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Research Article

Sequential Routing-Loading Algorithm for Optimizing One-Door Container Closed-Loop Logistics Operations

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A B S T R A C T

One-door container type of vehicle is the main tool for urban logistics in Indonesia which may take the form of truck, car, or motorcycle container. The operations would be more effective when it is performed through pickup-delivery or forward-reverse at a time. However, there is difficulty to optimize the operation of routing and container loading processes in such a system. This article is proposing an improvement for algorithm for sequential routing- loading process which had been tested in the small datasets but not yet tested in the case of big data set and vehicle routing problem with time windows. The improvement algorithm is tested in big data set with the input of the vehicle routing problem with time windows (VRP-TW) using the solution optimization of the Simulated Annealing process with restart point procedure (SA-R) for the routing optimization and Genetic Algorithm (GA) to optimize the container loading algorithm. The large data sets are hypothetical generated data for 800-2500 single-sized products, 4 types of container capacity, and 100-400 consumer spots. As result, the performance of the proposed algorithm in terms of cost is influenced by the number of spots to be visited by the vehicle and the vehicle capacity. Limitations and further analysis are also described in this article.

INTRODUCTION

E-commerce had been grown for high number by the penetration of internet and lifestyle shifting for urban population, especially for South East Asia. Data had shown that Thailand, Malaysia, Vietnam, Singapore, Indonesia are the big five in terms of annual growth of e-commerce consumer goods transaction from 2017 to 2018 [1]. The percent figure of e-commerce growth is higher in developing countries rather. This growth is supported by some success factors such as: security system, technical expertise [2]. One of the important technical expertise in the e-commerce is service of delivery. On the other hand, shipping is one of the important performance measurements that shall be noticed by the e-commerce actors [3]. One of a strategy for maintaining high delivery service quality is by using the logistics third party providers which, in the terms of e-commerce, is known as logistic service provider or carrier [4]. The common delivery from a particular business location to home delivery is referred as Business to Consumer (B2C) delivery [5]. The number of courier service providers had growth for more than USD 5 million in 2019 and expected to rise 19% annually until 2027 [6]. This growth is influenced by the growth of e-commerce [7]. Therefore, courier service provider must be able to maintain and improvie their shipping performances as their competitive advantag1es.

The process flow of shipping the product from e-commerce seller (e-store) to their customers is depicted in Figure 1, and explained as follow. E-commerce seller or e-store, as the shipper, is sending their product parcel or package through courier service provider by two ways: firstly, dropping the package to courier's branch office, or secondly, asking a courier service provider's massager to pick up the package in the seller's location. Second way of sending the parcel, marked by the orange arrow, is mostly accepted only for primary or exclusive consumer as an extra privilege for their regular and enormous size of delivery. The flow of shipment beyond the courier service provider's consolidation warehouse is explained as per follow: from the carrier's branch, parcels are then sent to courier service provider's consolidation warehouse before being shipped to another city (for out of town and overseas delivery) or scheduled to delivery. Several researches had proposed e-store's consumer pick up point, commonly known as customer delivery point [8] and [9]. However, the pick-up point is not yet popular in South East Asia, Business to Consumer (B2C) type is the common practice of e-commerce delivery. The example of parcel's tracking system is as seen in Figure 2.

From Figure 1 and Figure 2, we can see that there are two courier service provider's main activities. Those activities are last mile forward logistics and reverse logistics. In the practice of courier service, those two activities mainly happen amongst consolidation warehouse of a courier service provider with their agents (branch office) or between branch offices to their primary consumers (shippers and recipients). Forward logistics is an activity that deliver a product to consumers while reverse

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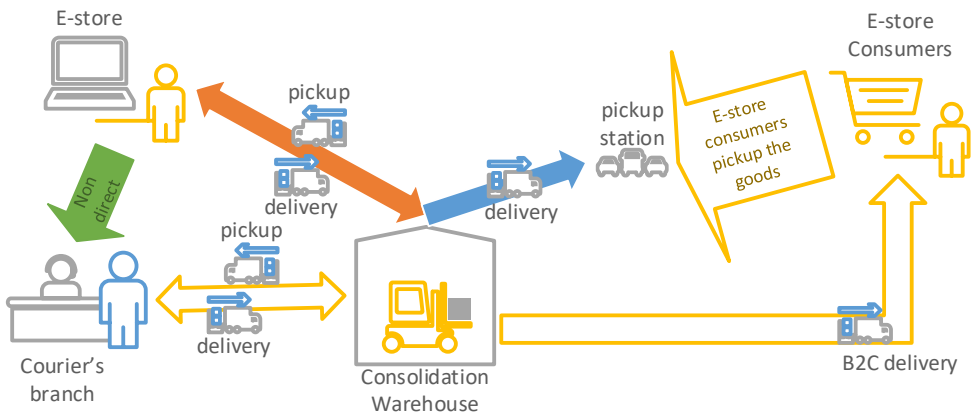


Figure 1. Process Shipping Flow from E-Store to Its Consumers

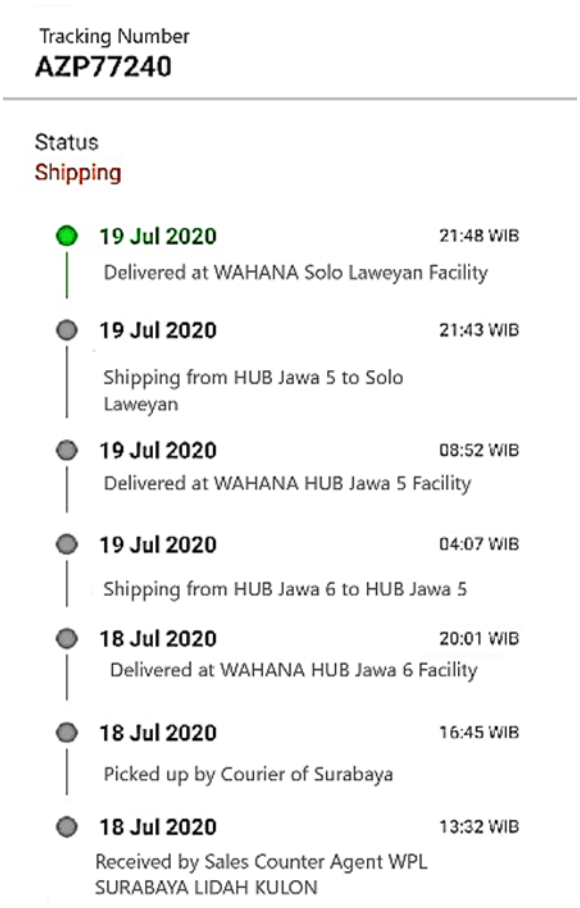


Figure 2. Sample of Tracking Delivery Process from Solo to Surabaya in an E-Commerce Platform as Per July 2020

logistic is an activity that withdraw product from consumers [10]. Thus, in courier service, the forward logistics means delivery from a regional consolidation warehouse to branch office or recipients. Meanwhile the reverse logistics means pickup from shipper or courier's branch office to a regional consolidation warehouse. Full truck load is normally implemented for the delivery between two regional warehouses. Meanwhile, the delivery of last mile forward logistics and reverse logistics are happening in the area of urban, since the location of agents of delivery couriers are spread over areas in the city. Proper planning should also be carried out on reverse logistics to create more efficient logistics operations [11]. However, not many researches on reverse logistics had been performed in the context of populous countries, including South East Asia and Indonesia [12].

In order to increase the efficiency of operations, many courier service providers use the concept of city logistics. This concept is utilizing the multi-echelon networks by utilizing a consolidation warehouse in sub urban for minimizing the number of trucks entering a city [9] [13]. In intercity, the goods are normally being distributed via small truck with one door container [14]. In South East Asia, including Indonesia, that type of truck is normally known as "colt diesel" with capacity 2 to 4 tons (see Figure 3). City logistics aims to increase the efficiency of logistics operations in urban areas without neglecting the economic and social development of the city [14]. This concept is very suitable to be used to support e-commerce business activities which are mainly focused on urban society. With the purpose of better delivering the value and concept of city logistics in proper manner, efficient operations shall become priority of delivery service provider. City logistics' efficiency can be achieved by finding optimum solution of operational problems. Main operational problems in that particular logistics are vehicle assignment, routing, and container loading optimization.

Many researches had proposed different mathematical models to solve the different optimization problems, such as vehicle routing problem and container loading problem. Vehicle routing problem (VRP) aims to optimize vehicle routing cost or distances. It was originally derived from traveling salesman problem and had been developed into several types of sub problems such as capacitated vehicle routing problem (CVRP), vehicle routing problem with time windows (VRPTW), and vehicle routing problem with pick-up and delivery (VRP-PD) of which the solution is obtained by analytics, heuristics or metaheuristics [15]. Process of assignment is defined as matching job of delivery into a certain container [16]. Container loading problem is a problem which seeks the solution of optimi-

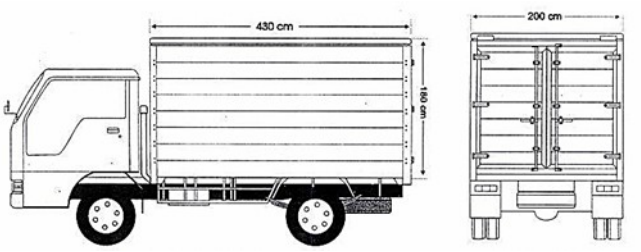


Figure 3. Illustration of Cold Diesel Double Truck Type with One Door Container

Zing the volume of a container based on a priority of the goods that should be loaded. In other word, solving a container loading problem would maximize the space available in a container. Optimization research on container loading problem had been developed from solving two-dimensional loading problem to three-dimensional loading problem which involves many constrains [17]. Three-dimensional container loading problem has several terms, and it is defined into three categories: 3D-CLP (three dimensional-container loading problem), 3D-BPP (three dimensional-bin packing problem), and 3D-CVRP (three dimensional-container vehicle routing problem) [18]. 3D-CVRP problem is using the VRP as input of the container loading problem. One of three-dimensional container loading problem had developed based on three-dimensional bin packing problem [19].

Many researches had already proposed the solution of two different type of algorithm at once by developing simultaneous or sequential algorithm. Simultaneous or sequential algorithm is seen to have better solution and more practical to be implemented because simultaneous algorithm ensures the generation of a solution which would not violate all system constrains. The inventory routing problem is one example of the simultaneous algorithm to solve the inventory replenishment assignment problem and vehicle routing problem at once [20]. Metaheuristic approach had been developed to combine vehicle assignment problem and container loading problem which is common problem in military practices [21]. Meanwhile simultaneous algorithm to solve routing and packing problem are proposed by [19], [22] and [23].

The mathematical model proposed by Ruan et al. [19] was developed based on capacitated three-dimensional loading constrains (3L-CVRP). They had actually separate the solution procedure of simultaneous model 3L-CVRP into two-step: first step is solving the routing and assignment problem, and second step is solving the problem of loading the goods in the container. Moura [23] had developed a mathematical model based on heuristic process to develop simultaneous process for forward logistics. Lin et al. [24] had developed the optimization model for container packing problem under home delivery (courier service) for two-doors container which had improved the work of [25] in one-door container loading problem. However, the model and procedure of [19] and [24] are not considering reverse logistics activity. Fisher and Jaikumar[16] had developed a heuristic solution for improving the limitation of [19]. The proposed algorithm is named as packing first routing second (P1R2) which as its name, it starts with determining the packing inside then optimizing the route. This algorithm had been considering forward and reverse logistics activities and solved through heuristic mechanism. However, the P1R2 algorithm is unable to be implemented in one door container. Moreover, the algorithm is not considering cost of unloading/loading cost. In practices, loading and unloading cost is determined based on the activities. The more activities of loading and unloading happens in a job of courier services, not only the more cost absorbed by the job, but also the more time needed to complete the job. Therefore, development of algorithm to adopt the cost concept was important to be considered.

Budi et al. [10] has proposed the reverse methods in comparison to the work of [22]. This method is considered as early exploration which aims to accommodate the cost calculation in sequential routing and loading algorithm for forward and reverse logistics. Beside, it was also to complement the works of [26] which proposed the solution approach to solve routing-packing problem in two-dimensional loading constrains. Such approach was adapted to develop a sequential routing-three-dimensional container loading problem for one door container of forward and reverse logistics. It had been tested in small data and had given satisfying results in hypothetical data set of [27].

On the other hand, in the practices of logistics, time windows of operations are applied on each warehouse or loading dock. Cattaruzza et al. [28] had highlighted that time windows had been crucial aspect of consideration in optimization in the practice of city logistics of which was not considered in [10]. While the solution routing problem itself had been proven its implementation by heuristics and analytics method, little study had specifically tested how input of the larger data size influences the output of container problem, especially in more realistic condition which considers the time windows. Therefore, this study aims to propose a sequential routing and container loading algorithm which is capable to be implemented in larger data size and considering time windows in the operations. This study is, in particular, contributing to the courier delivery service in Indonesia.

This study is reported in four main sections. First section is the introduction section where the main background and research gap problem are identified, including previous relevant works and researches. Section two is the brief explanation of the methodology and initial results. Third section is Analysis and Discussion section which describes the results of study, its managerial implications as well as the future potential research opportunities. Last section is the conclusion where the study is wrapped up or summarized.

METHOD

The methodology used in this research is depicted in Figure 4. It is clearly seen that, at the beginning, mathematical models are built for both vehicle routing problem with time windows and container loading problem. Afterwards, algorithm for each solution generation of the mathematical model is developed from which the proposed algorithm is generated by combining both vehicle routing problem and container loading problem algorithm as a sequential algorithm. Since data in larger data size are used for testing purpose, metaheuristic optimization procedure for generating the solution is used. Metaheuristic optimization procedure had been widely used in VRP and 3D-CLP researches [17]. Here, simulated annealing with restart point procedure (SA-RP) for VRPSPD-TW and genetic algorithm for CLP are applied. Meanwhile, the container algorithm is developed based on [10], adding several assumptions of the real-world application and several rules of thumbs as listed in Table 1.

The hypothetical data sets are then generated by modifying the data set of [27] in order to test the ability of the solution generation procedure. The proposed container loading algorithm is optimized using Genetic Algorithm. After the implementation, analysis is carried out for the cost per moving goods or fraction of cost. Here, we build a regression model to determine the effect of the number of cities visited on the cost per moving goods.

Vehicle Routing Problem with Simultaneous Pick-up Delivery and Time Windows (VRPSPD-TW)

VRP-SPDTW is the quite appropriate problem to deal with the general operations of closed-loop logistics in Indonesia. This problem specifies the type of service that

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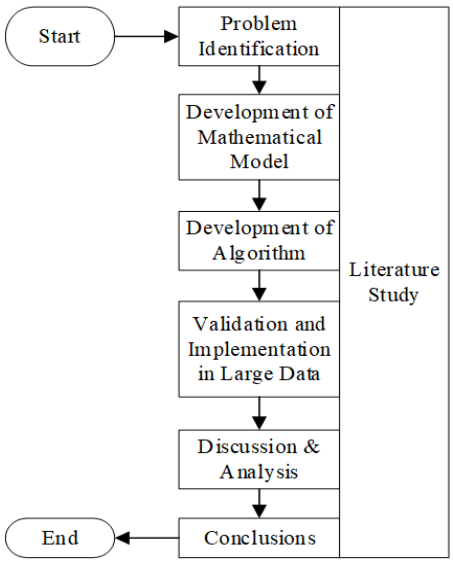


Figure 4. Flowchart of Research Methodology

that a vehicle may operate: pick-up and delivery which are similar to forward and reverse logistics. Time windows operational constrains is very common in Indonesia. Problem formulation of VRP-SPDTW for the courier service provider is described in the following paragraph.

A courier service provider needs to deliver and pick up a number of parcels from its consolidation warehouse to its branch offices. In order to accomplished it, a number of vehicles should be assigned to fulfil several pickup and delivery routes. One vehicle should work on a particular route assigned to it, that always starts from the consolidation warehouse and ends at the consolidation warehouse as well. The vehicle has different loading capacity. Each branch as a certain operational schedule (time and hours) namely operational or time windows. A cost will occur if a certain vehicle travel from a delivery or pickup point to another point. Therefore, we develop the mathematical model upon the problem as per below.

Decision variable of the problem is to decide if a particular vehicle v should go to arch route (i, j).

v_{ijk} = 1, if *arc* (i, j) is the solution

= 0 otherwise

with $i,j \in V; k \in K$

The objective function of the problem is to minimize cost, i.e.,

$$\text{Min} \quad \sum_{i\in K}\sum_{i\in V}\sum_{j\in V} c_{ij}v_{ijk} \tag{1}$$

Subject to:

$$\sum_{k\in K}\sum_{i\in V} v_{ijk} = 1 \qquad j \in C, i \neq j \tag{2}$$

$$\sum_{k\in K}\sum_{i\in V} v_{jik} = 1 \qquad j \in C, i \neq j \tag{3}$$

$$\sum_{i\in C} X_{0i} \leq K \tag{4}$$

$$ld_i \geq ld_j + d_i - M_1(1 - v_{ij}) \qquad i \in V, j \in C;\ ld_i, l_i \geq 0 \tag{5}$$

$$l_j \geq ld_j - d_j + p_j \qquad j \in C;\ ld_i, l_i \geq 0 \tag{6}$$

$$l_j \geq l_i - d_j + p_j - M_2(1 - v_{ij}) \qquad i,j \in C \tag{7}$$

$$d_i \leq ld_i \leq Q_k \qquad i \in V;\ ld_i, l_i \geq 0 \tag{8}$$

Table 1. Assumptions and Rule of Thumbs of Container Loading Algorithm

No	Descriptions
1.	Input of the routing problem had fulfilled the capacity and volumetric constraints for pick-up and delivery
2.	Items involved in the system is one sized, therefore arranging item so that overlapping one and another are impossible
3.	Items position always orthogonal to the containers
4.	Delivery items are arranged following last input first out (LIFO) mechanism
5.	Container load stability is carefully considered during loading/unloading activity
6.	Load stability changes are possible.
7.	Decrease in load stability should be overcame by technical tools such as providing solid divider for example wooden board or net
8.	The loading activity start from bottom edge of a truck and then arrangement priority is intended to give support for bottom part of container
9.	The transported items can be rotated yet still maintain their quality

$$p_i \leq l_i \leq Q_k \qquad i \in Cl_i \geq 0 \tag{9}$$

$$v_{ijk} \in \{0, 1\} \qquad i,j \in V \tag{10}$$

$$v_{ijk}(s_{ik} + t_{ij} - s_{jk}) \leq 0 \qquad i \in V, j \in C, k \in K \tag{11}$$

$$a_i \leq s_{ik} \leq b_i \qquad i \in V, k \in K \tag{12}$$

Equation (1) shows that the ultimate goal of this mathematical model is to obtain minimum cost by minimize vehicle routing distances. Equation (2) and (3) shows that for each consumer can only be visited once. While equation (4) defines the maximum number available in the system is limited with the number of routes is in, equation (5) shows the number of products which is loaded in a certain vehicle in a particular depo (consolidation warehouse) as well as shows the non-sub tour constraint. Equation (6) and (7) shows the number of deliveries after visiting the first branch office and the other branch office in a route. The capacity constrains are stated in equation (8) and (9) keeping that the number of products loaded in a vehicle will not exceed its maximum capacity. Equation (10) describes the binary decision variable. Time windows constrain is shown in equation (11) which shows the relationship between time of visit in a branch office *i* to other branch office as well as equation (12) which shows the time windows of branch office *i*.

Container Loading Problem (*CLP*)

Globenewswire.com has described the loading problem as per follow [7]. Supposed that a truck (vehicle) with a particular capacity and size has to visits minimum 1 consumer for pickup and or delivery with the number of items that has to be delivered or picked up for each city are minimum 0. In the warehouse or depo, the vehicle container should be loaded with all delivered items. For each city, the vehicle has to pay additional cost for re-arranging the items inside its container due to fitting picked up items or unloading delivery goods which are blocked by another items. Problem formulation for CLP with Pickup and Delivery (CLP-PD) is described in the following paragraph.

A container can be considered as three dimensions axis. A con-

tainer has maximum value of axis x, y, and z which determines the container's capacity of loading. The number of parcels loaded in a certain capacity will be depend on the volume of loaded parcels. A number of parcels must be loaded inside the container. Thus, a certain parcel can be located in a particular feasible location coordinate (x, y, and z are not exceeding maximum value of each axis). The parcels stacking cannot overlap one another. If a parcel would be loaded or unloaded, a particular cost is occurred. Therefore, parcels for a particular delivery points should be placed nearby and parcels for the earliest delivery points should be located in nearest exit door's coordinate. Optimization in CLP-PD means minimizing the cost by arranging the loaded and unloaded items inside the container, which had been developed by modifying [15] as per follow:

Suppose a vehicle carries *n* number of loaded goods to be delivered and *m* goods for pick up to *j* consumer. Therefore, the minimum of goods movement is $\sum_{i=1}^{j}(2n_i + m_i)$ meanwhile *o* position changes will happen in a particular consumer. Thus, the movement of goods are $\sum_{i=1}^{j}(2n_i + m_i + o_i)$. The change of movement will happen if a particular good applied LIFO (last in first out) for delivery unloading and if the number of deliveries in a certain node is smaller to the number of pickups.

There are two sets involved in this activity:
a. AN_i set of delivered goods for node *i* (0, *q*, ... *n*)
b. AM_i set of picked up goods for node *i* (0, *q*, ... *m*)

The objective function follows:

$$\text{Min} \quad \sum_{i=1}^{j}(c_i * o_i) \tag{13}$$

subject to:

$$(L \times W \times H) - (\sum_{l=1}^{J} l_{ni} \times w_{ni} \times h_{ni} + l_{mi} \times w_{mi} \times h_{mi}) \geq 0 \tag{14}$$

$$x_q + l_q X_{lq} + w_q(Z_{lq} - Y_{wq} + Z_{hq}) + h_q(1 - X_{lq} - Z_{lq} + Y_{wq} - Z_{hq}) \leq x_r + M(1 - a_{qr}) \tag{15}$$

$$y_q + w_q Y_{wq} + l_q(1 - X_{lq} - Z_{lq}) + h_q(X_{lq} + Z_{lq} - Y_{wq}) \leq y_r + M(1 - b_{qr}) \tag{16}$$

$$z_q + h_q Z_{hq} + w_q(1 - Z_{lq} - Z_{hq}) + l_q Z_{lq} \leq z_r + M(1 - c_{qr}) \tag{17}$$

$$x_q + l_q X_{lq} + w_q(Z_{lq} + Y_{wq} + Z_{hq}) + h_q(1 - X_{lq} - Z_{lq} + Y_{wq} - Z_{hq}) \leq L \tag{18}$$

$$y_q + w_q Y_{wq} + l_q(1 - X_{lq} - Z_{lq}) + h_q(X_{lq} + Z_{lq} - Y_{wq}) \leq W \tag{19}$$

$$z_q + h_q Z_{hq} + w_q(1 - Z_{lq} - Z_{hq}) + l_q Z_{lq} \leq H \tag{20}$$

$$a_{qr} + a_{rq} + b_{qr} + b_{rq} + c_{qr} + c_{rq} \geq 1 \; \forall AN_i, AM_i \tag{21}$$

$$X_{lq} + Z_{lq} \leq 1 \tag{22}$$

$$Z_{lq} + Z_{hi} \leq 1 \tag{23}$$

$$0 \leq (Z_{lq} - Y_{wq} + Z_{hq}) \leq 1 \tag{24}$$

$$0 \leq (1 - X_{lq} - Z_{lq} + Y_{wq} - Z_{hq}) \leq 1 \tag{25}$$

$$0 \leq (X_{lq} - Y_{wq} + Z_{hq}) \leq 1 \tag{26}$$

$$\sum_{l=1}^{J}(s_{ni} + s_{mi}) \geq 0 \tag{27}$$

$$\sum_{l=1}^{J} 2n_i + m_i + o_i \geq 1 \tag{28}$$

Equation (14) shows the volumetric optimum restriction. The overlap for goods' arrangement is prevented with equation (15), (16) and (17). Equation (18), (19) and (20) show that transport objects are arranged not to exceed the size of containers. The limitation of two transport object *q* and *r* for a particular node *i* to be arranged close together is stated in equation (21). The binary variables that show the transported goods are controlled by practical position are stated in equation (22), (23), (24), (25) and (26). The priority of loading is stated in in equation (27) and total movement of transported goods is defined by equation (28).

Enumeration and analytical procedure are commonly used to solve the CLP problem. However, because of CLP is NP-hard problem, enumeration and analytical procedure would require enormous amount of computation time [27]. The simplest and practical way to get the minimum cost of movement and positioning is by developing algorithm. The container loading algorithm is developed based on several considerations: the mathematical model, assumptions made in the practice situation, single size of transported good, and several rules of thumbs as listed in Table 1 (see [7] for more detail). Meanwhile the loading algorithm illustration of the rule of thumb are shown in Figure 5 and Figure 6, respectively.

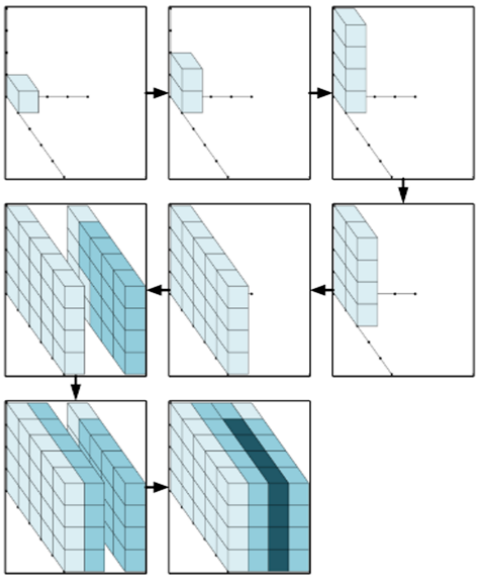


Figure 5. Item loading process

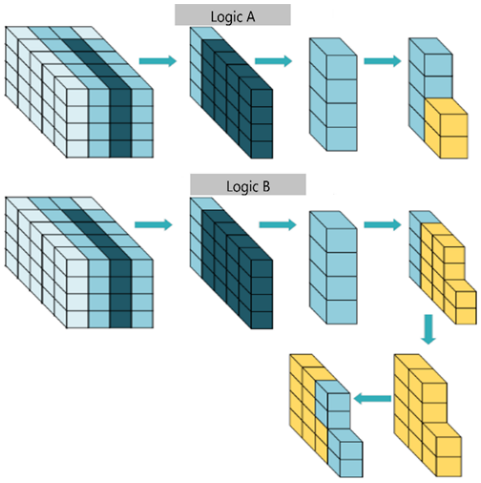


Figure 6. Item unloading/re-loading process [7]

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Supposed that a container has to visits three cities to deliver a product and in the first city, the container must pick up a number of products to be sent back to warehouse. We may see in the Figure 5 that the goods delivered in each city are colored with different blue color, while in Figure 6, we can see that the pick-up items are colored with yellow. There are two possible scenarios, if the picked-up items are fewer than delivered item for a city, logic A is applied. By logic A, the worker would not have to re-arrange any product since the unloading process in the next city is still being able to be done. Meanwhile if the picked-up items are bigger in number, re-arrangement would be done. Worker must take out delivered product and then re-arranged so that it can be easily unloaded. The pseudocode for fraction cost calculation and the loading unloading procedure are written in the pseudocode as per below:

****

START

#This program is an algorithm to pack the goods inside one door container and to calculate the cost due to movement of products during the packing sections
get Solution[0][*j*]Ysequenceascending[*i*][*k*]

#set cost per movement
unitmovementcost = input ("cost per movement")

#check position of a particular node towards its routing selections
IF node[j] < 1 THEN
  previoussolution = Solution[0][j]Ysequenceascending[i][k]
ELSE
  previoussolution = Solution[0][j-1]Ysequenceascending[i][k]
ENDIF

FOR each node
#setting the solution into 1-0 matrix (0=empty cell; 1=nonempty cell)
BEGIN assign 0 in previoussolution
EXCEPTIONS
WHEN cell in previossolution ≠ 0 assign 1
END

#unload the goods
FOR every good shall be take out for a node check
IF a product is located in blocked cell so it can't be unloaded (cell z+1 and y+1 with 1) THEN
  assign cell z+1, or y+1 and that cell with 0 #unloading blocking cell
ELSE
  assign that cell with 0 SAVE as previoussolution
ENDFOR

#remainingcapacity
GET capacitydata[x,y,z]
FOR every previoussolution [x,y,z]
remainingcapacity = CALCULATE [0]

#reloads the goods
FOR every good shall be loaded for a node check
IF z1 = 0 THEN
  assign z1 = 1 and upward until zmax = 1 or all loaded goods had been assigned
  #start from the bottom upwards then move to x = x+1
ELSE
  IF z1 ≠ 0 THEN

Table 2. Data of Vehicle Capacity

Data set	Capacity (unit)	Container size (unit)			Maximum value axis		
		l	w	h	x	y	z
R121_100_800	800	10	5	4	5	10	4
R121_150_1000	1000	10	10	10	10	10	10
R121_200_1200	1200	12	10	10	10	12	10
C141_250_1500	1500	15	10	10	10	15	10
C141_300_2000	2000	20	10	10	10	20	10
C141_350_2500	2500	25	10	10	10	25	10
C141_400_2500	2500	25	10	10	10	25	10

    assign empty cell number of loaded goods as much as the goods shall be loaded = 1
    #start from the bottom upwards then move to x = x+1
  ELSE
    empty the blocked cell
THEN
  load the empty cell from the bottom upwards then move to x = x+1
SAVE [x,y,z] as previoussolution
COUNT change 1- 0 -1
SAVE as change
ENDFOR

#total movement
FOR every changes ASSIGN movement = 1
  CALCULATE totalmovementi = summovementi
ENDFOR

#total cost calculation
totalmovementcosti = totalmovementi * unitmovementcost
print (totalmovementcosti)

****

The process in Figure 5, Figure 6, and Table 1 had aligned with the principle of optimization of container loading problem in [30] to emphasize the balance of container during the process. The optimum result based on [30] emphasizing the loading in center of gravity for loading a container. Since the scope of this study is to make sure the effectiveness of unloading/re-loading process the loading in the center of gravity had become the main point of unloading and reloading process in the proposed algorithm [10].

The process is also treating first consumer or recipient to become the priority of loading and unloading thus should be placed as near as possible to container's door. This priority is aligned with the principle of loading for expiring orders developed by [31]. However, in this study, the priority is set as descending order to follow the operational of routing process as well as forward and reverse logistics.

Large Data Set for Implementation

As mentioned in previous sub section, the data set is modified from [27], the capacity of vehicle is modified as shown in Table 2. The modification is located on the generation of solution VRPSPD-TW and the generation of loading and unloading algorithm.

RESULT AND DISCUSSION

The sequential algorithm is as depicted in Figure 7. In the figure, we see that the algorithm is a sequential of two proce-

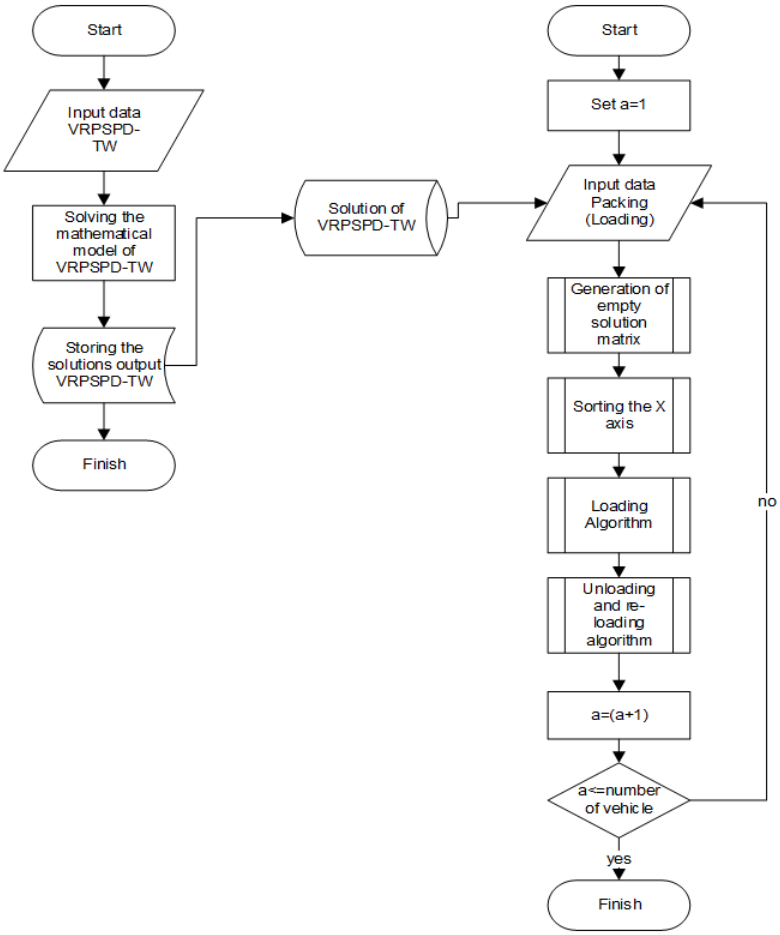


Figure 7. Sequential Algorithm modification from [10]

dure of VRPSPD-TW and CLP algorithm which is modified from [10]. Even though in this study we generate the solution of VRPSPD-TW through SA with restart procedure of metaheuristics, the algorithm itself did not specify a certain procedure. The user may choose any other methods to solve the VRPSPD-TW. The generation of loading and unloading are modified as written in the pseudocode in section methods.

Based on the algorithm, a performance measurement of this problem had moved from filling rate to minimize unloading/re-loading cost. The filling rate had been used by many research of container loading problem such as [30], [24], [32], [25], and [19]. In this study, the filling rate is ensured by the result of VRPSPD-TW. Thus, the overall problem can be swift into minimizing cost: cost of transportation for VRPSPD-TW and cost of unloading/re-loading for CLP-PD.

This study, two different computational are performed for each VRPSPD-TW and for container loading algorithm each with different type of computers. Thus, it is not an apple to apple to compare the computational of this problem with another methods. Several research had measured the performance of a method based on computational time [23] [24] [25]. Further research may be performed to understand the performance of this algorithm toward computational processing time.

This algorithm had considered forward and reverse logistics for one door container to be used in city logistics. The procedure proposed in this algorithm therefore can be used in any type of multi-echelon type which a vehicle is assigned to pick-up and delivery activities. Even though currently delivery point for B2C is not yet common practice in Indonesia, the procedure in the algorithm is still being able to overcome the application for delivery point, not just home delivery.

Implementation of Proposed Algorithm in Large Data Size

Implementation of VRP PD with TW model were done for vehicle with certain (limited) capacity. The process of generation generation solution is completed with metaheuristic methods which is Simulated Annealing with restart point (SA-RP) as noted by [33]. The problem VRP PD with TW is modified from set data in [33] (see Table 2). Implementation results are detailed in Table 3. The results in Table 3 are used as the input for the loading problem.

JAVA program was developed to implement the algorithm (and the pseudo code) for two set of data: small and large data. The input for container loading algorithm for small data is solution of 25 data sets of vehicle routing problem with pickup and delivery (VRPPD), while the large data input is solution of 7 data sets of vehicle routing problem for pickup and delivery with time windows (VRPPD-TW). VRPPD data sets are taken from [27] while VRPPD-TW data sets are modified from [27]. Small data sets consist of three figures of consumers: 15, 17, and 20 and two vehicle capacities (sizes): 80 and 120. Large data sets are having six different capacities (sizes): 800, 1000, 1200, 1500, 2000 and 2500; while the numbers of customers are varying: 100, 150, 200, 250, 300, 350 and 400. The solution of VRPPD is obtained from analytical calculation while solution of VRPPD-TW is obtained from performing metaheuristics algorithm to speed up the calculation time. The

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Table 3. Result of SA-RP for VRP PD with TW in Larger Data Set

No.	Dataset	Total distance			Computation Time (s)	Customer served per truck			
		Min	Max	Average		Truck 1	Truck 2	Truck 3	Truck 4
1	R121_100_800	1352,49	1743,75	1487,80	35,41	6	45	45	4
2	R121_150_1000	1618,45	2107,96	1769,88	55,58	60	56	34	n.a
3	R121_200_1200	1755,58	2129,04	1892,34	74,64	71	70	59	n.a
4	C141_250_1500	2013,83	3935,04	2619,28	109,17	102	101	47	n.a
5	C141_300_2000	2168,90	3701,26	2633,85	145,79	135	139	34	n.a
6	C141_350_2500	2043,63	3145,72	2413,82	163,14	167	170	13	n.a
7	C141_400_2500	2303,30	2712,37	2470,59	191,59	175	166	59	n.a

Table 4. Simulation Result of Proposed Container Loading Algorithm for Small Data Sets [7]

No.	Data Sets	Route (vehicle)	Additional Cost for Each Activity			Average Fraction Cost per Citu			
			Min	Avrg.	Max	Truck 1	Truck 2	Truck 3	Truck 4
1	R121_15_120	2	0	0	0	0	0	n.a	n.a
2	R121_15_80	3	0	1	3	0	0.75	0	n.a
3	R121_17_120	2	0	0	0	0	0	n.a	n.a
4	R121_17_80	4	0	0	0	0	0	0	0
5	R121_20_120	2	2	5.5	9	0.25	0.75	n.a	n.a
6	R141_15_120	2	6	11	16	1.5	1.46	n.a	n.a
7	R141_15_80	3	0	1	3	0	0.5	0	n.a
8	R141_17_120	2	0	3.5	7	0.7	0	n.a	n.a
9	R141_17_80	3	0	3.7	11	0	0	1.58	n.a
10	R141_20_120	2	6	11	16	0.67	1.46	n.a	n.a
11	R161_15_120	2	0	0	0	0	0	n.a	n.a
12	R161_15_80	2	0	3.5	7	0	0.78	n.a	n.a
13	R161_17_120	2	0	2	4	0	0.4	n.a	n.a
14	R161_17_80	3	0	3	7	0.29	0.78	0	n.a
15	R161_20_120	2	0	0	0	0	0	n.a	n.a
16	R181_15_120	2	0	3	6	0.6	0	n.a	n.a
17	R181_15_80	2	0	2	4	0.5	0	n.a	n.a
18	R181_17_120	2	0	2	4	0	0.45	n.a	n.a
19	R181_17_80	3	0	0	0	0	0	0	n.a
20	R181_20_120	2	0	2	4	0	0.45	n.a	n.a
21	R1101_15_120	2	0	7	14	0	1	n.a	n.a

result for small data sets is as seen in Table 4 [10] and the running result for large data sets is as seen in Table 5.

Table 4 shows that 59.65% of the trucks (routes) have not charged any cost, meanwhile the rest of the trucks (routes) have in average maximum cost per city 1 fraction of cost. After checking the correlation, the correlation coefficient between number of cities visited per truck and number of costs per truck is highly correlated (0.512). Meanwhile it is clear to see in Table 5 that the cost per city is increasing along with the increment of capacity and number of cities visited of that particular truck.

Comparing Table 4 and Table 5, it is clearly seen that the minimum additional cost for each city in Table 2 is 0 while higher minimum additional cost for each city are noted in Table 3 (minimum cost = 1). By considering the process of obtaining the VRP solutions which are becoming input for the proposed container loading problem, solutions of VRPPD for small data set are global optimum since it is gained from analytical calculation. In contrary, solutions of VRPPD-TW for large data set are probably local optimum as the application of metaheuristics algorithm. It is tempting to presume that the increasing of minimum additional cost is an effect of local-global optimum differences. A further examination needs to be carried out to determine the effect of local-global optimum differences toward the minimum additional cost that a truck will have. The container size can be a suspect on this discrepancy result. The container size ratio in small data sets and large data sets is different to fit with real world container size. In such heuristic algorithm, parcels arrangement and configuration are very reliant to the size of container, therefore, differences of items configuration may happen to same capacity but different container size ratio which leads to additional cost variances. Further simulation study needs to be done to understand the impact of container size ratio towards additional cost.

Pearson correlation calculation performed for large data sets has produce strongly high correlation coefficient (0.772) between numbers of cities visited and additional cost of loading/

Table 5. Simulation Result of Proposed Container Loading Algorithm for Large Data

No.	Data Sets	Route (vehicle)	Additional Cost for Each Activity			Average Fraction Cost per Citu			
			Min	Avrg.	Max	Truck 1	Truck 2	Truck 3	Truck 4
1	R121_100_800	4	1.00	50.50	100.00	62.50	53.33	42.74	64
2	R121_150_1000	3	2.00	74.00	149.00	72.18	75.95	80.62	n.a
3	R121_200_1200	3	1.00	104.72	199.00	104.59	104.86	90.41	n.a
4	C141_250_1500	3	1.00	122.78	249.00	109.47	136.22	137.26	n.a
5	C141_300_2000	3	1.00	156.28	308.00	157.01	155.58	140.15	n.a
6	C141_350_2500	3	1.00	176.67	350.00	182.84	170.60	145.23	n.a
7	C141_400_2500	3	1.00	200.50	400.00	204.05	199.17	193.71	n.a

loading. Therefore, for each type of data set, we plot the data to understand the correlation between number of cities visited by a truck and the fraction of the truck and perform regression analysis. The graphs are shown in Figure 8 and Figure 9.

Linear regression equation is developed for better understanding and predicting the impact of number of customers served towards fraction of cost. Based on the result, the figure of of coefficient determination (R-square) and coefficient of x (slope) of each regression in Figure 8 and Figure 9 had shown different phenomenon. In small data sets, slope is higher but coefficient determination is smaller compared to the result in large data sets. R-square in Figure 8 had shown that for small data sets, only 26.2% variance of the additional cost can be explained by the number of cities visited meanwhile in Figure 9, 52.14% additional cost variance in large data sets can be explained by number of cities visited. This is aligned with the result of correlation coefficient which are smaller in small data sets. However, the value of coefficient determination for large and small data are below 0.6 which means that large variation would expect to be found in using the prediction equation of fraction cost. This may happen due to the possibility that there are other variables that affect the cost fraction apart from the number of customers served per container, such as: the number of delivered and picked up goods per customers and the sequences or route of a vehicle. Thus, another test should be performed for more data sets to meet the assumptions for linear regression modelling.

The results of the implementation of the algorithm show a tendency which are in accordance to the supposition that the amount of additional costs will be higher if a truck shall involve in more complex logistics experiences which may come from more objects to be loaded (larger container capacity) or more cities to be visited. The number of items to be delivered or picked-up shows that the difficulty level of loading and unloading will determine the successful implementation of this algorithm resulting in a better cost fraction. The more cities visited, the greater the fraction of the costs. This is also due to the unload (delivery) and loading (pick-up) activities in a container, the frequency will be higher along with the number of cities visited considering that in one city there is at least one of these delivery or pick-up activities.

The challenge to adjust field practices and conditions with container loading algorithm such as considering non-uniform size objects, improving truck balance, weight constraint, different shape of transport containers, damage to goods, and dynamics of routing, are certainly an interesting thing to study further in near future. Ramos et al. [32] had proposed the algorithm, which considering load weight balance, however, the algorithm is not yet implemented to forward and reverse logistics.

CONCLUSION

It is to conclude that the performance of proposed container loading algorithm had been able to be performed in large data as well as small data. The proposed container loading algorithm is also being able to receive input from the feasible routing process for large and small data. This fact is strengthening an argument that by using the vehicle routing, capacity is not becoming a constraint especially for single unisize product. The larger frequency of loading/unloading goods that should be served by a container, the higher cost would be. The performance of container loading algorithm thus would only depend on the complexity (number) of loading/unloading goods and the number of cities visited by a particular truck. However, the coefficient determination in the model are still below 0.6 because the data set used in this study were only seven (7) data sets. Further research should be conducted with more data sets to model the impact of number of customers served toward the fraction of cost.

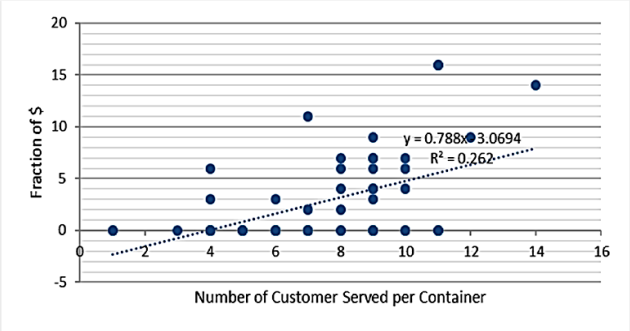


Figure 8. Plot Data of Number of Cities Visited by a Truck in Small Data Sets

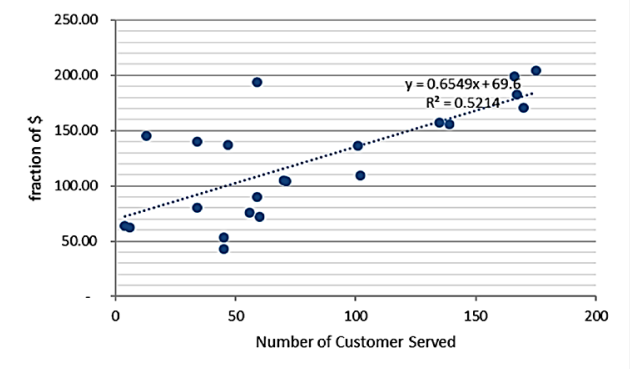


Figure 8. Plot Data of Number of Cities Visited by a Truck in Large Data Sets

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Since Proposed algorithm was applied on the hypothetical data, therefore further study needs to be done to understand the implementation on real world problems. The complexities of real-world problems are also being simplified in this study, therefore further developments are needed to develop fit algorithm such as considering un-uniform sized goods, weight, and damage constraints. Furthermore, the concept of delivery and pick-up is common to be presented for green logistics and circular economy. Therefore, further study can also be performed for improving this algorithm by considering the green performance measurement parameters.

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NOMENCLATURE

C	consumer set (1,2,.....C)
K	vehicle set (1,2,.....,K)
c_{ij}	distances from i to j
Q_k	capacity of vehicle k
d_i	delivery to consumer I
p_i	pickup in consumer I
l_i	number of deliveries after visiting consumer I
ld_i	total delivery to consumer i and all consumers
$[a_i,b_i]$	consumer time windows i when the consumer open to vehicle arrival (a_i) and close to vehicle service (b_i), the time windows for depo is $[a_0,b_{n+1}]$
s_{ik}	the time when vehicle k starts to serve consumer i, when $a_0 = 0$ then $s_{0k} = 0$ for all vehicle k
t_{ij}	time of travel from node i to j
n_i	number of delivered goods for node I
m_i	number of pick up goods for node I
s_{ni}	sequence of loading for goods n in node I
L,W,H	length, weight, and height of the container
l_q,w_q,h_q	length, weight, and height of the transported goods
a_{qr},b_{qr},c_{qr}	binary variable to show the relative placement of object q to goods r. The value = 1 if the q placed in line-up coincide from any side with object r.
p_q	priority of loading transported goods q
$X_{lq},Z_{lq},W_{lq},H_{lq}$	binary variable to show if the length of the object q is parallel to the x and z axis of the transport vehicle; the direction of width is parallel to the y axis; and the height is in the direction of the z axis. This determines the orientation of the transport object.

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