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Optimizing the Arrangement of Goods in Box Van Using the Tabu Search Algorithm

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Abstract A country's economic progress can be seen from the industrial sector's contribution to its economic growth. Transportation plays an important role in the distribution of products to consumers, where the smooth flow of goods can reduce costs and optimize company profits. Distribution problems often occur due to the arrangement of goods that is not optimal, thereby increasing costs and labor. Optimizing the placement of goods in expedition van has not been widthly studied until now. Therefore, a method for optimizing the arrangement of goods(items) is needed, one of which is using the tabu search algorithm. The Tabu Search algorithm is a metaheuristic algorithm that aims to find the optimal solution from various possible solutions. In this study, all goods sent were packaged in cubes or blocks and the vehicles used to send them were also in boxes. The essence of this article is how to arrange goods (packed in boxes) into a van so that it has maximum contents. This research also discusses how to place items if the item cannot be reversed (fragile) along with the visualization.

Keywords Tabu Search Algoritm, Arrangement of Goods, Optimization, Van Box

AMS 2010 subject classifications 65C50

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1. Introduction

A country's economic progress can be seen from how much the industrial sector contributes to its economic growth. Consistent economic growth is a driving factor for increased industrial activity, thereby pressing the need for transportation as a more efficient system for transporting goods. The role of transportation starts from the process of bringing in raw materials for products to the process of distributing products to consumers [1]. [2] Good transportation will determine the smooth flow of goods distributed. [3] The challenge faced is placing goods into containers optimally so that the container can accommodate the maximum quantity of goods.

The problem that often occurs in the goods distribution process is that the arrangement of goods is not optimal, which increases distribution costs because additional vehicles are needed to distribute them. Apart from that, considerations are required, such as field officers who will continue to try to place and shift the position of one item to another so that it remains optimal, which can drain more energy [4]. Therefore, an appropriate process for preparing goods is needed to minimize distribution costs and use of labor [5]. Several previous studies have discussed the problem of optimizing the arrangement or arrangement of goods using several algorithms, such as Evolution, Genetic, and Tabu Search algorithms [6]. In this research, the arrangement or arrangement of items uses the Tabu Search Algorithm. Tabu Search can handle difficult discrete optimization problems within a reasonable processing time as a metaheuristic method [7]. Research using the Tabu Search algorithm has been carried out by many previous researchers. Research by [8] shows that the Tabu Search algorithm is suitable for solving type I U-shaped path balance problems with stochastic operating times. Research by [9] obtained the best results in the

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scheduling process, while research by [10] produced a scheduling application. Research by [11] produces shorter distribution routes, reducing distribution costs and delays in product delivery. Tabu Search can also solve the 3D Bin Packing Problem in containers [12]. [13] The Bin Packing Problem focuses on maximizing the space used by objects in a limited space, for example, a container [14]. The research explains that Tabu Search can also be applied to other storage areas such as warehouses, shelves, and train carriages. Item arrangement research produces the best coordinates for 3D container objects, but further research is needed to determine its accuracy [15].Research by [16] created a web-based attendance and scheduling system.

2. Basic algorithm and extensions

The history of Tabu Search began in the 1980s when Fred Glover, a computer scientist and operational mathematician, developed a new method for solving complex combinatorial optimization problems. Initially Fred Glover was inspired by the food behavior of ant colonies [17]. Fred Glover realized that ants were able to find the shortest path to a food source by avoiding previously explored paths. This concept is the basis for Tabu Search to avoid revising solutions into areas that have been previously explored [18]. Tabu Search is an optimization method used to find adequate or close to optimal solutions in a search space with reasonable computing time [19]. According [20] the steps of the Tabu Search Algorithm are shown in the Figure 1 below.

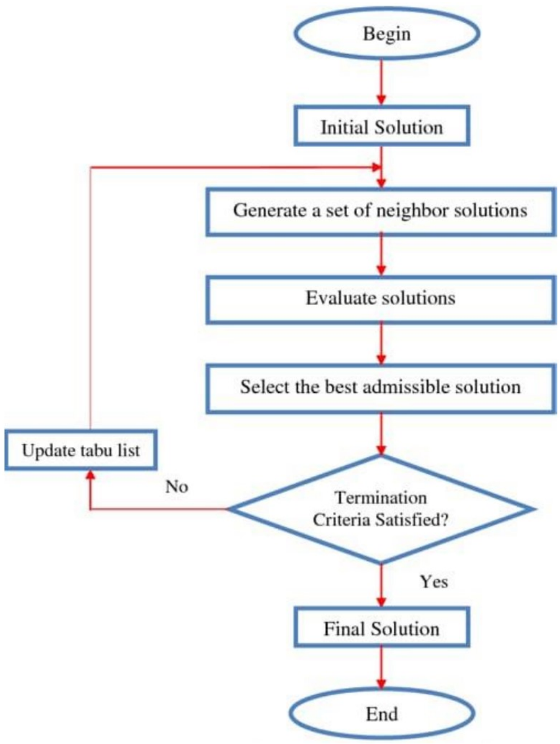

Figure 1. Flowchart of Tabu Search Algorithm

According to [21] the application of Tabu Search to optimization problems has four main components, namely neighborhood, tabu list, aspiration criteria, and termination. The following is an explanation of the four components:

1. Neighborhood is the set of all possible neighbors of the current solution. These neighbors refer to the solution obtained by making one or more changes to the current solution [22].

2. Tabu lists are used to store information about certain solutions or steps that have been previously evaluated [23]. The main purpose of the tabu list is to prevent the search process from cycling in the same solution area and guide the search process through solution areas that have not been visited [24].
3. Aspiration criteria are used to decide whether a step that would normally be considered ”taboo” can be permitted or skipped under certain conditions. More precisely, aspiration criteria allow otherwise taboo solutions to be used if they meet certain requirements [25].
4. Termination (termination criteria) is a rule or condition that determines when the search for a solution must be stopped. The stopping criterion aims to avoid infinite search and determine the point at which the algorithm is considered to have reached an adequate solution.

Tabu search also requires additional elements if a series of successive iterations fail to produce improvements, namely intensification and diversification. Intensification is a strategy to focus searches on areas that are considered more promising or have the potential to produce optimal solutions. Diversification is a strategy to move away from previously explored solutions and search in different parts of the search space [26].

3. Methods

This section discusses research procedures which contain the steps that will be used in the research. The following is a description of the steps in this research:

3.1. Modeling Items

The items to be arranged are items in the form of blocks or cubes that have length, height, and width. One item is identical to six-item positions, starting from position 0 to position 5. If one item position is selected then the five item positions representing that item will be removed from the set of item positions. There is no difference in the rules for naming items, whether they are cubes or blocks. Each item has 3 inputs, namely length (p), width (l), and height (t). Reversible items have six positions, starting from the 0th position to the 5th position. For example: p¿t¿l, then the possible position of the item is shown in Figure 2.

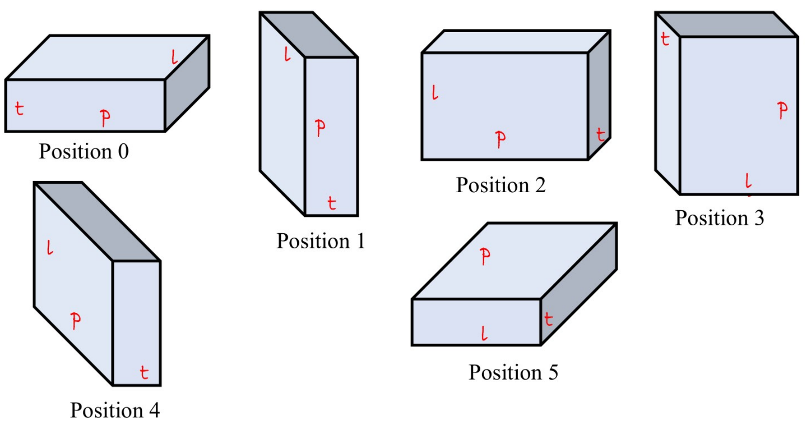

Figure 2. Possible positions of items that can be rotated

Items that cannot be reversed (fragile) only have one position, so that all six positions have the same shape.

3.2. Implementation of the Tabu Search Algorithm

Initial Solution: As an initial solution, we select the items to be put into the box randomly until they fill the first layer of the van box.

Generate a set of neighbour solution: The Solution set is the possible positions of the items when placed into the van. Each item has 6 possible positions as shown in Figure 2.
The following is the implementation of the tabu search algorithm in optimizing the arrangement of goods in the van [27]:

1. Input the box size of the van (length/P, width/L, height/T).
2. Input the box size of the item (length/p, width/l, height/t).
3. Extract each item into six positions (0-5) as figure 2.

$$HPB = BRG \times 6 \tag{1}$$

   Where HPB is the number of possible item positions and BRG is the total goods. For example, item 1 will be extracted into $HPB_1 - HPB_6$, item 2 will be extracted into $HPB_7 - HPB_{12}$, and so on.
4. Enter the number of iterations and the number of tabu lists.
5. Select items randomly from the set of item positions to put into the van.

$$X = rand(HPB) \tag{2}$$

$$B = ceil(\frac{X}{6}) \tag{3}$$

$$P = mod(X, 6) \tag{4}$$

   where X is a randomly selected item from the HPB, B is the selected item, and P is the position of the selected item.
   For example, the X selected based on Equation 1 is HPB211 then based on Equation 3 the item put into the van is item B36, and based on Equation 4 the placement position is position P5.
   If an item is selected, it will delete the item in the HPB along with its position and the item order will increase. For example, the selected item is item 36 (HPB211-HPB216), then in the HPB, this item is deleted and the sequence is replaced with item 37 (HPB217-HPB222).
6. Repeat step 5 above until the length (P) and width (L) of the van are full
   If the length P and width L are fulfilled then it is said that the level is fulfilled, with the height of the level being the maximum height of goods entering that level. The volume at this level is

$$V_i = P * L * t_i \tag{5}$$

   Where V_i is the volume on level$-i$ and t_i is the maximum height of the item in level i.
7. Repeat steps 5 and 6 until all items are selected to be loaded into the van.
   Evaluate Solution: In this section, calculations are made on the remaining space that other items could occupy.
8. Base on Equation 5, Input the following tabu list equation

$$list_k = P * L * T - \sum_{i=1}^{n} V_i \tag{6}$$

   Where listk is the number of taboo lists at iteration k, V_i is the volume on level i, and n is the total levels. Repeat steps 5 to 8 until the total taboo list or iteration is met.
   Criteria Satified ?: The arrangement of goods in a van is said to be good if the remaining space is large, meaning that the more space there is, the better the arrangement of goods in the van is.
9. Based on Equation 6, the best performance for organizing goods in a van is

$$Best = max\{list_1, list_2, ..., list_k\} \tag{7}$$

   Final Solution: The process of arranging goods in a van is said to be complete when all the goods have been arranged in the van.
   This process of arranging goods can be applied to all types of goods transport vehicles that have box-shaped storage media.

4. Results and Discussion

The process of arranging goods in a van using the Tabu Search algorithm in this research was completed with the MATLAB software. The data used in this research is simulation data. Simulation data for the size of the box on the van is 250 cm long, 170 cm wide, and 150 cm high. Simulation data for the items used in this research are shown in Table 1.

Table 1. Item Size Data

Items	Item Size (cm)			The amount of goods
	Long	Width	Height	
1	50	40	30	4
2	100	20	20	4
3	40	30	30	4
4	40	30	15	4
5	50	40	30	4
6	30	30	15	4
7	100	50	50	4
8	20	20	30	4
9	30	30	30	4
10	60	60	60	4
11	70	70	70	4
12	75	75	75	4
			Total Items	48

The item size data used in this research is stored in an Excel file ”datacoba”. The data input process is carried out in the command window. The items used in this research will be checked to see whether they fit in the van, if they fit then the MATLAB program runs, and if not then the MATLAB program will stop with the message ”Some items do not fit in the van”. Next, all items are extracted, where one item is extracted into six HPB, starting from position 0 to position 5. The next step is to determine the set of item positions. The number of sets of item positions can be calculated using Equation 1. The parameters used in this research are the number of iterations and taboo lists, each of which is 10.

Example:
10 items will be put into the car box. Calculate the number of sets of item positions using Equation 1 to obtain a result of $10 \times 6 = 60$.
Then determine alternative solutions by randomizing items as shown in Equation 2. For example, the item selected is 34. Next, the 34^{th} index includes which item using Equation 3, thus obtaining the result $34/6 = 5.666$. Rounded up (ceil), The 34^{th} index is the 6^th item.
The 6^th item has item positions, namely 31, 32, 33, 34, 35, and 36, because the 34^{th} item position has been selected, the item positions of 31, 32, 33, 34, 35, and 36 are removed from the set of item positions.

The best solution is carried out by calculating the remaining volume of the van box minus the volume of goods arranged in the van box. The best solution produced in this research is obtained from the maximum value of the height of the box car (T) minus the total height of the items that have been arranged. The way to calculate the best function value is in Equation 7. In this study, the stopping criteria are a maximum of 10 iterations. The results of the evaluation values stored in the tabu list are shown in Figure 3. The results of the best solution are shown in Figure 4.

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============================
Tabu List Evaluation
1.0e+09 *

9.0717    9.4907    9.4933    9.5036    9.5105    9.5117    9. 95140    9. 5157    9.5198
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```

Figure 3. Evaluation of the Best Solution Selection

Best Evaluation:
Objective Function value: 9071664000
Best Solution:

1	50	40	30	25	50	40	30
2	100	20	20	26	100	20	20
3	40	30	30	27	40	30	30
4	40	30	15	28	40	30	15
5	50	40	30	29	50	40	30
6	30	30	15	30	30	30	15
7	100	50	50	31	100	50	50
8	20	15	10	32	20	15	10
9	50	40	30	33	30	30	30
10	100	20	20	34	60	60	60
11	40	30	30	35	70	70	70
12	40	30	15	36	75	75	75
13	50	40	30	37	30	30	30
14	30	30	15	38	60	60	60
15	100	50	50	39	70	70	70
16	20	15	19	40	75	75	75
17	50	40	30	41	30	30	30
18	100	20	20	42	60	60	60
20	40	30	15	43	70	70	70
21	50	40	30	44	75	75	75
22	30	30	15	45	30	30	30
23	100	50	50	46	60	60	60
24	20	15	10	47	70	70	70
				48	75	75	75

Figure 4. Objective Function Value and Best Solution

The final step is positioning the items taken, which can be calculated using Equation 4. In this study, all items have the 0th position only. This research also provides visualization results of the item placement process which is shown in Figure 5.

The research results show that the Tabu Search algorithm with MATLAB software can find solutions that are close to optimal. The best solution from this research is obtained if the difference between the volume of the van box and the volume of goods arranged is maximum. In other words, the more free space, the better the arrangement results are said to be. The programming complexity of this program is $O(n^2)$.

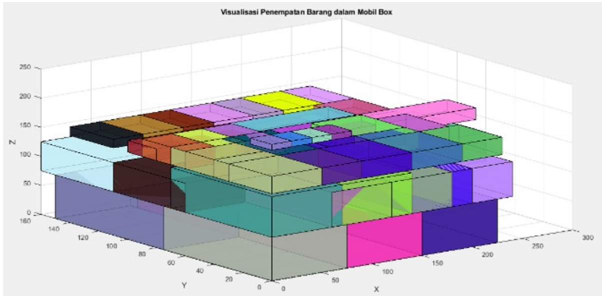

Figure 5. Items Placement Visualization

5. Conclusion

In this paper, the implementation of the Tabu Search algorithm in arranging goods in a van box can produce an optimum solution. In arranging goods, there are several levels, where in each level the goods are arranged as optimally as possible so that they meet the length and width of the van box, while the height is the maximum height of the goods at that level. The arrangement of goods is said to be optimal if the difference in volume between the van box and the volume of goods that have been arranged is maximum. In other words, the more empty space in the car box after the goods are arranged in it, more better.

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