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Original Article

An algorithm for packing postal items into roll pallets: A case study on a local branch of Thailand Post

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Abstract

Three dimensional packing is a major problem occurring in the transportation sector. It is also a challenging problem to overcome the limitations of existing businesses. This research studies the problem for packing items of Thailand Post (local branches) which provide delivery service to customers and arrange to pack items by staff for delivery to the distribution center. Moreover, the staff want to arrange and pack items into limited roll pallets which must be delivered within the specified period.

In this paper, we analyze the problem under the limitations of different types of items and the number of roll pallets and developed an algorithm for sorting and packing items to minimize the amount of items left at the branch when limited roll pallets are available. Moreover, this algorithm can reduce the number of items left at the branch and serve as a guideline for staff.

Keywords: block, item, layer, roll pallet, three-dimensional packing

1. Introduction

Nowadays, online shopping has gained great popularity. As a result, the item delivery business has a large number of users and a tremendous growth. Thailand Post is a company that provides item delivery services including the postal services: express mail service, registered postal service, logispost service, etc. This research has studied information from the Rusamilae branch of Thailand Post which is also a sub-branch serving in Pattani. From studying and observing the collection of delivery items, it was found that this caused a residue of some items which could not be delivered on time or were delivered later than usual during the festival or during the period with a large number of items. The items are packed in either the standard boxes of Thailand post or nonstandard boxes provided by the customers. Here, we focus on all items packed into the standard boxes of six types (Figure 1a). From observing and analyzing the problem, it was found that this

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(a)

(b)

Figure 1. (a) Six types of items, (b) A roll pallet of 58 cm x 100 cm x 138 cm.

sub-branch had limited number of roll pallets which is a three-dimensional cuboid rectangular container of width 58 cm, length 100 cm, and height 138 cm, (Figure 1b), and that the packing of items into the roll pallets was random or unregulated.

Thailand Post (local branches) still arrange and pack all items by staff to deliver them to the distribution center. The aim of this research is to devise a methodology or an algorithm to guide the staff of Thailand Post of Rusamilae branch for packing the items into roll pallets where the numbers are limited, and to allow roll pallets to be packed to their full capacity or to minimize the available space, which can reduce the amount of items left at the branch.

Here, we review some researches associated with our problem as follows. He and Huang (2010) proposed a caving degree based flake arrangement approach for binding items with the same size into a larger flake and packing the flake into a fringe corner which was close to the eight vertices of the container. This placement meant that the flake could be compact and close to other flakes which were already placed in the container. Later, He and Huang (2011) reported new algorithm modified from the caving degree approach and presented a fit degree algorithm for solving the container loading problem (CLP). To do that, they began to consider all items with the same size and combine them into one or several layers to place at the possible position of container. Next, Ren, Tian, and Sawaragi (2011) studied CLPs focusing on a shipment and used tree search based on a greedy heuristic. This method showed that all blocks could be generated with the same item type and orientation. Moreover, they presented the block selection by five evaluation functions, each of which could be used to select the different blocks. Later, Boussaïd, Lepagnot and Siarry (2013) provided a survey on some of the main metaheuristics. This described both single-solution and population-based metaheuristics. In 2016, Sheng, Hongxia, Xisong, and Changjian (2016) considered the loading of different pallets in a container. All items could be combined in each pallet then it was packed in the container. After that, there were some free spaces, so they solved this problem by adding infill items to obtain the least free spaces in the container. Moreover, they showed a heuristic algorithm to solve the above problem by using tree search in a process that managed pallets into the container and using greedy algorithm to fulfill the free spaces with infill items. Next, Dokeroglu, Sevinc, Kucukyilmaz, and Cosar (2019) reviewed the new generation metaheuristic algorithms such as artificial bee colony optimization, which is a population-based algorithm to generate solutions for searching spaces.

The remaining parts are organized as follows. Section 2 presents a mathematical formulation of this problem. The placement procedure with five stages for managing all items into each roll pallet is given in Section 3. The algorithm relating to the previous section and two experimental results are included in Sections 4 and 5, respectively. Finally, conclusions are given in Section 6.

2. Mathematical Formulation

Here, we will describe the problem with a mathematical formulation as follows. Let R be a roll pallet of W x L x H cm^3. This problem is a three-dimensional problem to optimize the highest volume utilization for packing items into R described by two cases:

The first case is that the block B_j with the same item type is positioned in R represented by an objective function:

$$\max\left\{\sum_{j=1}^{N} q_j l_j w_j h_j \mid q_j \in \{0,1\},\, j = 1,2,\ldots,N\right\},$$

where $q_j = 1$ when the block B_j is positioned in R and $q_j = 0$ when the block B_j is not positioned in R, where N is the number of all blocks.

The second case is that the block B_j with the different item types is positioned in R described by an objective function:

$$\max\left\{\sum_{j=1}^{N} r_j l_j w_j h_j \mid r_j = 1 - q_j,\ j = 1,2,\ldots,N\right\},$$

where $r_j = 1$ when the block B_j is positioned by different item types in R and is filled with other items, and $r_j = 0$ when the block B_j is not positioned by different item types in R and is not filled with other items.

Both cases satisfy the following constraints:

- All items are the standard boxes with six types: A, B, C, D, E and F.
- All items cannot be overlapped.
- Each item put in R must be supported by other boxes and placed parallel to the edge of R.
- All items can be orientated by six possible forms as in Figure 2.
- The maximum weight of each item should not exceed 4 kg.
- There are 12 roll pallets at the Rusamilae branch.
- Each roll pallet can load the maximum weight which should not exceed 180 kg.

Here, we provide some definitions as follows:

- Volume utilization is to pack items with volume management in three dimensions for the maximum efficiency.
- Area utilization is to pack items with two-dimensional space management for the maximum efficiency.

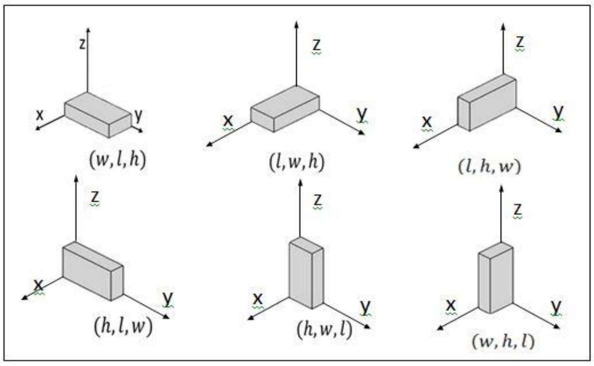

Figure 2. Six orientations of each item where w, l, h are width, length, and height, respectively

3. Placement Procedure

There are five states to manage all items into each roll pallet as follows:

3.1 Item arrangement

Here, we distinguish all items into six types (sizes): A, B, C, D, E and F. The details of each type can be given as follows: A: 14 x 20 x 6 cm^3, B: 17 x 25 x 9 cm^3, C: 20 x 30 x 11 cm^3, D: 22 x 35 x 14 cm^3, E: 24 x 40 x 17 cm^3, and F: 30 x 45 x 20 cm^3.

3.2 Block arrangement

Each block is generated by combining items with the same size and orientation to form the largest cubes to be put into the roll pallet by applying ideas of He and Huang (2010), Boussaïd, Lepagnot and Siarry (2013), and Dokeroglu, Sevinc, Kucukyilmaz, and Cosar (2019). Since an item can orient into six forms, this provides the different volume utilization and total number of items in *R*. The total number of items can be calculated by six forms based on the orientation in Figure 2 as follows: if the first form is (w, l, h) then $n_w = \lfloor W / w_i \rfloor$, $n_l = \lfloor L / l_i \rfloor$, $n_h = \lfloor H / h_i \rfloor$. For the second form ($l, w, h$), it has $n_w = \lfloor W / l_i \rfloor$, $n_l = \lfloor L / w_i \rfloor$, $n_h = \lfloor H / h_i \rfloor$. For other four forms, this can use the same ideas to calculate n_w, n_l, n_h, where W, L and H are width, length, and height of the roll pallet, respectively, w_i, l_i and h_i are width, length, and height of item for each size, respectively, and $i = A, B, C, D, E, F$. The maximum number of items along with the width of R (n_w) is the greatest integer of the quotient between the width of R and the size on which side of the item is placed parallel to the width of R. In the same way, to calculate the maximum numbers of items along with the length of R (n_L) and the height of R (n_H), so the total number of items in R (n) is $n = n_w \times n_L \times n_H$. Moreover, we also calculate volume utilization (in percent) with six orientations in Figure 3. After packing items and computing volume utilization, this gives that items with types A, B, C show high volume utilization (%), 96.55%, 91.75%, and 82.46%, respectively. On the other hand, items with types D, E, F give the low volume utilization. Hence, we cannot complete the packing in R with one type of item. Moreover, to pack items with types A, B, C in R to be full is not good because this takes a long time for packing. In practice, we can put items with types A, B, C in the bags, then these bags are packed into the roll pallet. For packing with one type of item by considering types D, E and F, they give low volume utilization resulting in ineffective management and many free spaces remain. It may result in causing damage of items during transportation. Thus, we should pack items with more than one type into R focusing on convenient usability. To do this, we combine items with the same size into a large horizontal block, then it is packed into R.

In practice, the first step for creating a block is to bring items of the same size (types D, E, F) without considering the height of items. This means that the items are combined into blocks horizontally with six orientations. Each orientation gives a different number of items (n) in a block and area utilization in R as in Table 1. To create a block from one type of item, we can generate it into six forms. On the other hand, if we focus on one orientation to select the best block, then we will consider from the highest area utilization because it first must be managed in two dimensions to be effective. This also gives that the highest area utilization of each item type (D, E and F) presents the orientation satisfying the best management for the block.

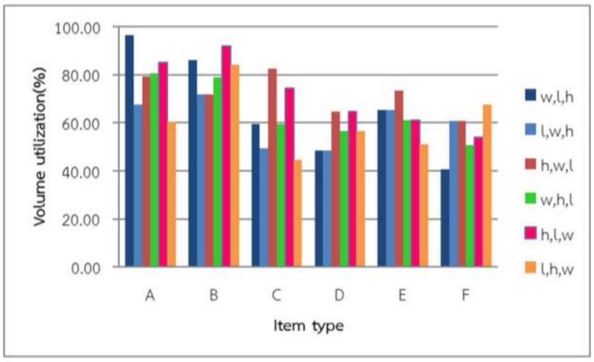

Figure 3. Volume utilization (%) of item types with six orientations

Next, the width (w_b), length (l_b) and height (h_b) of the block can be calculated as follows:

$$w_b = \alpha \lfloor W / \alpha \rfloor,\ l_b = \beta \lfloor L / \beta \rfloor \text{ and } h_b = \gamma.$$

Table 1 shows that B_D and B_E give the highest area utilization of 84.97%, 84.41% with h, w, l respectively, and B_F reveals the highest area utilization 77.59% with l, h, w. So these forms are used to produce blocks for items types D, E, F.

After we get a block, it is placed and compared with the area in R by putting it at the origin in Figure 4(a). Moreover, there are free spaces between the space in the block and roll pallet that is the free space on the side of block (S_s) or the front of block (S_f) in Figure 4(b).

Table 1. Details of the number of items (n) in a block and area utilization in R of types D, E and F, with six orientations

Block	Orientation	n	Area (cm^2)	Area utilization (%)
B_D	w, l, h	4	3,080	53.10
	l, w, h	4	3,080	53.10
	h, w, l	16	4,928	84.97
	w, h, l	14	4,312	74.34
	h, l, w	8	3,920	67.59
	l, h, w	7	3,430	59.14
B_E	w, l, h	4	3,840	66.21
	l, w, h	4	3,840	66.21
	h, w, l	12	4,896	84.41
	w, h, l	10	4,080	70.34
	h, l, w	6	4,080	70.34
	l, h, w	5	3,400	58.62
B_F	w, l, h	2	2,700	46.55
	l, w, h	3	4,050	69.83
	h, w, l	6	3,600	62.07
	w, h, l	5	3,000	51.72
	h, l, w	4	3,600	62.07
	l, h, w	5	4,500	77.59

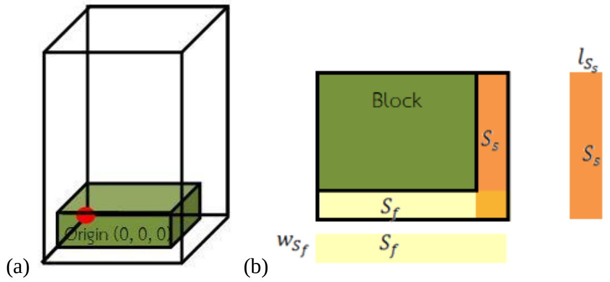

Figure 4. (a) Putting a block in R at the origin. (b) The free space on the side of block (S_s) and the front of block (S_f). Ws_f and ls_s are width and length, respectively, of the free space on the side of block.

3.3 Layer building strategy

A layer is formed by combining blocks from the previous step and adding infill items (using items with types A, B and C) to fulfill the remaining space. Here, we applied the ideas of He and Huang (2011), Boussaïd, Lepagnot and Siarry (2013), and Sheng, Hongxia, Xisong, and Changjian (2016). The infill items are placed to generate the height of the layer equal to the height of block. Table 2 shows three layer types: Q, R and S, including the number of main items and infill items. Each layer contains only one type of infill item. Moreover, the weight of items for each layer does not result in damage to other layer placed below it because the maximum weight of each item should not exceed 4 kg.

Table 2 is considered by the following conditions.

- Consider the free spaces on the side of block (S_s) and the front of block (S_f) by computing $Ws_f = W - w_b$, $S_f = Ws_f \times L$, $ls_s = L - l_b$, $S_s = W \times ls_s$, where Ws_f is the width of the free space on the front of block, ls_s is the length of the free space on the side of block, W and L are the width and the length of R.
- Compute the largest free space $S_{\max}$:

$$S_{\max} = w_S \times l_S = \begin{cases} S_f & \text{if } (W_{S_f} \times L) > (W \times l_{S_S}) \\ S_S & \text{if } (W_{S_f} \times L) < (W \times l_{S_S}) \end{cases},$$

  where w_s parallels with W and l_s parallels with L. After we get $S_{\max}$, we consider the height of $S_{\max}$, denoted by h_s, which is equal to the height of block (h_b).
- Focus on four conditions of infill items added into the largest free space $S_{\max}$ by considering size (w_i x l_i x h_i) and six orientations of them for placing into $S_{\max}$ with size (w_s x l_s x h_s).
  - The first condition is that all infill items should be item types: A, B and C. This cannot be taken to build a block.
  - The second one is that infill items in any layers are defined by $Inf_{L_i} = (\alpha, \beta, \gamma, m)$ where m is the number of infill items in any layer, $\alpha, \beta, \gamma,$ of infill items in any layer are defined as follows.

Table 2. Three layer types: Q, R and S. Each layer type consists of main items (n) and infill items (m).

Type of layer	Height of layer (cm)	Type of main item in a block	Type of infill item	n	m	Area utilization (%)
Q	35	D	-	16	-	84.97
R	40	E	A	12	14	94.55
S	30	F	C	5	5	96.55

$$\alpha = \begin{cases} w_i & \text{when the width of infill item parallels to the width of } R, \\ l_i & \text{when the length of infill item parallels to the width of } R, \\ h_i & \text{when the height of infill item parallels to the width of } R, \end{cases}$$

$$\beta = \begin{cases} w_i & \text{when the width of infill item parallels to the length of } R, \\ l_i & \text{when the length of infill item parallels to the length of } R, \\ h_i & \text{when the height of infill item parallels to the length of } R, \end{cases}$$

$$\gamma = \begin{cases} w_i & \text{when the width of infill item parallels to the height of } R, \\ l_i & \text{when the length of infill item parallels to the height of } R, \\ h_i & \text{when the height of infill item parallels to the height of } R. \end{cases}$$

Here, $i = A, B, C, D, E, F$.

- The third one is to calculate the largest free space $S_{\max}$ of each layer and to consider items for each type satisfying the following three sub conditions:
  - If any side of item can be put or stacked, then the height of side of item (γ) is equal to the height of $S_{\max}$, this can be given by

$$\gamma = \begin{cases} w_i & \text{if } h_S - w_i \lfloor h_S / w_i \rfloor = 0, \\ l_i & \text{if } h_S - l_i \lfloor h_S / l_i \rfloor = 0, \\ h_i & \text{if } h_S - h_i \lfloor h_S / h_i \rfloor = 0, \\ +\infty, & \text{otherwise.} \end{cases}$$

    Note that if $\gamma = +\infty$, it means that the considered item cannot be packed into $S_{\max}$, then we can take a new type of item to be an infill item. If all types of infill items give that $\gamma = +\infty$, then there are no infill items to put into $S_{\max}$. This results in there being no infill items which can put in the layer.
  - After we get γ, we have to consider the remaining sides of item for finding α :
    - ★ If $\gamma = w_i$

      then

$$\alpha = \begin{cases} l_i & \text{if } w_S \geq l_i \text{ and } w_S - l_i \lfloor w_S / l_i \rfloor < w_S - h_i \lfloor w_S / h_i \rfloor, \\ h_i & \text{if } w_S \geq h_i \text{ and } w_S - h_i \lfloor w_S / h_i \rfloor < w_S - l_i \lfloor w_S / l_i \rfloor, \\ +\infty, & \text{otherwise.} \end{cases}$$

★ If $\gamma = l_i$

then

$$\alpha = \begin{cases} w_i \quad \text{if } w_S \geq w_i \text{ and } w_S - w_i \lfloor w_S / w_i \rfloor < w_S - h_i \lfloor w_S / h_i \rfloor, \\ h_i \quad \text{if } w_S \geq h_i \text{ and } w_S - h_i \lfloor w_S / h_i \rfloor < w_S - w_i \lfloor w_S / w_i \rfloor, \\ +\infty, \text{ otherwise.} \end{cases}$$

★ If $\gamma = h_i$

then

$$\alpha = \begin{cases} w_i \quad \text{if } w_S \geq w_i \text{ and } w_S - w_i \lfloor w_S / w_i \rfloor < w_S - l_i \lfloor w_S / l_i \rfloor, \\ l_i \quad \text{if } w_S \geq l_i \text{ and } w_S - l_i \lfloor w_S / l_i \rfloor < w_S - w_i \lfloor w_S / w_i \rfloor, \\ +\infty, \text{ otherwise.} \end{cases}$$

- After we get γ and α, we have to consider the remaining sides of item for finding β:

★ If $\gamma = w_i,\ \alpha = l_i$ or $\gamma = l_i,\ \alpha = w_i$

then $\beta = \begin{cases} h_i \quad \text{if } l_S \geq h_i, \\ +\infty, \text{ otherwise.} \end{cases}$

★ If $\gamma = w_i,\ \alpha = h_i$ or $\gamma = h_i,\ \alpha = w_i$

then $\beta = \begin{cases} l_i \quad \text{if } l_S \geq l_i, \\ +\infty, \text{ otherwise.} \end{cases}$

★ If $\gamma = l_i,\ \alpha = h_i$ or $\gamma = h_i,\ \alpha = l_i$

then $\beta = \begin{cases} w_i \quad \text{if } l_S \geq w_i, \\ +\infty, \text{ otherwise.} \end{cases}$

- The last one is to calculate the number of infill items in any layers by $m = \lfloor w_S / \alpha \rfloor \times \lfloor l_S / \beta \rfloor \times (h_S / \gamma)$.

3.4 Layer placement

After the previous step, this results in many patterns of layer which can be placed into *R*. They are found by using tree search (Ren, Tian, & Sawaragi, 2011) in Figure 5. However, there are two limitations on placement: the first one is that the total height of each layer that cannot exceed the height of *R*and the second is that the area of the below layer that should be larger than the area of the above layer.

Moreover, Figure 5 shows 12 patterns of layer placement including the same or different layer types with three or four layers. Each pattern has different volume utilization (Table 3).

3.6 Remaining item strategy

In this stage, the remaining items are considered by using only three largest item types (D, E, F) to form new blocks, then the new blocks are placed with the same size of block until the roll pallet is full. The step to manage of these remaining items is to put the same type of items into a new roll pallet using the same orientation in block arrangement and calculating the number of blocks (n_b) from $n_b = \lfloor H / h_b \rfloor$ and

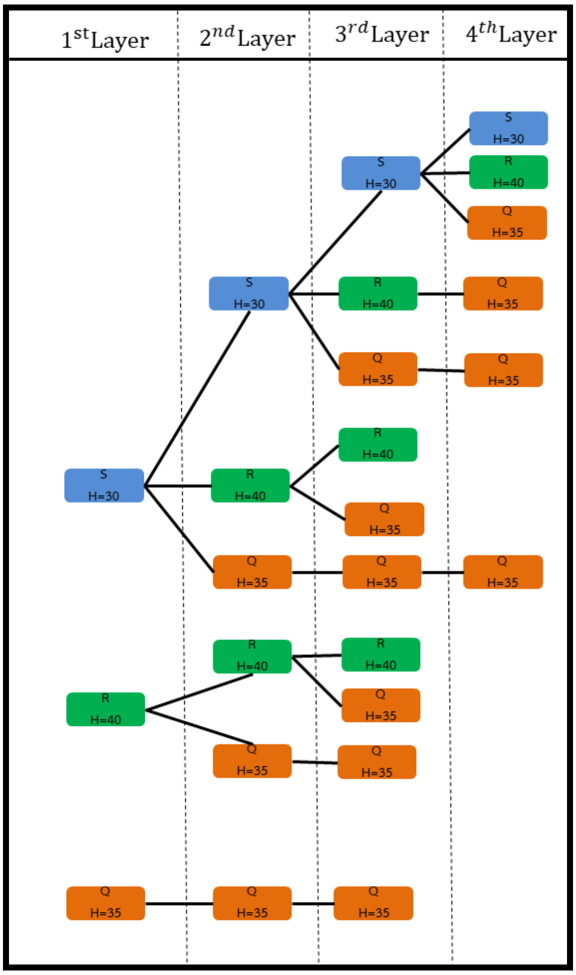

Figure 5. Tree search for all patterns on layer placement, where S, Q, R are the layer types, and H is the height of each layer (cm).

Table 3. Details of volume utilizations for layer placement with 12 layer types

Layer type	Height of layer (cm)	Volume (cm^3)	Volume utilization (%)
Q,Q,Q	35,35,35	517,440	64.65
R,R,R	40,40,40	658,080	82.22
S,S,S,S	30,30,30,30	672,000	83.96
S,R,R	30,40,40	606,720	75.80
S,R,Q	30,40,35	559,840	69.95
R,R,Q	40,40,35	611,200	76.36
R,Q,Q	40,35,35	564,320	70.50
S,S,S,R	30,30,30,40	723,360	90.37
S,S,S,Q	30,30,30,35	676,480	84.52
S,S,R,Q	30,30,40,35	727,840	90.93
S,S,Q,Q	30,30,35,35	680,960	85.08
S,Q,Q,Q	30,35,35,35	685,400	85.63

$n_{total} = n \times n_b$, where H and h_b are the heights of *R* and block, respectively, n_{total}, n_b and n are the total number of items, the number of blocks, and the number of items in a block, respectively. Table 4 shows the results for putting the remaining items with the same type into *R* with the details of orientations, n_{total}, n_b, n, and volume utilization.

4. Algorithm

Here, we give an algorithm for packing all items into roll pallets as follows.

Algorithm.

Input: The total number of items
Output: The remaining items
Distinguish items into six types
Count the number of items for each type: n_A, n_B, n_c, n_D, n_E, and n_F
If layer placement of pattern {S,S,R,Q} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {S,S,S,R} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {S,Q,Q,Q} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {S,S,Q,Q} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {S,S,S,Q} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {S,S,S,S} is selected **then**
Generate a layer
Update the number of remaining items
Else if layer placement of pattern {R,R,R}is selected **then**
Generate a layer
Update the number of remaining items
Else Count the number of remaining items
If the single block type D is selected **then**
Generate the block
Update the new number of remaining items
Else if the single block type E is selected **then**
Generate the block
Update the new number of remaining items
Else the single block type F is selected **then**
Generate the block
Update the new number of remaining items
End if
End if
Count the total number of remaining items
Count the total number of roll pallets

Table 4. Details for packing the remaining items into R where n is the number of items in a block and n_{total} is the number of all items of each type.

Item type	Orientation	Number of blocks	n	n_{total}	Volume utilization (%)
D	*h, w, l*	3	16	48	64.65
E	*h, w, l*	3	12	36	73.40
F	*l, h, w*	4	5	20	67.47

Moreover, this algorithm can be presented by a flowchart as in Figure 6.

The number of item type for each pattern on the layer arrangement can be presented by ordering from the highest to the lowest volume utilization.

1. Pattern {S,S,R,Q} consists of $n_A \geq 12$, $n_c \geq 10$, $n_D \geq 16$, $n_E \geq 14$, $n_F \geq 10$.
2. Pattern {S,S,S,R} consists of $n_A \geq 12$, $n_c \geq 15$, $n_E \geq 14$, $n_F \geq 15$.
3. Pattern {S,Q,Q,Q} consists of $n_C \geq 5$, $n_D \geq 48$, $n_F \geq 5$.
4. Pattern {S,S,Q,Q} consists of $n_c \geq 10$, $n_D \geq 32$, $n_F \geq 10$.
5. Pattern {S,S,S,Q} consists of $n_c \geq 15$, $n_D \geq 16$, $n_F \geq 15$.
6. Pattern {S,S,S,S} consists of $n_c \geq 60$, $n_F \geq 60$.
7. Pattern {R,R,R} consists of $n_A \geq 36$, $n_E \geq 42$.

For the remaining items to generate a new block shown as follows.

1. Single block type D consists of $n_D \geq 48$.
2. Single block type E consists of $n_E \geq 36$.
3. Single block type F consists of $n_F \geq 20$.

5. Experimental Results

Here, two experimental results are described as follows:

Experimental result 1

Step 1: Input the number of all items, 695 items randomly, reported by staff.
Step 2: Distinguish items into six types: $n_A = 168, n_B = 96, n_C = 87, n_D = 199, n_E = 99$ and $n_F = 46$.
Step 3: Check the constraint of each pattern for layer placement into the roll pallet.
3.1 Layer {S,S,R,Q} can put into 4 roll pallets and remain items: $n_A = 120, n_B = 96, n_C = 47, n_D = 135, n_E = 43$ and $n_F = 6$.
3.2 Layer {S,S,S,R} cannot put into a roll pallet and there are the remaining items:

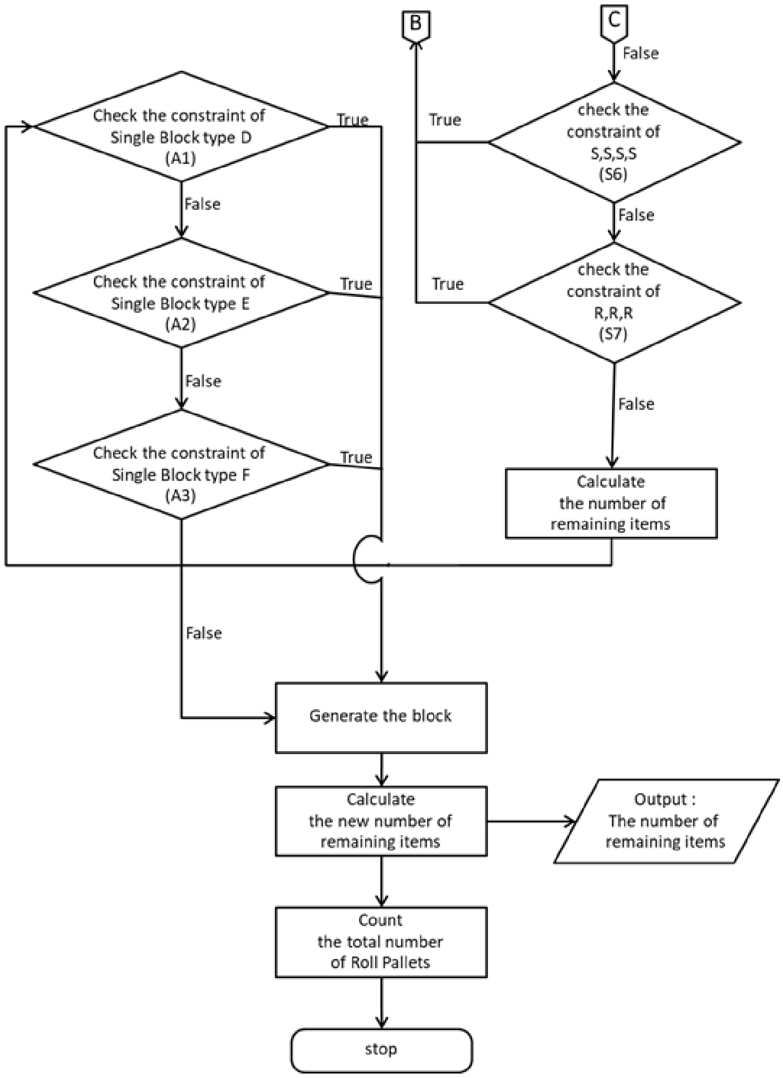

Figure 6. A flowchart of the algorithm

$n_A = 120, n_B = 96, n_C = 47, n_D = 135, n_E = 43$ and $n_F = 6$.

3.3 Layer {S,Q,Q,Q} can put into a roll pallet and remain items: $n_A = 120, n_B = 96, n_C = 42, n_D = 87, n_E = 43$ and $n_F = 1$.

3.4 Layer {S,S,Q,Q} cannot put into a roll pallet and there are the remaining items:

$n_A = 120, n_B = 96, n_C = 42, n_D = 87, n_E = 43$ and $n_F = 1$.

3.5 Layer {S,S,S,Q} cannot put into a roll pallet and there are the remaining items:

$n_A = 120, n_B = 96, n_C = 42, n_D = 87, n_E = 43$ and $n_F = 1$.

3.6 Layer {S,S,S,S} cannot put into a roll pallet and there are the remaining items:

$n_A = 120, n_B = 96, n_C = 42, n_D = 87, n_E = 43$ and $n_F = 1$.

3.7 Layer {R,R,R} can put into a roll pallet and remain items:

$n_A = 84, n_B = 96, n_C = 42, n_D = 87, n_E = 1$ and $n_F = 1$.

Step 4: From step 3, there are the remaining items:

$n_A = 84, n_B = 96, n_C = 42, n_D = 87, n_E = 1$ and $n_F = 1$.

to generate a new block.

4.1 Single block type D can put into a roll pallet and remain items: $n_A = 84, n_B = 96, n_C = 42, n_D = 87, n_E = 1$ and $n_F = 1$.

4.2 Single block type E cannot put into a roll pallet and there are the remaining items:

$n_A = 84, n_B = 96, n_C = 42, n_D = 39, n_E = 1$ and $n_F = 1$.

4.3 Single block type F cannot put into a roll pallet and there are the remaining items:

$n_A = 84, n_B = 96, n_C = 42, n_D = 39, n_E = 1$ and $n_F = 1$.

Step 5: Count the number of roll pallets from steps 3 and 4, this is 7.

Experimental result 2

Step 1: Input the number of all items, 1,002 items randomly, reported by staffs.
Step 2: Distinguish items into six types: $n_A = 167, n_B = 167, n_C = 167, n_D = 167, n_E = 167$ and $n_F = 167$.
Step 3: Check the constraint of each pattern for layer placement into the roll pallet.
3.1 Layer {S,S,R,Q} can put into 10 roll pallets and remain items: $n_A = 47, n_B = 167, n_C = 67, n_D = 77, n_E = 37$ and $n_F = 167$.
3.2 Layer {S,S,S,R} can put into 2 roll pallets and remain items: $n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
3.3 Layer {S,Q,Q,Q} cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
3.4 Layer {S,S,Q,Q} cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
3.5 Layer {S,S,S,Q} cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
3.6 Layer {S,S,S,S} cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
3.7 Layer {R,R,R} cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
Step 4: From step 3, there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
to generate the new block.
4.1 Single block type D cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
4.2 Single block type E cannot put into a roll pallet and there are the remaining items:
$n_A = 23, n_B = 167, n_C = 37, n_D = 7, n_E = 9$ and $n_F = 37$.
4.3 Single block type F can put into a roll pallet and remain items: $n_A = 84, n_B = 96, n_C = 42, n_D = 39, n_E = 1$ and $n_F = 17$.
Step 5: Count the number of roll pallets from steps 3 and 4, this is 13.

Since there are only 12 roll pallets at the branch, the first result needs 7 roll pallets to pack 695 items. The staffs can do this directly. On the other hand, the second result needs 13 roll pallets. So this can do by considering only 12 roll pallets and canceling the roll pallet that has only single block type F.

Since each pattern has unequal number of items, so the total weight of all items for each roll pallet is not more than 180 kg. This is a rule from the branch. Hence, the weight of each item from the layers {S,S,R,Q}, {S,S,S,R}, {S,Q,Q,Q}, {S,S,Q,Q},{S,S,S,Q} and {R,R,R} should not be more than 3-4 kg, and the weight of each item in the layer {S,S,S,S} should not be more than 1.5 kg. Moreover, the weight of all items should not be more than 20 kg.

6. Conclusions

The purpose of this study is to pack all items into roll pallets compactly using heuristic approach and reduce movement of items during transportation. This can be described by taking all standard items with the same size to build the blocks and reducing the remaining area in the roll pallet. After we put the block into the roll pallet, the infill items can be added in the remaining space to generate a layer.

The layer placement into the roll pallet starts with putting layers from the highest to the lowest area utilization. All patterns of layer placement can be generated by the tree search method. However, we focus on patterns for layer placement with more than 80% of volume utilization.

The experimental studies give that the placement procedure shows the good result with 90.93% in volume utilization of patterns for layer placement. Additionally, this method can help the staff for working in practice. It can be an idea for the future policy of the branch to manage all items at the beginning to the final steps. Moreover, it can apply in other situations if we know the size of items and containers.

However, there are some further practical constraints such as nonstandard items including in this system as well. Focusing on the weight from the top of each item is important to increase security. Here, the system in Thailand post does not specify weight of the cross-sectional area on the top of standard items. Moreover, it is easy to manage all items for staffs at the branch if there are some small cards showing item orientation and layer compositions of each item.

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