Design of Storage Allocation Using Interaction Frequency Heuristic-Order Oriented Slotting Approach to Reduce Delay Time on Traveling Searching Activities in Refinery Unit V Warehouse PT XYZ

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Abstract

Refinery Unit (RU) V is a processing company owned by PT XYZ located in Balikpapan. Refinery Unit V has twelve warehouses with four warehouses being the main focus in this research of RGM, RMS, RIN, and RSP used to store products for refinery maintenance processes. In the initial conditions, there is a delay in traveling searching activities. The occurrence of delay in traveling searching activity caused by the absence of details of the product location clearly. The proposed product allocation is using Interaction Frequency Heuristic-Order Oriented Slotting method. The last step is to create a new layout for each RU V warehouse.

The first step is to calculate the cycle time for each work order list by calculating the distance between the storage point with the point of I / O based on the aisle distance calculation. Next is to compare between the cycle time of each work order list with the standard time of the warehouse, so it will know the percentage of work order list that experienced delay for one year. Next, allocate product storage based on the popularity value of the product and the value of the interaction frequency between the products. The final step is to simulate using new work order list based on the proposed allocation layout to know the effect of change from the proposed layout. The result of this research is a new layout for each warehouse. All stock taking performance are better than the standard time while the exisiting condition violate the standard time.

Keywords: Storage Allocation, Work order list, Layout, Interaction frequency Heuristic-Order Oriented Slotting

Introduction

In the process of storing the product, RU V Warehouse divides the warehouse into two categories, namely category S (Small) using Mezanine system and category M (medium) using single deep racking system. The total rack capacity for product with category M (medium) is 369 position palette and compartment capacity for product with category S (small) is 372 compartment. To build inbound and outbound processes, the RU V warehouse has one access door that is used for inbound and outbound processes.

The inbound process begins with the receipt of the product sent by the vendor to the receiving area of the RU V warehouse. Products stored in the receiving area will be checked by the engineering process department to ensure that the shipped product is in accordance with the PT XYZ order in terms of both quantity and quality. After the product passes the test by the engineering process, the product will be stored in the warehouse according to the product type. Admin in each warehouse will do input data in accordance with the products submitted. After the recording (input data), the next stage is the docking inbound and put away.

Outbound process begins from the arrival of a request from the plan or called a work order list. From the work order list sent to the warehouse concerned, then continued with sorting process based on product categories which then proceed with the taking of goods and then will be sent to the plan. Problems that occur in the outbound process was delay of the activity of traveling searching.

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The problem with traveling searching is the domino effect of the inbound process. In the inbound process the product is placed in an empty place and not done process of recording the location of the product. As a result, on the activities of traveling searching operators must search the product to the entire warehouse. Searching the product to entire warehouse will cause long process fulfillment work order list at a warehouse and will make a delay on fulfillment work order list. This is supported by the percentage data of work order list which experienced delay which can be seen in Table 1.

Table 1. Percentage of fulfillment of Work Order List

No.	Product	Total *work order list*	Work order list that does not occur delay	Percent-tage
1	RGM (M)	313	55	18%
2	RSP (M)	312	72	23%
3	RIN (M)	86	16	19%
4	RMS (M)	90	20	22%
5	RGM (S)	237	48	20%
6	RSP (S)	217	47	23%
7	RIN (S)	45	9	21%
8	RMS (S)	41	10	24%

Based on Table 1, the average of four warehouses experiencing delay from the overall work order list that occurred during one year is 20.5% for products with category M and 22% for products with category S. Determination of work order list delayed done by comparing between Cycle time of each work order list with standard time of each warehouse.
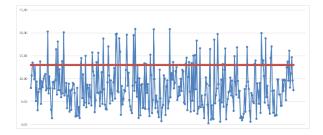

Figure 1. Comparison of cycle time and standard time on RGM warehouse category M (Blue line = cycle time, Red line = Standard Time)

An example of comparison between standard cycle time and time in RGM warehouse with product category M is presented in Figure 1

From the data of the Work Order List process time figure 1, the red line represents the standard time of each warehouse and the blue dot is the cycle time of each work order list.

Based on the problem described, it is necessary improvements in the activities of traveling searching on RU V warehouse so that traveling searching activity does not experience delay. The suggestion given is to make the proposed layout based on the results of the product allocation. The allocation process is done by sorting the product based on the level of popularity and the value of interaction between products. After the product has an allocation in the warehouse, the next step is to create a new layout for each warehouse and each category. The last step is to compare the time traveling searching between the time of the initial conditions with the time proposed conditions. Contribution of this research is using Interaction Frequency Heuristic-Order Oriented Slotting Approach and evaluate the performance using Monte Carlo Simulation and prove that this approach can create a better result in searching activities in warehouse.

Literature Review and Research Methodology

a. Interaction Frequency Heuristic-Order Oriented Slotting

The order-oriented slotting approach method (Tsige, 2013) can be described that SKUs with high Interaction Frequency values should be kept close together to make the order picking process minimal (Tsige, 2013). In addition, SKUs that have high popularity value should be kept close to the I / O point. One of the methods developed to overcome the problem of order oriented slotting is Interaction Frequency Heuristic. Here is a procedure to allocate products using Interaction Frequency heuristic - order oriented slotting method (Tsige, 2013):

F_{ij} = frequency of interaction, number of requests / work

   order list requiring SKU i and SKU j

F_{i0} = popularity of SKU-i

D_{ij} = distance between SKU i and SKU j

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D_{i0} = specific distance between SKU i with point I / O

Procedure (Tsige, 2013) :
1. Determine the distance between SKU i and SKU j then enter it into a distance matrix.
2. Determine the distance between the SKU i and the point I / O.
3. Determine the value of the popularity and frequency of interactions between products that are then incorporated into a matrix.
4. Determine the temporary location of the SKU by using the value of the popularity of each product.
5. Identify whether there are single SKUs (SKUs that never share with other SKUs in each work order list).
6. Allocate products based on their popularity value and frequency of interaction, if all couples have been allocated but all SKUs have not been allocated because their partner has been previously allocated then the SKU will be allocated based on their popularity value in the empty space.

b. Horizontal Traveling Time Calculation and Vertical Traveling Time Calculation

Horizontal Travel Time is obtained from the division between the previously measured horizontal distance using the aisle distance with the speed of the road (travel speed) of the material handling used. Vertical Travel Time is obtained from the division between the vertical distance obtained from the rack height specification with the specification of the lifting speed of material handling. The distance measurement used in this study using Aisle Distance, this distance measurement measures the actual distance along the path that will be passed by material handling (Heragu, 2008).

c. Calculation of standard time

Standard time is the time required by an operator with average level of workability (not too fast / not too slow) (Wignjosoebroto, 2003). Here is a formula for calculating default time / standard:

$$\text{Standard time} = \text{normal time} \times \frac{100\,\%}{100\,\% - \%\,\text{allowance}}$$

(1)

Allowance = allowances given by workers to complete their work.

d. Previous Research

In previous research conducted (Wignjosoebroto, 2003), (Fajriyanti, Ridwan, Santosa, 2016) the allocation of storage is done at the warehouse of PT PINDAD's raw material by first designing the business process and the later activities are classified and slotted using FSN analysis and Class Based Storage Policy method to reduce time Delay. Another study was conducted by Amalia, Ridwan, Santoso (2016), storage allocation was carried out at raw material warehouse with the initial step of mapping the flow of goods and information using current state design, then looking for causes of waste and causes of problems using cheklist and fishbone diagram. Proposed improvements made using the lean concept of warehouse slotting and visual control. Judging from the problems in this research that happened at RU V warehouse PT XYZ also has problem because of the happening of delay in an activity, the writer use interaction frequency heuristic-order oriented slotting method to allocate product storage to reduce the delay time on traveling searching activity.

e. Research Methodology

The following is a conceptual model in this study illustrated in Figure 2:

Figure 2. Conceptual model

In this study, the first thing to do is to calculate the distance between the storage location with the point of I / O in each warehouse using the aisle distance calculation to determine the Travel Distance of each storage location based on the

initial warehouse layout. After determining the Travel Distance of each storage location the next thing is to determine the Travel Searching Time for each Work Order List by considering Forklift Specification and Racking Specification. After getting the Travel Searching Time for each Work Order List for each warehouse then calculate the percentage of Work Order list that is delayed. After calculating the percentage of Work Order List which is delayed then needed analysis to know the cause of delay time on Traveling Searching activity. The cause of delay in traveling searching activities because there is no fixed location of storage products contained in the warehouse, so that when the operator will do search for the requested product, the operator must search through the warehouse to get the product. Based on the analysis of the cause of the delay, it is necessary to determine the method of allocating the product into the storage location to determine the location of the position of each SKU. The method used in this research is Interaction Frequency Heuristic-Order Oriented Slotting method. The workings of this method is first, determine the level of popularity of each SKU, determining the level of popularity of each SKU calculated using the method of COI Based on Popularity. After determining the level of popularity of each SKU next is to determine the level of Interaction Frequency between SKUs for one year then group them into the matrix. If the value of Interaction Frequency has been calculated then allocate each pair of products based on Interaction Frequency value, if in one pair of products there is one SKU previously allocated then to determine the storage location of SKU that has not been allocated is to use the value of the popularity of the SKU just have to wait Until all pairs of SKUs have all been allocated then empty locations will be filled with the remaining SKUs based on their level of popularity. If all products have been allocated to their respective locations, then create a new layout for all warehouses so that the location of each SKU can be defined. Next step, calculated again Travel Searching Time using a new Work Order List that has been obtained using monte carlo simulation. The results of the calculation of travel searching time using the proposed conditions will be compared with the calculation of

travel searching time using the initial conditions. The results of the comparison will be analyzed to prove that by doing product allocation using interaction frequency heuristic-order oriented slotting method will reduce the delay time on traveling searching activity in RU V XYZ warehouse.

Calculation and Result

a. Calculation of the distance between the storage point and the point I / O

The calculation of the distance between the product location and the I / O point is used to determine the shortest distance between the storage location and the point of I / O, so that the product with the highest popularity value will be stored in the location closest to the I / O point. Distance calculation on the design of this proposed improvement using distance aisle distance measurement. The choice of distance measurement using aisle distance because this measurement is different from other distance measurement. At this distance measurement will measure the actual distance along the path that will be passed by material handling. The actual distance is the sum of the horizontal distance and the vertical distance. Distance measurements using aisle distance are also commonly used during planning / design. Measurement of distance between storage location and I / O point using layout of warehouse initial condition. The storage location is represented by a box shape. Figure 3 is an example of a layout of the RGM repository. Initial condition of Figure 4 is an example of calculating the distance between a storage location and an I / O point.
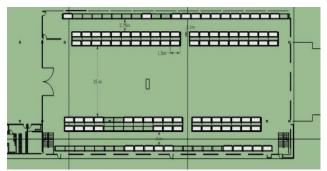

Figure 3. Example layout of the RGM repository

b. Traveling Searching Time (Cycle Time)

Cycle time is the actual time required by the operator to meet a single work order list. The cycle time of each work order list is the amount of time it takes to reach all the storage location points contained in each work order list.
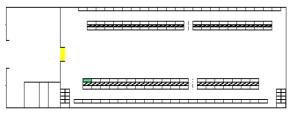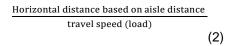

Figure 4. Example of calculating the distance between a storage location and an I / O point

The cycle time of each storage point is obtained from the increase between horizontal traveling time and vertical traveling time. Here is the formula of horizontal travel time and vertical travel time :

1. Horizontal Travel Time

$$\frac{\text{Horizontal distance based on aisle distance}}{\text{travel speed (load)}} \quad (2)$$

2. Vertical travel Time

$$\frac{\text{vertical distance}}{\text{lifting speed MHE}} \quad (3)$$

The following is an example of traveling time calculation in Table 2 :

Table 2. Calculation Cycle Time

Time	Storage Location
7,268	1101
8,308	1102
9,348	1103

c. Standard Time

Standard time calculation is obtained from the multiplication of the normal time which has been calculated by the percentage of allowance factor. The value of the allowance factor and the performance rating are obtained by adjusting the work activities performed by the operator according to the Westinghouse.

After obtaining adjustment factor and leeway factor for each product category, the values are inserted into the normal time and standard time. Table adjustment factor can be seen in Table 3, and allowance factor table can be seen in Table 4.

Table 3. Adjustment factor

Traveling adjustment factor			
Factor	**Class**	**Emblem**	**Adjustment**
Skill	Good	C1	0,06
Effort	Average	D	0
Work Environment	Good	C	0,02
Consistency	Fair	E	-0,02
Total			0,06

Table 4. allowance factor

Allowance factor		
power	Slow	0,06
Work attitude	Standing on two legs	0,02
Work movement	Normal	0,00
Eyestrain	Continuously	0,07
Temperature	High	0,05
Atmosphere	Enough	0,03
Environment	Clean and healthy	0,00
Personal	man	0,03
total		0,35

The following is the formula of calculating the standard time:

1. Normal Time
$$Nt = Ct \times (1 + p) \quad (4)$$

2. Standard Time
$$St = Nt \times \frac{100\%}{100\% - \%allowance} \quad (5)$$

Table 5 : Table standard time calculations

No.	Storage	Ct	p	Nt	allowance	St
1	RGM (M)	8,18	0,06	8,67	0,35	13
2	RSP (M)	8,80	0,06	9,32	0,35	13
3	RMS (M)	5,44	0,06	5,76	0,35	8
4	RIN (M)	4,89	0,06	5,18	0,35	7
5	RGM (S)	4,18	0,06	4,43	0,30	5,87
6	RSP (S)	4,46	0,06	4,73	0,30	6,26
7	RMS (S)	1,64	0,06	1,74	0,30	2
8	RIN (S)	2,32	0,06	2,46	0,30	3

Information:
Ct   : cycle time
Nt   : normal time
St   : standard time
P   : adjustment factor

From the calculation in Table 5, it can be seen for the calculation of traveling searching activity in RGM warehouse with category M (medium) obtained result 8.67 minutes for normal time and 13 minutes for standard time / standard.

After the standard time for each warehouse and each category has been determined, then the next step is to compare between the completion times of each work order list with standard time / standard that has been determined. The following will show comparison between cycle time and standard time in RIN warehouse with product category S in Table 6.

Table 6. Comparison between cycle time and standard time

			RIN		
No.	Work order list	Time (sec.)	Time (min)	Standard time (min)	Percent-tage
1	P.99	65,6	1,09	2	55%
2	P.88	73,6	1,23	2	61%
3	P.770	134,7	2,25	2	112%
4	P.768	111	1,85	2	93%
5	P.766	133,7	2,23	2	111%
6	P.764	97,1	1,62	2	81%

Table 6 gives an overview of the percentage calculation of the 6 work order list located in the RIN warehouse category S. Work order list in red is the work order list that is delayed because the percentage is produced above 100%.

Figure 5. Comparison between cycle time and standard time for Warehouse RIN

This means that the cycle time worked for the work order list is longer than the standard time of the warehouse. Whereas, figure 5 is a graph of comparison of cycle time and standard time of all work order list located in RIN warehouse category S.

d. Analysis of causes of delay

The cause of delay in traveling searching activity is a domino effect of inbound activity. In the inbound activity of the product already placed in the warehouse is not reclaimed the location of the product in the warehouse. So when the demand comes from the plan the warehouse operator must find each of these products to the entire warehouse. Without a detailed location about the location of the product will take a long search time. In addition to the lack of detail about the location of the product in the warehouse is the cause of the other delay time is the absence of categorization of appropriate product allocation. During this time the warehouse put its products only based on empty space only, so that the product should be placed close to the warehouse because often reserved its location even away from the warehouse door whereas the low popularity of the product placed near the door

e. Calculation of the popularity level of each product

The calculation process of the popularity level of each product is determined based on how often the product is ordered within a period of one year. After gaining popularity from each of the next product is determine the level of popularity, the level of popularity obtained from the calculation of 1 divided by the value of the popularity of each product. The product that has the greatest popularity value then it will have the least popularity level value. An example of the popularity level of each product in each warehouse can be seen in Table 7.

Table 7. The popularity level of each product

No.	Product	Popularity	Level of popularity
1	I090902464	21	0,047619048
2	H500900169	17	0,058823529
3	H840400326	16	0,0625
4	H840400113	16	0,0625
5	H840200207	14	0,071428571
6	I750200691	13	0,076923077
7	I750200751	13	0,076923077
8	I750200678	13	0,076923077

$$COI_j = \frac{S_j}{T_j} \qquad (6)$$

COI = level of popularity

f. Calculating the distance between points of storage location

The determination of the distance between products is calculated based on the distance between product one with other products. The result of this distance calculation will be made in a relationship distance matrix. An example of determining the distance between the product locations in the RGM warehouse with the category S is as follows:
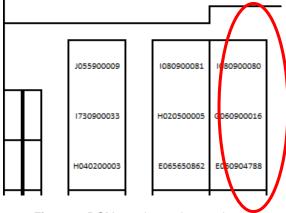

Figure 6. RGM warehouse layout pieces

An example of determining distance between product locations is as an example in Figure 6 and Table 8, SKU J055900009 with SKU I730900033 having a location distance of 0.6 meters. 0.6 meter figure obtained from the width of shelving that is equal to 1.8 meters divided by 3 because in one shelving there are 3 compartment and 1 compartment there is 1 SKU.

Table 8. shelving specification

Shelving			compartment		
rack long	=	0,4	com.long	=	0,4
rack wide	=	1,8	com.wide	=	o,6
rack height	=	0,5	com. Height	=	0,5
aisle walk	=	1,7			

g. Allocation of products with interaction frequency heuristic method

The allocation of products using interaction frequency heuristic method is intended to allocate products based on the value of the popularity and the value of the interaction frequency between products so that will minimize traveling searching time. The process of allocating this product also aims to provide information about the location of each product located in the warehouse. In the previous section has been explained about the determination of the value of the popularity of each product, in this section will be explained about the determination of the frequency of interaction between products. In table 9 shows examples of the frequency of interactions between products located in the category RGM warehouse S.

Table 9. Interaction frequency values between products

No.	Product 1	Product 2	IF
1	H020500007	H020900012	6
2	C641902769	H100900053	6
3	C398900240	H260100080	6
4	C449900262	H260100244	6
5	H020500022	H260100263	6
	C392500327	H260100436	6
7	H020500022	H260100437	6
8	H340902756	H260100442	6
9	I090902318	H340902577	6
10	H020500007	H340902584	6
11	H260100298	H340902608	6

Table 9 consists of 11 pairs of products. The determination of the interaction frequency value is determined manually by looking at the relationships between products in each work order list for one year. If one pair of products, for example between product H020500022 and H260100263 meet 6 times means that the two products meet at 6 work order list for 1 year and 6 times the meeting is value of interaction frequency of the couple.

After knowing how to determine the value of interaction frequency between products, then is to allocate each pair of products into the storage location. The ways of allocation are:

1. See the value of popularity and value of the interaction frequency of each product. In the example of this study can be seen again in table 9 which is 11 pairs of products that have the highest interaction frequency is 6. after getting the product pair that has the highest interaction frequency, then is looking at the popularity level of the 11 pairs of the product. The highest level of product pair popularity is found in product pairs 5, 7, and 10, the

popularity value can be seen in table 10.

Table 10. The value of each product's popularity

Product	Popularity	Level of popularity
H340900183	13	0,076923077
H020500022	13	0,076923077
H340902584	13	0,076923077

2. Allocate product pairs

Allocate product pairs that have the highest popularity and interaction value, in this example are the 5, 7, and 10 product pairs. The three pairs must be kept close to the I / O point and should be close to their respective product pairs.

3. Allocate another pair

All product pairs in each warehouse shall be determined the location of the storage. But, if there is a pair of products that one partner has been previously allocated then the partner is allocated based on the value of the popularity of the product. However, have to wait until all product pairs are allocated. Table 11 is an example of product allocation using interaction frequency heuristic.

Table 11. The result of the allocation using the Interaction Frequency method

Product	Time	Storage location
H020500022	2,86	3101
H260100437	3,90	3102
H260100263	4,94	3103
H020500007	5,98	3104
H340902584	6,68	4101

h. Create proposed layouts for each warehouse and each category

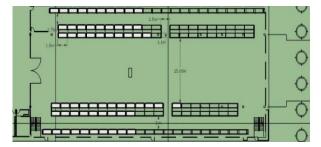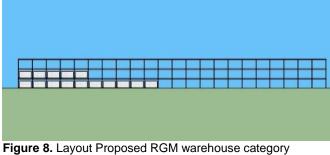In figure 7 is the result of making the proposed layout in RGM category M warehouse.

Figure 7. Layout proposed RGM warehouse category M top view

Figure 8. Layout Proposed RGM warehouse category M side view

Analysis

Comparative Analysis of the initial and proposed conditions

The analysis to compare the initial conditions and the proposals is done by comparing the results of the initial conditions with the proposed conditions by generating a new work order list obtained from performing a simple Monte Carlo simulation. Here is one comparison between the initial conditions with the proposed conditions.
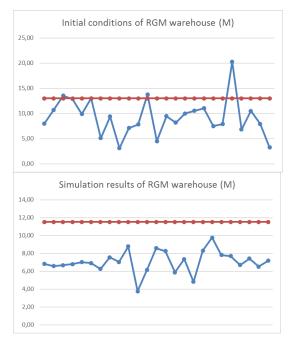

Figure 9. Comparison between initial conditions and proposal (simulation)

In Figure 9 shows that the allocation of products using the interaction frequency method gives the impact of speeding up the traveling searching activity because by using this method the location of the product is known and placed in accordance with the level of popularity and

interaction. By using interaction frequency method, all work order list experiments are below the standard time so there will be no delay in traveling searching activity. All the stock taking performance are better than the standard time while the existing condition violate standard time.

Conclusion

Class based storage is a method that usually being used to solve delay problem in stock taking (Parama, Yanuar, Santoso, 2016), (Wibisana, Ridwan, Santoso, 2017),. This research use a little different approach. To identify the occurrence of delay in traveling searching activities in the warehouse PT XYZ, the steps taken is to calculate the distance using the initial condition of the layout data in the form of AutoCad. The next step is to calculate the cycle time of each work order list and compare it with the standard time owned by each warehouse. After knowing that there is a delay on the average of 20.5% in each warehouse then it is necessary to do analysis to determine the cause of the delay time. Once we know the cause of delay in each work order list, the next step is to reallocate for all products in each warehouse.

To improve the delay in traveling searching activity, it will use interaction frequency heuristic method and use the value of popularity of each product to allocate the product. After all the products are allocated to their new storage location the next step is to do a simple simulation to generate a new work order list random list used to test whether the allocation by interaction frequency method gives better impact than the initial condition.

The result of the proposed improvement on the activity of traveling searching in the product warehouse service part RU V is the proposed layout for each warehouse which is then compared with the initial condition layout by using the comparison graph between the initial conditions with the proposed condition. Based on the proposed graph, it is found that the interaction frequency method is better than the initial condition because it gives the completion time for each work order list which is faster and all the performance better than the standard time while the existing condition violate standard time.

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