CONTAINER LOADING ALLOCATION TO IMPROVE SPACE AND LOADING UTILIZATION OF FLEET COMPARTMENT CAPACITY BY USING GENETIC ALGORITHM

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Abstract
PT. XYZ is the current leading automotive company, the supplier that is part of its subsidiary company provides services in form of supply and distribution of raw material. Based on data collected from January till March, the problem appears is the compartment fleet utilization that is far from the maximum capacity. According to the plan production control department, the desired average loading utilization is 16 ton per delivery, while the average loading utilization is 42% or 6,8 ton per delivery. In addition, there are also some deliveries exceeding maximum capacity allowed. Therefore in this research, the most suitable loading pattern is needed to improve utilization of fleet compartment with heterogeneous fleet and heterogeneous material dimension. Loading pattern is also needed as supporting tools for the department by considering weight limit, physical dimension of material and compartment fleet dimension, so that overloaded and unburdened deliveries can be avoided. The research is conducted in plan production control department to gain more information about the fleet, production demand, and raw material properties. Genetic algorithm is used as method for solving the problem and visualize the loading pattern by using Matlab. The calculation is conducted toward loading and space utilization of compartment fleet. From the research, the utilization of space can be optimized to 6% and loading utilization can be optimized up to 50%.

Keywords – Container Loading Problem (CLP), Genetic Algorithm, Matlab

1. Introduction

Logistics and transportation management is essential part of supply chain management. However in the term of supply chain, the goals of logistics and transportation management is to get minimum cost while maintaining service level and quality of delivered service by planning and coordinating all activities involved in the business. The scope spans from the management of raw materials through to the delivery of the final product (Christopher, 2011). Thus, in order to achieve desired service and quality at lowest possible cost, a good management and appropriate method implementation should be the main concern in accordance with the characteristics and the needs of the company.

PT. XYZ provides 2 kinds of fleet especially assigned for department of production, e.g. colt double diesel (CDD) long box & wingbox that can be seen in Table I.1 with the total fleet as much as 2 (two) fleets. Those fleets are used to deliver raw material. Each fleet has different container volume and capacity as seen in Table I.1.

Table I. 1 Fleet Information

Fleet Type	#
CDD Longbox	1
CDD Wingbox	1

In department of press production in 1 work day there are 12 times material order where material order is conducted 6 times at 1st shift and the rest at 2nd shift. The lead time of material order is 1 cycle where each cycle is 70 minutes.

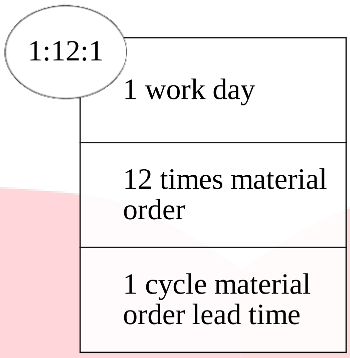

Figure I. 1 Cycle issue of press production department

In department of press production in 1 work day there are 12 times material order where material order is conducted 6 times at 1st shift and the rest at 2nd shift. The lead time of material order is 1 cycle where each cycle is 70 minutes. Initial identification of the problem existed in fleet compartment utilization is by comparing between ideal efficiency of compartment usage with the monthly efficiency of actual average compartment usage that can be seen at Figure I.1.

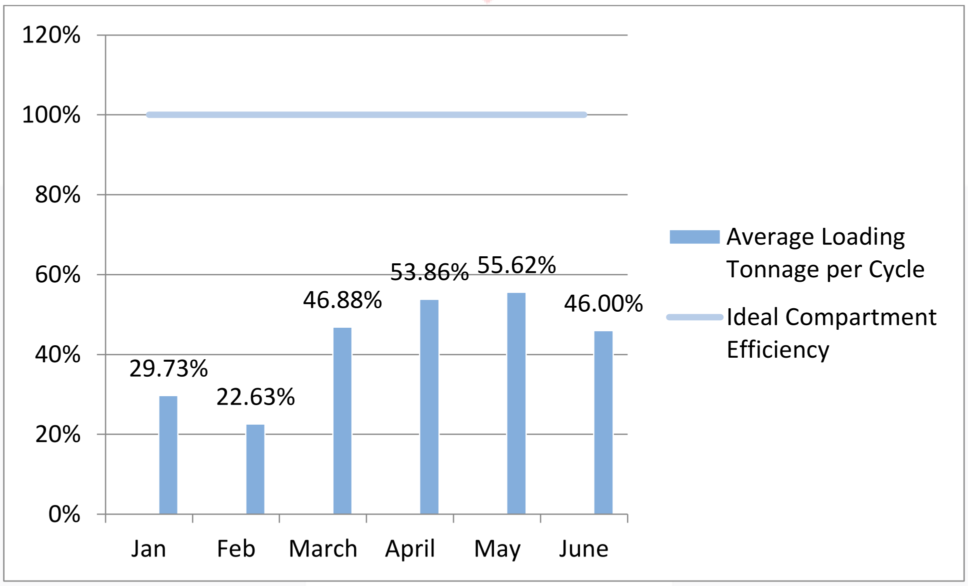

Figure I. 2 Fleet Compartment Efficiency Compared to Ideal Efficiency

All this time, press production department ordered material only as much as their production needs. Meanwhile, PT. TTMI fleet can accommodate up to 16 ton/delivery and resulting less efficiency on fleet compartment capacity because PT. TTMI can not afford delivery on fleet with smaller capacity.

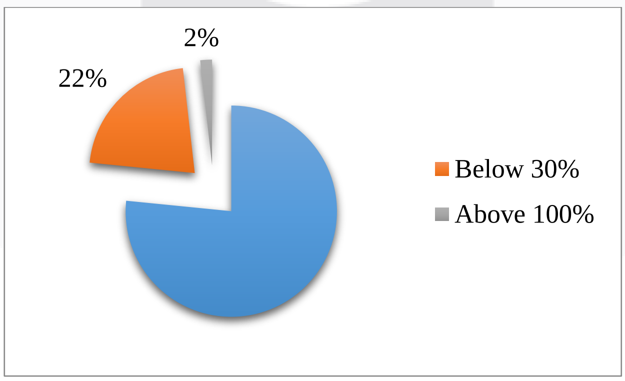

Figure I. 3 Loading Efficiency In March

In order to gain specific information toward the loading efficiency in press production department, observation is conducted. Based on data collected, there are many deliveries conducted that is extremely far from fleet capacity. As shown at the graph above, for instances there are 22% deliveries that is conducted on March in which the efficiency of loading is below 30%.

This condition is eventually resulting both sides spend more cost on operations. Press production department should bear the cost caused by an increase from total order cost and vice versa supplier has an increased cost caused by the utilization efficiency of their fleet compartment that is immensely far from maximal capacity they can accommodate in one single trip.

In other hand, press production department stated that the fleet can accommodate up to 16 ton per delivery for least, based on observation there are 2% of delivery exceeding maximum capacity on March. Overloaded compartment can increase the cost of maintenance, therefore delivery conducted below maximum capacity is preferable.

2. Basic Theory and Research Methodology

2.1 Container Loading Problem

According to (Pisinger, 2002) container loading problem is known as the problem of maximizing packed palletes by configuring the loading of a subset of pallets into container. There are many benefits obtained from improving the container loads such as shipping cost and increase the stability and support the load.

According to (Dyckhoff, 1990) many factors can be considered into the problems, some other constraints may be put onto the above problems, for instance, specific rotation of palletes, maximum palletes to be stacked and stability of the stacking, because the pallet, for example, pallet can not be solely placed at the corner of another pallet.

Types of cargo should also be distinguished between homogeneous and heterogeneous. Homogeneous means the cargo consists of identical palletes, the other way around heterogeneous means the cargo consists of different types of palletes. If the cargo consists of many different types of palletes then the cargo is strongly heterogeneous while if the palletes consists of a small set of pallet type, then the cargo is considered as weakly heterogeneous. According to typology introduced by (Wäscher et al, 2007), container loading problems can be classified as input (value) minimization type and output (value) maximization type.

In this research, the problem is categorized as Multiple Bin-Size Bin Packing Problem (MBSBPP). Multiple Bin-Size Bin Packing Problem (MBSBPP) is input (value) minimization type by loading a strongly heterogeneous set of cargo into a weakly heterogeneous assortment of containers with the result that the containers used can be minimized.

2.2 Mathematical Formulation

Based on the analytical model developed by (C.S. Chen, 1995) the problem of this container loading problem can be described as follows. A set of n boxes of dimensions (p_i, q_i, r_i) and weight $w_i(i \in \{1, \ldots, n\}$ has to be loaded to m containers of dimension $\left(L_j, W_j, H_j\right)$ such the capacity of weight and volume can be maximized while satisfying the constraints set.

Parameters

N	Total number of boxes to be packed	
m	Total number of containers available	
M	An arbitrarily large number	
w_i	Weight of box i	$\forall i,$
C_j	Weight limit along the x_j axis	$\forall j,$
(p_i, q_i, r_i)	Length × width × height of box i	$\forall i,$
$\left(L_j, W_j, H_j\right)$	Length × width × height of container j	$\forall j.$

Variables

s_{ij}	A binary variable, the value is equal to 1 if box number i is placed in container j
n_j	A binary variable, the value is equal to 1 if the container j is used, otherwise 0
(x_i, y_i, z_i)	Continuous variables (for location) indicating the coordinates of front left bottom (FLB) corner of box i

(l_{xi}, l_{yi}, l_{zi})	Binary variables indicating whether the length of box i is parallel to the $X, Y, or\ Z$ axis.
(w_{xi}, w_{yi}, w_{zi})	Binary variables indicating whether the width of box i is parallel to the $X, Y, or\ Z$ axis.
(h_{xi}, h_{yi}, h_{zi})	Binary variable indicating whether the height of box i is parallel to the $X, Y, or\ Z$ axis.
$\binom{a_{ik}, b_{ik}, c_{ik},}{d_{ik}, e_{ik}, f_{ik}}$	Binary variable indicating the placement of box relative to each other.

The objective function is formulated as the following linear mixed integer programming model (C.S. Chen, 1995):

$$Min \sum_{j=1}^{m} L_j * W_j * H_j * n_j - \sum_{i=1}^{N} p_i * q_i * r_i$$

$$x_i + p_i * l_{xi} + q_i * w_{xi} + r_i * h_{xi} \le x_k + (1 - a_{ik}) * M \qquad \forall i, k, \quad i < k, \qquad (1)$$

$$x_k + p_k * l_{xk} + q_k * w_{xk} + r_k * h_{xk} \le x_i + (1 - b_{ik}) * M \qquad \forall i, k, \quad i < k, \qquad (2)$$

$$y_i + q_i * w_{yi} + p_i * l_{yi} + r_i * h_{yi} \le y_k + (1 - c_{jk}) * M \qquad \forall i, k, \quad i < k, \qquad (3)$$

$$y_k + q_k * w_{yk} + p_k * l_{yk} + r_k * h_{yk} \le y_i + (1 - d_{ik}) * M \qquad \forall i, k, \quad i < k, \qquad (4)$$

$$z_i + r_i * h_{zi} + q_i * w_{zi} + p_i * l_{zi} \le z_k + (1 - e_{ik}) * M \qquad \forall i, k, \quad i < k, \qquad (5)$$

$$z_k + r_k * h_{zk} + q_k * w_{zk} + p_k * l_{zi} \le z_i + (1 - f_{ik}) * M \qquad \forall i, k, \quad i < k, \qquad (6)$$

The constraints (1)-(6) ensure that pallets do not overlap each other.

$$a_{ik} + b_{ik} + c_{ik} + d_{ik} + e_{ik} + f_{ik} \ge s_{ij} + s_{kj} - 1 \qquad \forall i, k, j, \ i < k \qquad (7)$$

The constraint (7) checks the overlap when a pair of pallet is placed in the same container.

$$\sum_{j=1}^{m} s_{ij} = 1 \qquad \forall i, \qquad (8)$$

The constraint (8) ensures that each pallet will be placed in exactly one container

$$\sum_{i=1}^{N} s_{ij} \le M * n_j \qquad \forall j, \qquad (9)$$

The constraint (9) ensures that the container is considered used when any pallet is assigned to container.

$$x_i + p_i * l_{xi} + q_i * w_{xi} + r_i * h_{xi} \le L_j + (1 - s_{ij}) * M \qquad \forall i, j, \qquad (10)$$

$$y_i + q_i * w_{yi} + p_i * l_{yi} + r_i * h_{yi} \le W_j + (1 - s_{ij}) * M \qquad \forall i, j, \qquad (11)$$

$$z_i + r_i * h_{zi} + q_i * w_{zi} + p_i * l_{zi} \le H_j + (1 - s_{ij}) * M \qquad \forall i, j, \qquad (12)$$

The constraints (10)–(12) ensure that all the palletes placed in a container fit within the physical dimensions of the container.

$$-C_x \le \sum_{i=1}^{N} \frac{w_i}{2} * \left[\sum_{j=1}^{m} L_j * n_j - 2x_i - p_i * l_{xi} - q_i * (l_{zi} - w_{yi} + h_{zi}) - r_i * (1 - l_{xi} - l_{zi} + w_{yi} - h_{zi} \right] \le C_x \qquad \forall j, \qquad (13)$$

The constraint (13) ensures the load will not exceed the limit allowed.

2.3 Conceptual Model

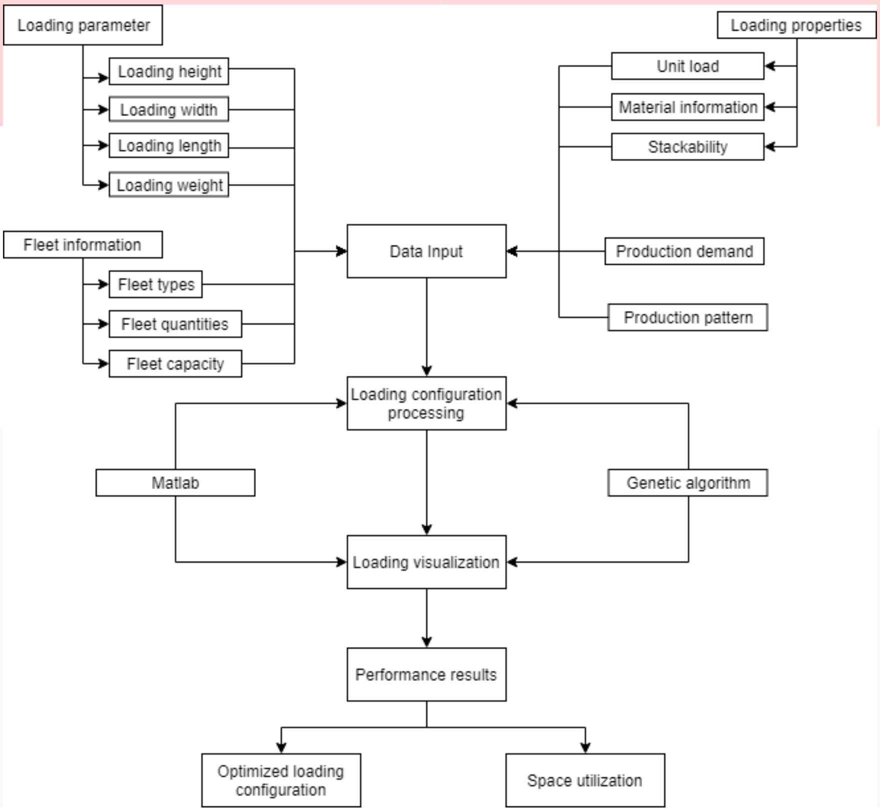

Figure II. 1 Conceptual Model

This research is initially started by collecting data of loading parameter, such as loading dimension and its weight for each pallet. The next data collected are the demand of production, fleet information such as fleet capacity, fleet types, and many others. The analytical model is chosen based on previous research with identical characteristics. In this case according to (Andreas Bortfeldt, 2012) the problem is categorized as Multiple Bin Size Bin Packing Problem (MBSBPP) hence (C.S. Chen, 1995) analytical model is used to formulate the problem. On the other hand, since the problem is NP Hard, metaheuristics in which genetic algorithm is used and the calculation and visualization are run at MATLAB. The outcome of the calculation is visualized by considering weight limit, dimensions of both container and loadings and orientation of the loadings. In order to evaluate the performance results, after the visualization of pallet arrangement in container comes out, the calculation outcome in the form of loading pattern is measured by calculating the space utilization between the before and after the research is conducted.

3. Discussion

3.1 Genetic Algorithm

In order to do the material configuration by using genetic algorithm there are several phases. Started from initializing the population, selecting and evaluating the initial population, crossover and mutation operator, and replacement process that renew the generation. The iteration is conducted many times until the criteria of generation met, hence the solution can be obtained. The flow of the data processing can be described by the flow chart below.

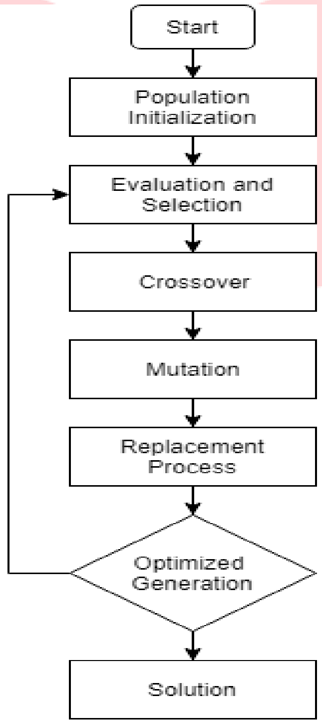

Figure III. 1 Genetic Algorithm Flowchart

3.2 Population Initialization Process

The first process to process data with genetic algorithm is to initialize the starting population. The chromosomes length determines how much genes felt in the chromosomes. Each gene represents product information such as product code, dimension, weight, etc. Random generator is used to initialize starting population.

3.3 Fitness Value Evaluation

This phase is done to evaluate how close is a chromosome as a initial solution to the desired criteria in order to solve the problem. In this case the fitness value parameter is based on the space utilization.

- In order to gain the value of space utilization fitness value (F_{su}) the input in the form of pallet loaded should be compared toward the container volume.

$$F_{su} = \frac{\sum Loading}{\sum Container} * 100\%$$

3.4 Selecting Process

Selection process is done to determine which chromosome that persists in population, better fitness value will give higher possibility of a chromosome to survive in population. The selection process in this research is done by using roulette wheel method.

The following are steps in roulette wheel method (Nunnari & Bertucco, 2001):

- Assign the probability of selection P_j to each individual j based on its fitness value.
- Generate a series of N random numbers and compare against the cumulative probability $C_i = \sum_{j=1}^{i} P_i$.
- $P(Individual\ i\ is\ chosen) = \frac{F_i}{\sum_{j=1}^{Popsize} Fj}$, where F_i equals the fitness of individual i.
- If $C_{i-1} < U(0,1) \leq C_i$ select and copy individual i into the population.

3.5 Crossover Process

Crossover process is the next process of selection and evaluation phase in genetic algorithm aiming to produce new chromosome that inherits the characteristic of its parents. In this research the crossover rate is determined to 95%, while the crossover rate is the possibility of a chromosome to crossover.

There are several methods that can be used to do crossover process, in this research the method used is uniform crossover based on the characteristics of the problem. The uniform crossover process can be explained as follow:

- Generate crossover mask consists of binary code as much as the length of chromosomes.
- Determine the offspring genes based on binary code of crossover mask. If binary code value is 1, then 1st offspring will inherit 1st parent’s gene, while if binary code value is 0, then 1st offspring will inherit 2nd parent’s gene.
- In order to determine gene’s inheritance of 2nd offspring, the opposites rule applies

3.6 Mutation Process

The method of mutation process used is order based mutation, the following explains the mechanism of order based mutation:

- Generate random number for each gene in a chromosome to determine mutation candidate randomly
- Determine mutation parameter
- Compare mutation parameter toward gene random rumber
- If random number in range of mutation parameter, then switch gene position.

3.7 Genetic Algorithm Parameter

In this research parameters set according to (Greenstette, 1986), the probability of mutation is about 0.01, crossover rate of 0.95, and population size range about 30 chromosomes.

3.8 Visualization

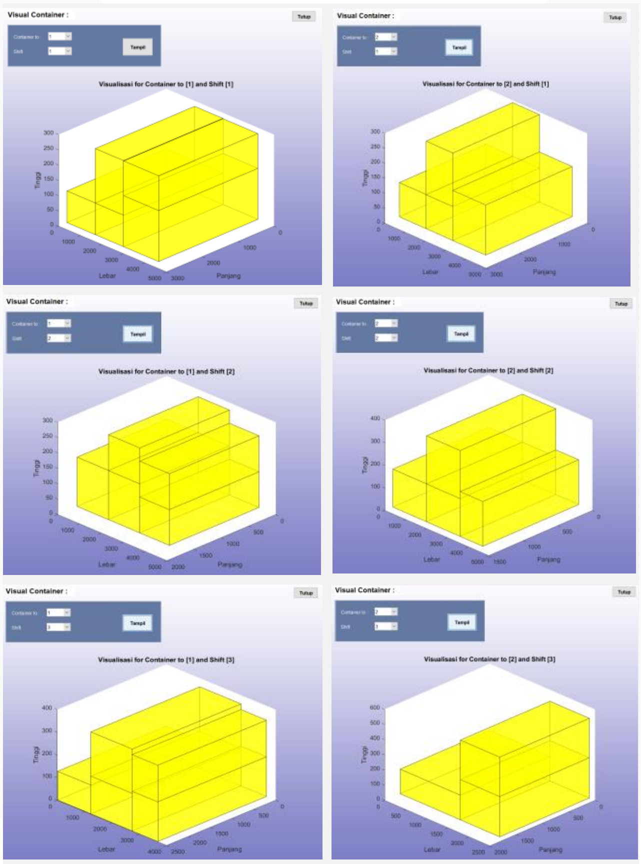

Figure III. 2 Visualization Result

4. Analysis

The result of the research is in the form of improvement in loading and space utilization. Space utilization percentage is influenced by weight limit of each compartment fleet, this makes the improvement of space utilization result in low percentage.

Table IV. 1 Analysis of loading utilization

Month	Existing			After Calculation		
	Loading (kg)	Utilization	Delivery Frequency(s)	Loading (kg)	Utilization	Delivery Frequency(s)
March	6484	46,8%	12	12970	81,06%	6
April	8617	53,86%	12	12927	80,79%	8
May	8899	55,62%	12	13349	83.43%	8

Table IV. 2 Fleet Compartment Efficiency After Improvement

Month	Existing			After Calculation		
	Space (mm3)	Utilization (Average)	Delivery Frequency(s)	Space (mm3)	Utilization (Average)	Delivery Frequency(s)
March	863992525	2%	12	1727985051	3%	6
April	1712351068	3%	12	3424702136	6%	8
May	1233737149	2%	12	2467474299	4%	8

5. Conclusion

In this research where the case is categorized as container loading problem, there are some points that can be concluded. The loading pattern where the placement consider the orientation, overlap condition, weight distribution, etc. can be solved by using genetic algorithm. This can be seen through the visualization where the result fit the constraints stated. The calculation of total fleet compartment used is measured in order to show the difference between before and after the implementation of loading pattern. From the research can be seen that in the existing condition the total of delivery order is as much as 12 times each day, after the loading pattern is implemented, the fleet compartment usage can be reduced up to 50% each day. This means by implementing loading pattern the proposed system can optimize the efficiency of fleet compartment by proposing program that results loading pattern on each delivery.

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