Clustering Approach on Layout Redesign to Optimize Container Handling Process

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ABSTRACT

Container Terminal of Semarang is a service provider for export and import container handling process. It represents one of the divisions of PT (Persero) Port of Indonesia III Branch TanjungEmas Semarang. As an anticipatory step to growth of containership capacity in Port of Indonesia III Semarang, the company need to improve the quality of container handling service and to reach a higher level of productivity. One of the ways to achieve these goals is to focus on layout planning and management that can potentially be beneficial to all factors involved such as space exploitation, process efficiency etc. The layout planning of a container terminal can significantly benefit from using Group Technology approach in which containers can be grouped into families of containers and transported between cells(block locations in the yard).With this type of layout, the company has many advantages like flexibility on production process to address high variability in the system. As a result, it can give alternative arrangement of container in the yards. We observed that based on Bond Energy Algorithm (BEA) method, container travel distance can be reduced to 188.06 metres/ month, which is approximately 9 % saving of distances travelled by each container. Moreover, using Group Technology approach can provide a higher flexibility to cope with fluctuations in process.

Keywords: optimisation, group technology, container terminal

INTRODUCTION

During the last few years, fluctuations in demand with underling growth trend and global competition have brought about major changes in different industries particularly in transportation industry. Most industries need to look at their operations and their resources to improve their customer relationship and achieve a high level of efficiency and flexibility. Container Terminal of Semarang (TPKS), represents one of the divisions of PT (Persero) Port of Indonesia (PELINDO) III Branch TanjungEmas. Semarang connects industries in Central Java province of Indonesia for international distribution channels. As a container terminal, TPKS need to provide sufficient capacity in order to facilitate smooth flow of containers. TPKS has devised a process oriented layout focused on repetitive movement of containers. The reduction of distance travelled by each container through terminal handling operation might be a good measure to analyse the effectiveness of the layout. Group Technology (GT) approach through classification of containers can improve yard operations and provide higher efficiency and flexibility.

In general, layout design, using Group Technology approach, requires four major steps: (1) Cell formation, (2) Performance measurement of cell formation, (3) Cell system layout (to arrange cells within floor), and (4) Material handling system measurement (Singh and Rajamani, 1996). In this paper, the cell formation is considered to be the collection of blocks with known container yard positions. With this cell formation, the arrangement of containers in the yard can reduce the length of container handling distance.

The framework of this paper as follows: The literature on container terminal system is reviewed in the first Section. The making of cellular manufacturing system is suggested in Section 2. In Section 3, a procedure for the arrangement of container positions using GT is presented. Section 4 shows the numerical experiments to compare three of GT algorithms on layout design and to analyze the optimization of containers handling distances. Finally, Section 5 gives some concluding remarks.

LITERATURE REVIEW

Facility planning for improving container terminal layout has been discussed widely in the literature. The studies can be subdivided into analytical approaches, simulation approaches, and approaches based upon distributed artificial intelligence. We will use an analytical approach in the following sections.

Container Terminal System

In general terms, container terminals can be described as an open system where material flow in/out with two external interfaces (Kamble, et al., 2019). These interfaces are the quayside activities with loading and unloading of ships, and the landside activities where containers are loaded and unloaded on/off trucks and trains (Azab, et al., 2019). Containers are stored in stacks thus facilitating the decoupling of quayside and landside operation. After arrival at the port, a container vessel is assigned to a berth equipped with cranes to load and unload containers. Unloaded containers are transported to yard positions near to the place where they will be transshipped next. Containers arriving by road or railway at the terminal are handled within the truck and train operation areas. They are picked up by the internal equipment and distributed to the respective stocks in the yard. Additional moves are performed if sheds and/or empty depots exist within a terminal; these moves encompass the transports between empty stock, packing centre, and import and export container stocks (Figure 1) (Steenken, et al., 2004).
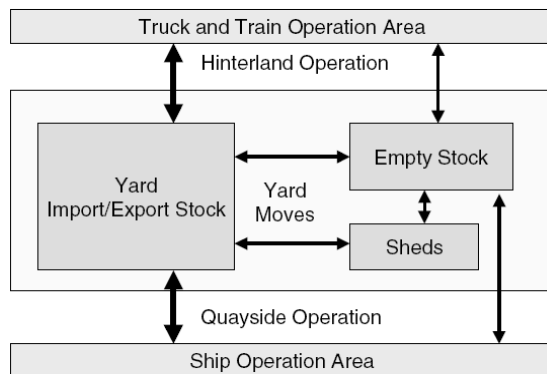

FIGURE 1. Operation area of seaport container terminal

The Layouts of Container Yard

The layout of container yard is an important aspect in the container handling operations. Its attributes are critical factors to determine the flows of different types of containers in a way that the total handling cost would be minimized (Kozan, 2000). Two types of container yard layouts are parallel layout and perpendicular layout (Kim, et.al, 2008) as indicated below. In the parallel layout, containers are arranged horizontally to the gate or the berth. Figure 2 shows how to arrange containers in parallel layout setting.
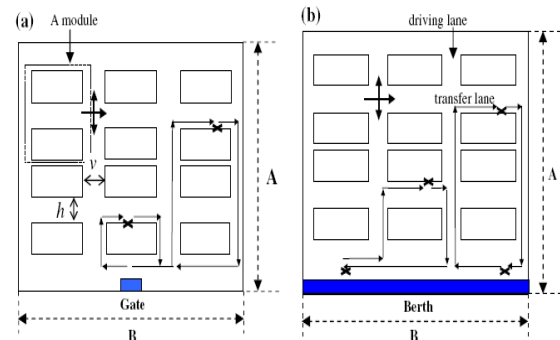

FIGURE 2. Travels on parallel layouts. (a) Travel between the gate and the yard of the parallel layout. (b) Travel between the berth and the yard of the parallel layout

The notation "v" represents the width of a driving lane that is a lane used only by trucks in the parallel layout, while it represents the width of a transfer lane for crane in the perpendicular layout. The notation "h" represents the width of a transfer lane in the paralleled layout, while it represents the width of the driving lane in the perpendicular layout. The perpendicular layout is arranging vessels vertically to the gate or the berth. Figure 3 shows the layout with a perpendicular arrangement of containers.
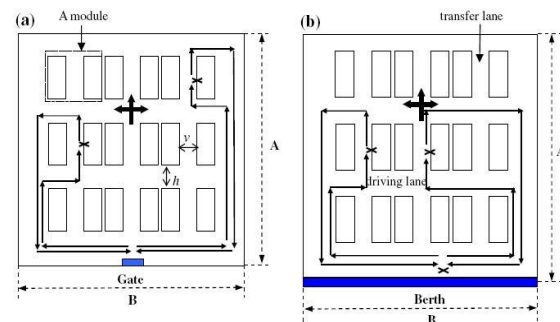

FIGURE 3. Travel on perpendicular layouts. (a) Travel between the gate and the yard of the parallel layout. (b) Travel between the berth and the yard of the parallel layout

The Making of Production Flow Analysis (PFA)/ Incident Matrix

PFA or incident matrix is a systematically procedure to analyse information from process routing (Sugiyono, 2006). PFA includes input the number of 0 and 1, where is the number of 1 show that the machine is in use, and the number of 0 show that the machine is not in use in process.

Bond Energy Algorithm (BEA)

Bond Energy Algorithm (*BEA*) introduced in 1972 by Mc Cormick, Schweitzer and White to identify the process of grouping or clustering data variables that have complexity of sequence (Singh and Rajamani, 1996). The purpose of algorithm is to define the value of matrix. This defined as Measurement of Effectiveness (ME).

The steps are:

a. Count of Column

$$MEcoloumn = \sum_{p=1}^{i} \sum_{m=1}^{m} a_{pm} \times a_{p+1,m} \qquad (1)$$

b. Count of Row

$$MErow = \sum_{m=1}^{i} \sum_{p=1}^{p} a_{pm} \times a_{p,m+1} \qquad (2)$$

Rank Order Clustering (ROC)

Introduced in 1980 by King for grouping process of part –machine(Singh and Rajamani, 1996). The Steps are:

a. Count of Row

$$Cm = \sum_{p=1}^{p} 2^{P-p}.a_{pm} \qquad (3)$$

b. Count of Column

$$Rp = \sum_{m=1}^{m} 2^{M-m}.a_{pm} \qquad (4)$$

Rank Order Clustering 2 (ROC 2)

Introduced in 1982 by King and Nakorchai, this algorithm begin with identification of column (right side) on the row for all part and machine name that have value 1 on incident matrix (Singh and Rajamani, 1996).

Performance Measure

To choose the best alternative solution from the making of manufacturing cells, we need to know the difference of each quality of solutions. It called a performance measure. There are three category of performance measure, which is (Li, et.al, 2016):

a. Grouping Efficiency (η)

$$\eta = w\eta_1 + (1-w)\eta_2 \qquad (5)$$

b. Grouping Efficacy (τ)

$$\tau = \frac{o-e}{o+v} \qquad (6)$$

c. Grouping Measure (η_g)

$$\eta_g = \eta_g - \eta_m, -1 \le \eta_g \le 1 \qquad (7)$$

Material Handling System

Material handling can be defined as an art and science to study of material handling, packaging, storing, and controlling in order to have the best flow of material (Apple, 1950). Terminals only consist of two components: stocks vehicles and transport vehicles. The yard stacks, ships, trains, and trucks belong to the category 'stock'. Stocks are statically defined by their ability to store containers while from a dynamic point of view a storage (or loading) instruction is necessary defining the rules how and where containers have to be stored (Köllmann, 2018). Transport vehicles means either transport containers in two or three dimensions. Cranes and vehicles for horizontal transport belong to this category. Their logistical specifics are that transport jobs have to be allocated to the means of transport and sequences of jobs have to be performed. Chu and Huang (2005) present a comparison of different container handling systems with regard to a terminal's capacity. The approach aims at supporting decisions on terminal planning with regard to the design of a terminal and the employed handling equipment.Based on routing process of container yards and frequency of container handling, can define the total distances of process.

EXPERIMENTAL DETAILS

Initial layout

In initial TPKS layout, company places containers on block yard randomly. Even same containers with same date of processing, it can be placed on different blocks. The initial layout using a type of parallel layout for placed the containers as shown in Figure 4.
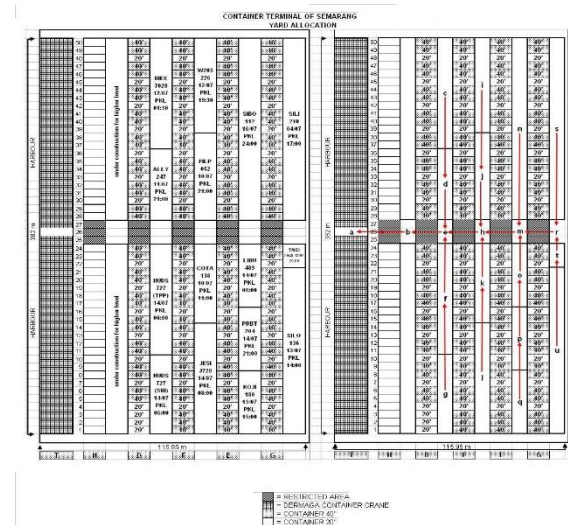

FIGURE 4. Initial layout of container terminal Semarang, Indonesia

Production Flow Analysis (PFA) for Containers Terminal System

Information of flow production can be arranged on initial matrix as an incident matrix (containers-block). As the assumption, process of containers handling coded as "1" and if there is no process coded as "0". The incident matrix can be shown on Table 1.

TABLE 1. Incident Matrix

Containers based on arrival date

Blocks Area		I	II	III	IV	V	VI
	D (1)	0	1	1	0	1	0
	E (2)	0	0	0	1	1	1
	F (3)	1	0	1	0	1	0
	G (4)	0	0	0	1	1	0
	T (5)	1	1	1	1	1	1

Bond Energy Algorithms (BEA)

This method need to arrange the optimal combination of row and column from incident matrix. The combination can be done by measuring the effectiveness of each row and column.

Step 1: find the optimal combination for column or containers.

Two combination of columns :

ME (column 1-2) = (0 x 1) + (0 x 0) + (1 x 0) + (0 x 0) + (0 x 0) + (1 x 1) = 1

ME (column 2-1) = (1 x 0) + (0 x 0) + (0 x 1) + (0 x 0) + (0 x 0) + (1 x 1) = 1

ME (column 1-3) = (0 x 1) + (0 x 0) + (1 x 1) + (0 x 0) + (0 x 0) + (1 x 1) = 2

ME (column 3-1) = (1 x 0) + (0 x 0) + (1 x 1) + (0 x 0) + (0 x 0) + (1 x 1) = 2

ME (column 1-4) = (0 x 0) + (0 x 1) + (1 x 0) + (0 x 1) + (0 x 0) + (1 x 1) = 1

ME (column 4-1) = (0 x 0) + (1 x 0) + (0 x 1) + (1 x 0) + (0 x 0) + (1 x 1) = 1

ME (column 1-5) = (0 x 1) + (0 x 1) + (1 x 1) + (0 x 1) + (0 x 0) + (1 x 1) = 2

ME (column 5-1) = (1 x 0) + (1 x 0) + (1 x 1) + (1 x 0) + (0 x 0) + (1 x 1) = 2

ME (column 1-6) = (0 x 0) + (0 x 1) + (1 x 0) + (0 x 0) + (0 x 0) + (1 x 1) = 1

ME (column 6-1) = (0 x 0) + (1 x 0) + (0 x 1) + (0 x 0) + (0 x 0) + (1 x 1) = 1

Etc.

Result of 2 columns combination are shown on Figure 5.

FIGURE 5. Result of 2 combination of column, the chosen one is 3rd column

Step 2: Find the optimal sequence for rows or blocks. As the same process as columns sequencing, place the row that gives the largest ME in its best position, as shown in Table 2.

TABLE 2. The result for every steps of ME rows

Stage	Chosen Column	ME Value
1	3-5	3
2	3-5-1	2
3	3-5-1-2	1
4	3-5-1-2-4	1
5	3-5-1-2-4-6	1

Step 3: Combining final columns and rows sequence as a final matrix of BEA as shown in Table 3.

TABLE 3. Final matrix of BEA

Containers / Blocks	3	5	1	2	4	6
6 (T)	1	1	1	1	1	1
1 (D)	1	1	0	1	0	0
3 (F)	1	1	1	0	0	0
2 (E)	0	1	0	0	1	1
4 (G)	0	1	0	0	1	0
5 (H)	0	0	0	0	0	0

Rank Order Clustering (ROC)

This algorithm read the matrix as a binary word as shown in Table 4. The procedure converts these binary words (binary weights) for each row and column into decimal equivalents. Decimal equivalent is value that read number of row/column as binary words. As other Group Technology methods, ROC also needs to find the optimal

solution from row and column combinations. Based on the ranking of decimal equivalent value, an arrangement of blocks yard can be constructed using following steps from ROC procedures.

TABLE 4. Initial matrix for ROC

Containers / Blocks	1	2	3	4	5	6	2^{B-b}
D (1)	0	1	1	0	1	0	2^5
E (2)	0	0	0	1	1	1	2^4
F (3)	1	0	1	0	1	0	2^3
G (4)	0	0	0	1	1	0	2^2
H (5)	0	0	0	0	0	0	2^1
T (6)	1	1	1	1	1	1	2^0
2^{C-c}	2^5	2^4	2^3	2^2	2^1	2^0	Binary Weight

*Step 1:*Computing the decimal equivalent for row.
Row1: $2^5.0 + 2^4.1 + 2^3.1 + 2^2.0 + 2^1.1 + 2^0.0 = 26$
Row2: $2^5.0 + 2^4.0 + 2^3.0 + 2^2.1 + 2^1.1 + 2^0.1 = 7$
Row3: $2^5.1 + 2^4.0 + 2^3.1 + 2^2.0 + 2^1.1 + 2^0.0 = 42$
Row4: $2^5.0 + 2^4.0 + 2^3.0 + 2^2.1 + 2^1.1 + 2^0.0 = 6$
Row5: $2^5.0 + 2^4.0 + 2^3.0 + 2^2.0 + 2^1.0 + 2^0.0 = 0$
Row6: $2^5.1 + 2^4.1 + 2^3.1 + 2^2.1 + 2^1.1 + 2^0.1 = 63$

The decimal equivalent for row is shown in Table 5.

TABLE 5. Decimal equivalent for row

Containers / Blocks	1	2	3	4	5	6	2^{B-b}	Cm	Ranking
D (1)	0	1	1	0	1	0	2^5	26	3
E (2)	0	0	0	1	1	1	2^4	7	4
F (3)	1	0	1	0	1	0	2^3	42	2
G (4)	0	0	0	1	1	0	2^2	6	5
H (5)	0	0	0	0	0	0	2^1	0	6
T (6)	1	1	1	1	1	1	2^0	63	1

*Step 2:*Computing the decimal equivalent for column.

Column1: $2^5.1 + 2^4.1 + 2^3.0 + 2^2.0 + 2^1.0 + 2^0.0 = 48$
Column 2: $2^5.1 + 2^4.0 + 2^3.1 + 2^2.0 + 2^1.0 + 2^0.0 = 40$
Column 3: $2^5.1 \; 2^4.1 + 2^3.1 + 2^2.0 + 2^1.0 + 2^0.0 = 56$
Column 4: $2^5.1 + 2^4.0 + 2^3.0 + 2^2.1 + 2^1.1 + 2^0.0 = 38$
Column 5: $2^5.1 + 2^4.1 + 2^3.1 + 2^2.1 + 2^1.1 + 2^0.0 = 62$
Column 6: $2^5.1 + 2^4.0 + 2^3.0 + 2^2.1 + 2^1.0 + 2^0.0 = 36$

The decimal equivalent for column is shown in Table 6.

TABLE 6. Decimal equivalent for column

Containers / Blocks	1	2	3	4	5	6
D (1)	0	1	1	0	1	0
E (2)	0	0	0	1	1	1
F (3)	1	0	1	0	1	0
G (4)	0	0	0	1	1	0
H (5)	0	0	0	0	0	0
T (6)	1	1	1	1	1	1
2^{C-c}	2^5	2^4	2^3	2^2	2^1	2^0
Rp	48	40	56	38	62	36
Ranking	3	4	2	5	1	6

*Step 3:*Combining the result of sequencing from row and column. The steps should run iteratively until the new matrix is unchanged formation. Table 7 shows the final matrix for ROC.

TABLE 7. Final matrix of ROC

Containers / Blocks	5	3	1	2	4	6
T(6)	1	1	1	1	1	1
F(3)	1	1	1	0	0	0
D(1)	1	1	0	1	0	0
E(2)	1	0	0	0	1	1
G(4)	1	0	0	0	1	0
H(5)	0	0	0	0	0	0

Rank Order Clustering 2 (ROC2)

This algorithm developed to overcome the computational limitations imposed by ROC. The algorithm begins by identifying in the right-most column all rows that have an entry of 1. For row arrangement, from the last column to 1st, locate the rows with an entry of 1, move the rows with entries to the head of the row list, maintaining the previous order of entries. Table 8 shows the arrangement of block area.

TABLE 8. The arrangement of blocks area

Blocks / Containers	D(1)	E (2)	F(3)	G(4)	H(5)	T(6)
6	1	2	3	4	5	6
5	2 / 2	6 / 6	1	3 / 3	4	5 / 5
4	6	6	1	3	5	4
3	6	3	4	2	1	5
2	6	4	5	3	2	1
1	6	1	4	5	3	2
Blocks	4	2	6	1	5	3

For the containers' arrangement as shown in Table 9, we used matrix from Table 8 as input. Table 10 shows the result of first iteration. These steps should be repeated until no change occurs.

TABLE 9. The arrangement of containers

Containers / Blocks	1	2	3	4	5	6
F (3)	1	2	3	4	5	6
H (5)	1	3	6	2	4	5
D (1)	1	3	6	2	5	4
T (6)	6	4	1	3	2	5
E (2)	4	5	6	1	3	2
G (4)	4	2	5	6	1	3
Containers	2	6	3	4	5	1

TABLE 10. Matrix Blocks – Containers using ROC2

Blocks \ Containers	2	6	3	4	5	1
G(4)	1	1	0	1	0	0
E(2)	0	1	0	0	0	1
T(6)	1	1	0	0	0	0
D(1)	0	1	1	0	0	0
H(5)	1	1	1	1	0	1
F(3)	0	1	1	0	0	1

RESULTS AND DISCUSSION

Performance Measurement

In this section, the performances of solutions are compared by three criteria which have been proposed in the literature review. The first measure is grouping efficiency (η). The best solution depends on the utilization of blocks within containers movement. The second is grouping efficacy (τ), to conquer the low differentiation of the grouping efficiency between good structured and bad-structured matrix. This measure implies a perfect grouping with no exceptional elements and voids. The third criteria is grouping measure (ηg), this is also a direct measure of the effectiveness of a final grouped matrix. The value of ηg is high if the utilization of blocks is high. Unlike the others, grouping measure also considered a few containers require processing on blocks in more than one cell. Table 11 shows the performance measurement for each solution.

TABLE 11. Result of performance measurement each solution

No	Layout	Cells	B	C	o	e	v	d	Performance Measurement		
									(η)	(τ)	(η_g)
1	BEA	2	6	6	17	0	16	17	0.757	0.515	0.515
2	ROC	1	6	6	17	2	12	15	0.67	0.52	0.44
3	ROC2	1	6	6	17	2	12	15	0.67	0.52	0.44

BEA method has the highest value of performance measurement. So, this method is chosen to arrange the manufacturing cells of the system.

1st Cells:
Containers family=C3 – C5 – C1 – C2 – C4 – C6
Blocks group   =T (6) – D (1) – F (3)

2nd Cells:
Containers family=C5 – C1 – C2 – C4 – C6
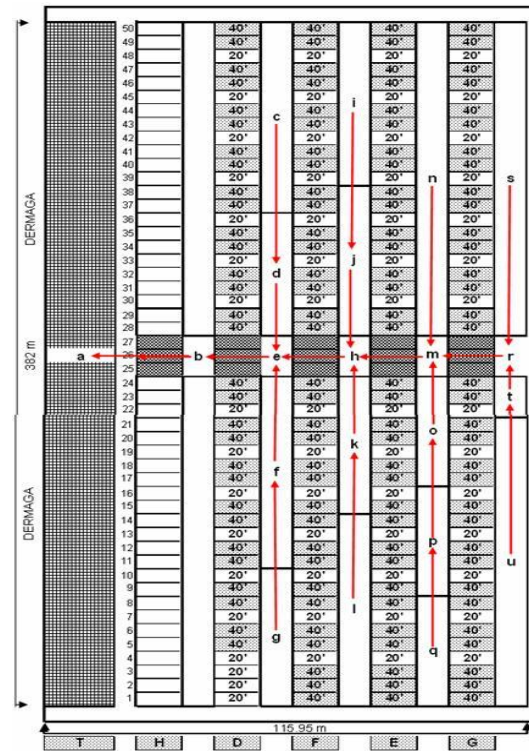Blocks group   = E (2) – G (4)

Solution layoutis shown on Figure 6.

FIGURE 6. Layout solution using BEA approach

Containers Handling Measurement

In general, a review of the literature has produced many excellent articles for models that proposed terminal designs that affect on terminal performance. In the following section, we present the performance comparison between layout designs using clustering approache with initial layout by measuring the length of container handling from yard to harbour.

Table 12 and 13 show the measurement results for the length of containers handling from initial layout and layout with using clustering approach. It can define that final layout give contribution on reducing the length of material handling for: 2080.515 – 1892,455 = 188,06 m.

TABLE 12. Length of containers handling for initial layout

Blocks Area	Ship Type	Route	Distances	Results (m)
H			Under Construction	
G	TMEX	g-e-a	7.57 + 7.7 + 45.88	61.15
G	SILO	h-g-e-a	54.54 + 15.15 + 7.7 + 45.88	122.47
G	SILI	f-e-a	56.05 + 7.7 + 45.88	109.9
F	JESI	m-l-i-a	36.36 + 51.51 + 7.7 + 64.07	159.64
F	COTA	l-i-a	25.75 + 7.7 + 64.07	97.52
F	FILP	k-i-a	57.56 + 7.7 + 64.07	100.55
F	W203	j-k-i-a	30.3 + 57.56 + 7.7 + 64.07	159.63
E	SIBO	o-n-a	56.05 + 7.7 + 82.26	146.01
E	LIBU	p-n-a	21.21 + 39.39 + 42.42 + 7.7 + 82.26	192.98
E	PRBT	q-p-n-a	19.69 + 42.42 + 7.7 + 82.26	152.07
E	KOJI	r-q-p-n-a	21.21 + 39.39 + 42.42 + 7.7 + 82.26	192.98
D	BIEX	t-u-s-a	36.36 + 45.45 + 7.7 + 100.45	189.96
D	ALLY	u-s-a	22.725 + 7.7 + 100.45	130.875
D	HUDS(TPP)	v-s-a	36.36 + 7.7 + 100.45	144.51
D	HUDS(SIN)	w-v-s-a	21.21 + 72.72 + 7.7 + 100.45	202.08
Total Distances				2080.515

TABLE 13. Length of containers handling for GT approach

Blocks Area	Ship Type	Route	Distances	Results (m)
H			Under Construction	
D	BIEX	t-u-e-a	36.36 + 45.45 + 7.7 + 45.88	135.9
D	ALLY	u-e-a	22.725 + 7.7 + 45.88	76.305
D	HUDS(TPP)	v-e-a	36.36 + 7.7 + 45.88	89.94
D	HUDS(SIN)	w-v-e-a	21.21 + 72.72 + 7.7 + 45.88	147.51
F	W203	j-k-i-a	30.3 + 57.56 + 7.7 + 64.07	159.63
F	FILP	k-i-a	36.36 + 7.7 + 64.07	100.55
F	COTA	l-i-a	24.45 + 7.7 + 64.07	97.22
F	JESI	m-l-i-a	36.36 + 50.9 + 64.7	151.33
E	SIBO	o-n-a	56.05 + 7.7 + 82.26	146.01
E	LIBU	p-n-a	21.21 + 7.7 + 82.26	111.17
E	PRBT	q-p-n-a	19.69 + 42.42 + 7.7 + 82.26	152.07
E	KOJI	r-q-p-n-a	21.21 + 39.38 + 42.42 + 17.7 + 82.26	202.97
G	SILI	f-s-a	56.05 + 7.7 + 100.45	164.2
G	TMEX	g-s-a	7.57 + 7.7 + 100.45	115.72
G	SILO	h-g-s-a	54.54 + 15.14 + 7.7 + 100.45	177.83
Total Distances				1892.455

CONCLUSION

This study proposes a procedure for determining blocks area at container terminal Semarang, Indonesia with using Group Technology (GT) approach. Results from the experiments are considered that from three methods of GT (BEA, ROC, and ROC2), BEA was has the best performance for well-structure matrix. For evaluating performances of the final solutions, high effectiveness, efficiency, and good structure are considered as objective terms. Results from comparison analysis, shows that the length of containers handling layout solution can bring contribution for lessening to 188.06 meters per month, which is approximately to 9 % efficiency.

Illustration of numerical solutions from clustering approache can be used for giving shorter expected containers handling distances for Containers Terminal of Semarang, Indonesia. Further research for this case study, will be done for simulation experiments and various other scenarios could be performed by others heuristics algorithm. It could also be considered to identifying and developing heuristics algorithm based model of practical logistics process at containers terminal.

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