + gajiTAW2 * (pXK(4) + pXK(5) + pXK(6) + pXK(7) + pXK(8)) + _
                     gajiTAW3 * (pXK(9) + pXK(10) + pXK(11)) + gajiTAW4 * pXK(12) + gajiDW * pH
            totWorkers = 0
            For K = 1 To 12
                totWorkers = totWorkers + pXK(K)
            Next K
            totWorkers = totWorkers + pH
            fitVal = fitVal + 1000000 * totWorkers
          End If
    End If
End Function
```

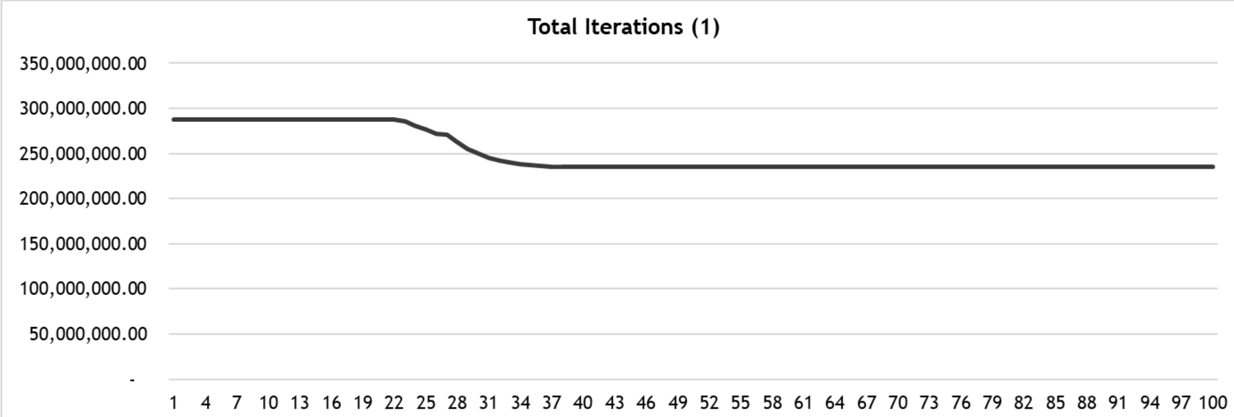
Step 05. Calculate velocity, update velocity and position and determine P*best* and G*best*

```
        'calculate velocities
        For p = 1 To numPtcl
            r = Rnd()
            For K = 1 To 12
                vXK(p, K) = w * vXK(p, K) + c1 * r * (pBestXK(p, K) - XK(p, K)) + c2 * r * (gBestXK(K) - XK(p, K))
                If vXK(p, K) > maxVel Then vXK(p, K) = maxVel
                If vXK(p, K) < minVel Then vXK(p, K) = minVel
            Next K
            vH(p) = w * vH(p) + c1 * r * (pBestH(p) - H(p)) + c2 * r * (gBestH - H(p))
        Next p
        'update particle positions
        For p = 1 To numPtcl
            For K = 1 To K
'                XK(p, K) = Round(XK(p, K) + vXK(p, K), 0)
                XK(p, K) = XK(p, K) + vXK(p, K)
                If XK(p, K) > maxNumPekerja Then XK(p, K) = maxNumPekerja
                If XK(p, K) < 0 Then XK(p, K) = 0
            Next K
'            H(p) = Round(H(p) + vH(p), 0)
            H(p) = H(p) + vH(p)
            If H(p) > maxNumPekerja Then H(p) = maxNumPekerja
            If H(p) < 0 Then H(p) = 0
        Next p
        Cells(iter, 1).Value = gbestFitVal
    Next iter
    For K = 1 To 12
        Cells(2, 4 + K).Value = WorksheetFunction.RoundUp(gBestXK(K), 0)
    Next K
    Cells(2, 4 + 13).Value = WorksheetFunction.RoundUp(gBestH, 0)
End Sub
```

The PSO algorithm is initialized with a population of particles, each representing a potential solution. The particles are then iteratively updated based on their own best positions and the best positions found by the entire swarm. The algorithm continues until a stopping criterion is met, such as a maximum number of iterations or a desired level of convergence.

5. Results and Discussion

In the total iterations that have been carried out, it can be seen that the optimal number of workers takes into account the overall constraints as follows:



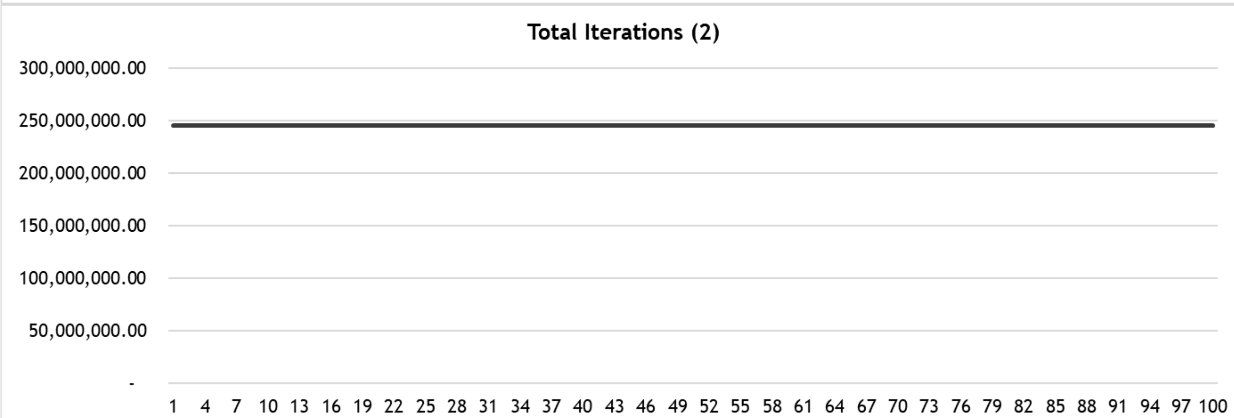


Figure 8. PSO calculations by iterations (1) and (2)

Table 8. Total contract & daily worker from PSO calculations

Category Worker	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	H
Total Worker (1)	0	2	1	2	1	2	5	5	3	3	7	3	0
Total Worker (2)	2	8	2	2	1	7	3	1	2	2	2	1	3

Descriptions	Calculations (1)	Calculations (2)
Total contract workers	34	33
Total daily workers	0	3
Total workers	34	36

Result showed using PSO algorithm for total cost manpower by comparing the results obtained are (1) IDR 234.971.838 & (2) IDR 245.277.832. The results show from the model if we exclude component of skill allowance based on current payment, using the model can significantly reduce the use of daily workers and optimize the distribution of manpower, resulting in a reduction of total manpower needed in the warehouse by around 25% (estimate average before total manpower 47 compare with 35). Moreover, the model optimization also leads to a cost savings of approximately 19% (estimate average before total cost IDR 252.834.629 compare with IDR 204.527.832) compared to the previous labor allocation system.

Table 9. Total salary workers without allowance skill (based on actual conditions)

Descriptions	Calculations - Exclude skill allowance (1)		Calculations - Exclude skill allowance (2)	
Total Salary Contract Worker	IDR	195,071,838	IDR	189,334,431
Total Salary Daily Worker	IDR	-	IDR	15,193,401
Total Salary	IDR	195,071,838	IDR	204,527,832

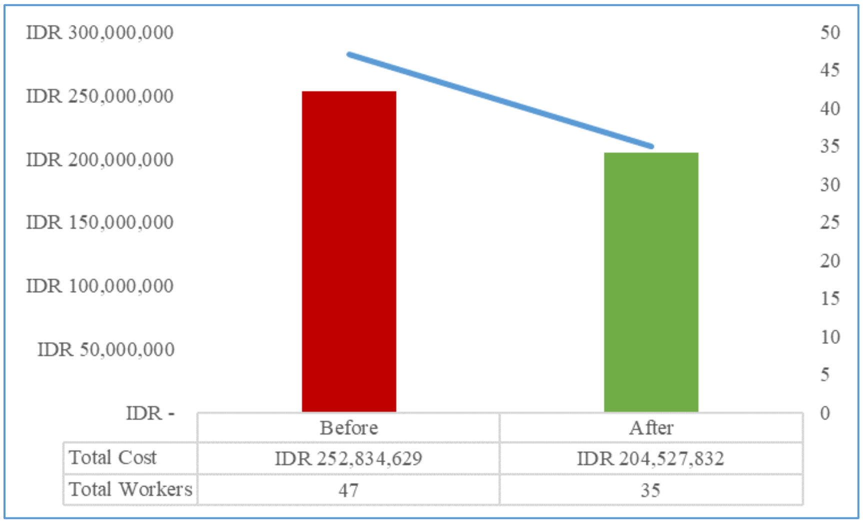


Figure 9. Comparison total cost and workers after calculations

6. Conclusion

This research optimization model using goal programming to formulated the model with all of the constraint and computational experiment conducted in this study showed that Particle Swarm Optimization (PSO) implemented in Microsoft Excel can effectively and efficiently solve multi-objective problems and provide significant reductions in cost and workers needed for the project. The PSO algorithm was able to find the optimal solution within a reasonable number of iterations, and the results were found to be consistent and robust to changes in input parameters. The reduction in total cost and workers needed for the project highlights the potential benefits of using GP and PSO for multi-objective optimization problems, and can provide valuable insights and the impact of resource allocation on project outcomes. Further research could explore the application of PSO to other problems and the use of different optimization techniques to compare the results. Additionally, the impact of PSO on other aspects of the project, such as the quality of the final product, could be investigated.

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Biography

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