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Improving efficiency on warehouse management: a case study of beverage company's distribution center

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Abstract

Inventory and warehouse management plays a key role in the performance and effectiveness of every company that carries any products. Sunk costs are inevitable when keeping a number of products to fulfill customers' needs, while storing items with less flexibility to satisfy customers' unforeseen demands may upset business opportunities. Therefore, the utmost priorities are to manage a storage of stock inventory efficiently. The purpose of this study is to improve the efficiency on warehouse management in one of the distribution centers of a beverage company in Thailand. A number of methods have been applied to find optimal safety stock, maximize space utilization, and revise pattern of storage locations by using a Warehouse Layout Model with an ABC analysis technique to place the products that have more activities to stay effectively accessible. The results indicated a 59.46% reduction of the company's safety stock, a 13.73% increase in storage volume which created capacity for 365 additional pallets, and a roughly 42.32% decrease for moving distance of goods in the distribution center.

Keywords: Warehouse layout model, ABC analysis, Safety stock, Storage assignment, Beverage industry

1. Introduction

A warehouse is a place for storing goods in many forms, for instance, raw materials, semi-finished and/or finished products [1]. For every distribution center where products are kept for a short period for distributing or longer for fulfilling customer's needs quicker as a stock, the warehouse is the main feature; however, lean management principle classifies stocking as a waste. The lean concept focuses mainly on delivering what the customer values and eliminating any possible excess [2]. As not all theories can be applied perfectly to every kind of process in the real world, keeping stock is beneficial to many businesses because forecasting is reluctant in a wide range or predicting demand is still difficult especially for fast moving products. Therefore, inventory management is necessary in balancing the warehouse usage and the lean techniques in the aim of gaining an advantage on fulfilling the customer needs on time [3]. To accomplish this goal, the optimal inventory is necessitated. It follows that maintaining inventories produces the need for effectively managing warehouse in assigning items to suitable storage location. Van den Berg (1999) [4] stated that typical management issues in warehouse are inventory management and storage location assignment. Inventory management decides which products are to be stored in the warehouse and in what quantities. The total inventory may be reduced by applying suitable ordering plan. The simplest method for controlling inventory levels is to find reorder point and safety stock. Meanwhile, storage location assignment decides where the products are to be stored. Average travel times for storage/retrieval and order-picking may be reduced by applying an effective storage location assignment method. Several concepts have been developed for solving stock location problem. For example, the cube-per-order index was purposed by Haskett (1996) [5] which suggested that products are stored based on how frequently they are picked per unit of stock space required [6]. The ABC class-based storage (ABC), which is frequently used in the practice, stores the A-class items closet to the depot in the warehouse [7]. The correlated storage assignment strategy (CSAS) allocates the products that often picked together near each other in the warehouse, so that more products could be picked in less time [8]. Furthermore, the class-based storage approach divides the products into classes and assigns to each class a set of areas in which the products are stored with an objective to reduce the travel time in a warehouse and improve the order picking efficiency [9].

This case study focuses on distribution center of beverage products. Beverages are known as fast moving consumer goods due to their accessibility (easy to find) and price (easy to buy or cheap). Their various types, tastes, and packages have also been created to match consumers' different lifestyles and behaviors. In 2015, the beverages' market value in Thailand reached 470 billion baht. Non-alcoholic beverages shared the market value at 237.5 billion baht, in which the carbonated drinks took the first place in this category by 42.5%. Beers had largest market share in alcoholic drink, valued at about 136.6 billion baht, followed by spirits which was valued at one hundred billion baht [10]. The large beverage company that this case study examined operates 4 kinds of main products: beers, the other alcoholic drinks, foods, and non-alcoholics. Sales of alcoholic drinks were 841 million baht in 2015 and rose 29.1% in 2016 while non-alcoholic drinks reached 1,170 million baht in 2015 increasing by 9.4% in 2016. Due to nationwide sales districts and various kinds of products and brands, the distribution centers are still in need to fulfill the consumers prompt demand. ‘Fast and always ready’ is often one of the key advantages over the competitors. Therefore, storage spaces are required to store large package dimensions and to ensure inventory agility.

The goal of this study is to improve an efficiency on warehouse management in one large distribution center of one of the biggest beverage companies in Thailand. For the reason that the signs of ineffectiveness inventory control and warehouse utilization shown in the forms of the products being left outside of the building overnight. Moreover, many set of pallets is blocking the 11 entries from the total of 15 available docks which caused alternative channels being eliminated for operation of inbound and outbound activities. The blockaded docks caused the detours that increase the traveling distance and time spending for storage/retrieval and order-picking. The paper shows various methodologies that were applied in order to improve efficiency of this distribution center. The optimal safety stock was calculated in order to find the right amount of inventory levels, layout was re-designed to maximize the space utilization, and products were assigned to storage locations by applying Warehouse Layout Model with ABC analysis technique in order to minimize total travel distance.

2. Materials and methods

2.1 Data collection

In order to improve overall efficiency in the conditioned area, this case study has been discussed to clarify the issues, set the area regulation, gather information, and suggest the compatible methods for applying. Then the data set of the product circulation, the storing pattern, and the goods moving distance have been collected for period of 12 months from the past year. Another data collection of order picking was conducted for 3 months after the improvement plan was adopted. Therefore, the result could be compared to see that the strategy progressed toward the intended direction. To firmly confirm that the recommended adjustment was suitable for the problem of interest, the data after an adjustment was compared to the statistical records from the prior year.

2.2 Method and mathematical models

2.2.1 Fish bone diagram

Founded by Kaoru Ishikawa in the 1980s, these cause-and-effect diagrams are also called Ishikawa diagrams [11]. This visualized written map, shown in Figure 1, helps identify any possible causes for an effect or a specific problem. It is a brainstorming chart that directs which reasons can conceivably cause a problem of interest from broad range narrowing down to deeper root of each split. The most-possible-to-be-fixed sub cause will be picked first to solve the problem one at a time. After the chosen sub cause is fixed, the process of picking the most likely to be fixed is continued to repeat until the satisfaction level is met. Each time, at least one sub cause is solved, and it is also possible that more than one sub cause can be eliminated at once. Therefore, every returning to the diagram means the improvement.

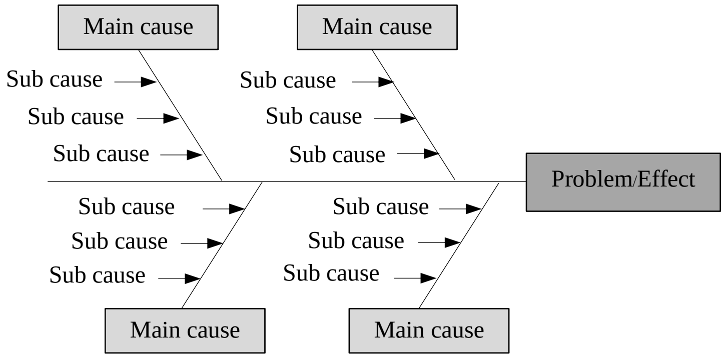

Figure 1 Fish bone diagram.

2.2.2 ABC analysis

In general, not all products to be stored are equal importance [12]. It is unreasonable to stock and control all products equally since extra storage costs will occur. Prioritize inventory that must be stored helps storing the right amount of products and inventory storage is more effective. Being one of the most common methods of overall materials management and inventory management, ABC analysis is a method of ranking inventory valuation into categories based on cost per unit and quantity held in stock or turnover in a period of time. Dividing overall inventory into three major groups, this technique is applied for managing different portions of the inventory which separate the critical few from the trivial many [13]. Tompkins and Smith (1998) [14] stated that ABC analysis is widely applied in stock location assignment for warehouse management by grouping items according to their movement or value. Inventory in group A represents approximately 20% of total items in a warehouse that have 80% of movement or sales, while group B represents the next 25-30% of items that have 15% of movement or sales. The rest in group C represents the left over 50-55% of items that only have movement or sales of about 5%.

Intending to save cost or ensure-stock availability of those high-volume items, ABC analysis is typically takes the following steps [15]. First, identifying the objective of the analysis and setting the achievement criteria. Second, collecting data on the inventory. Third, sorting out the most impacted inventory first and subsequently in decreasing order. Next, calculating the aggregated impact and dividing into classes. Even though the classified lists may not fit the exact 80/20 rule, the focal point is to seek out which areas that can be leveraged. Therefore, this valuable tool can help increase revenue and decrease costs if being applied over a period of time.

2.2.3 Safety stock inventory

Safety stock is one type of inventory that is carried for preventing stockouts due to factors such as customer demand fluctuation, forecast inaccuracy, and variability in lead times, etc. [16]. The company holds inventory in order to avoid customer service problems since competition in the beverage industry is intense. Safety stock inventory ensures that customer demand is always fulfilled when placing orders. It protects against uncertainties in demand, lead time, and supply [17]. In general, the longer the lead times are, and the greater the variability of demand and lead times, the more safety stock is required. In this case study, we considered the case when demand varies while lead time is constant. Safety stock can be computed by multiplying the number of standard deviations from the mean needed to implement service level by the standard deviation of demand during lead time probability distribution. It can be written in equation form as follows: safety stock = $z\sigma_t\sqrt{L}$, where z is the number of standard deviations from the mean needed to implement service level, σ_t is the standard deviation of demand, and L is lead time.

2.2.4 Warehouse layout model

The quantitative warehouse layout model is applied for the determination of assigning products to storage locations in a warehouse. This approach is used with dedicated or fixed slot storage in which a particular set of storage slots or locations is assigned to a specific product. In this case, a number of slots must be provided equal to the maximum inventory level for the product [18]. Rectilinear travel is used and is measured between the centroids of storage locations and docks. The notations are as follows:

Parameters:

q	number of storage locations
n	number of products

m		number of input/output points or docks
S_j		number of storage locations required for product j
T_j		number of trips in/out of storage for product j (throughput of product j)
p_i		percentage of travel in/out of storage to/from point i
d_{ik}		distance or time required to travel from point i to storage location k. *Decision variables:*
x_{jk}	=	1; product j is assigned to storage location k
	=	0; otherwise

An optimum dedicated storage layout can be calculated as follows:

$$Minimize \sum_{j=1}^{n} \frac{T_j}{S_j} \sum_{k=1}^{q} \sum_{i=1}^{m} p_i d_{ik} x_{jk} \quad (1)$$

Subject to

$$\sum_{j=1}^{n} x_{jk} = 1 \qquad k = 1, \dots, q \quad (2)$$

$$\sum_{k=1}^{p} x_{jk} = S_j \qquad j = 1, \dots, n \quad (3)$$

$$x_{jk} = \{0,1\} \quad for\ j = 1, \dots, n; k = 1, \dots, q \quad (4)$$

The objective function is to minimize the total distance traveled. Constraint (2) ensures that only one product type j can be stored in each storage location q. Constraint (3) assigns the required number of storage locations to each product. Constraint (4) states that x_{jk} is binary variable.

It is assumed that each item is equally likely to travel between point or dock i and any storage location assigned to item j. Hence, $1/S_j$ is the probability that a particular storage location assigned to product j will be selected for travel to/from a dock. Let f_k be the expected distance traveled between storage location k and the docks.

$$f_k = \sum_{i=1}^{m} p_i d_{ik} \quad (5)$$

The following approach is taken in order to minimize the total expected distance traveled:

1. Number the products (*1,2, …, n*) according to the non-increasing order of their T_j/S_j value:

$$\frac{T_1}{S_1} \geq \frac{T_2}{S_2} \geq \frac{T_n}{S_n} \quad (6)$$

2. Compute the values of f_k for all storage locations.
3. Assign product 1 to the S_1 storage locations having the lowest f_k values, assign product 2 to the S_2 storage locations having the next lowest f_k values, and so on.

3. Results and discussion

3.1 Identifying causes of the problem

The root causes of the problem were analyzed, as shown in the fish bone diagram in Figure 2. The head position of the fishbone diagram indicates the problem of this research, which is the products being stored outside of the warehouse. In the first of the causes, the working method, innate roots would go to an insufficient management, an inadequate allocation, or a substandard allowance on storing goods on the outer side of the wall—the temporary allowance finally becomes a regular routine overtime. The second cause was due to human errors. Many problems were not treated in a timely fashion. Most issues were traced to irresponsible operators, under-skilled workers, and/or misguided employees. The third cause was environmental issues. Overloading the capacity of the existing space may cause the problems to be unsolved; otherwise, insufficient uses of space, misplaced item's groups/categories, and inconvenient choices of routing could be the causes. The last potential cause would be the machine. The main machines used in warehouses are forklifts and hand-lifts and the lack of equipment or relying solely on machines could cause idle time and waiting gaps as well as insufficient sequencing usage.

The potential sources of issues were addressed in the fish bone diagram. After discussing with the warehouse manager and team, the sub cause in which can take action immediately has been chosen, an insufficient management. As a result, the following steps have been promoted to an improvement plan; by using the ABC analysis to group the products and finding the suitable safety stock for the optimal amount to keep in an inventory. After utilizing the storing area, each product has been re-assigned its storage location according to its travel distance, as known in the warehouse layout model. The framework used for improving the efficiency of warehouse management is illustrated in Figure 3.

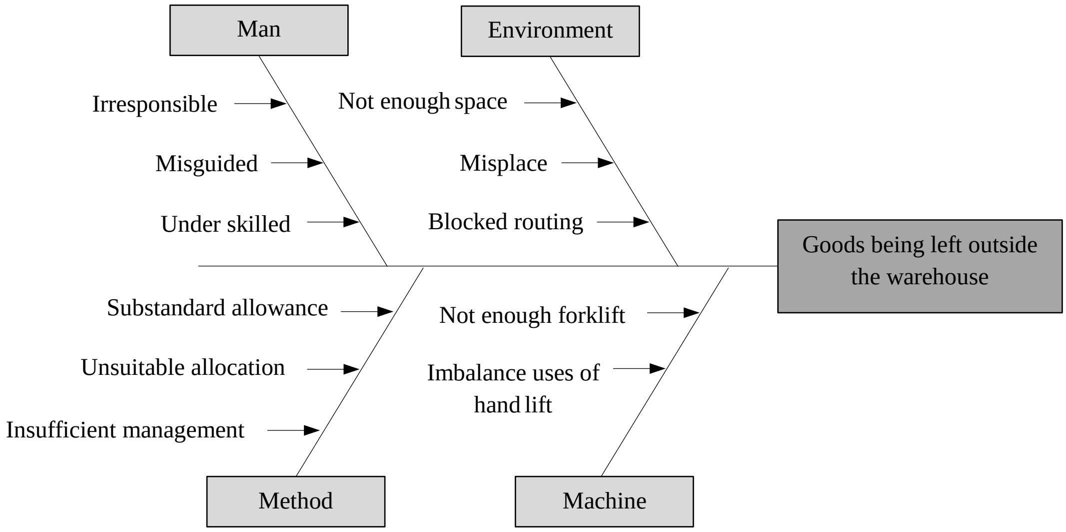

Figure 2 Analyzed fish bone diagram for a targeted distribution center.

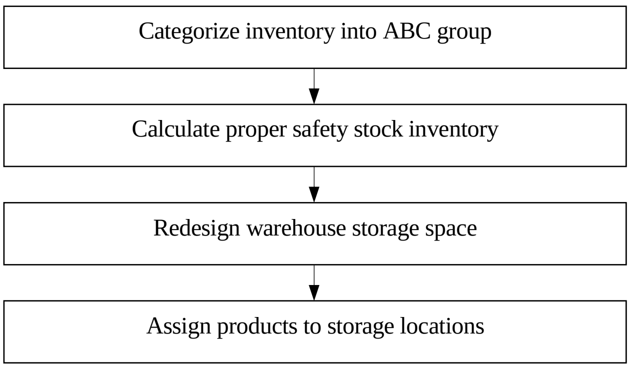

Figure 3 Framework for improving efficiency on warehouse management.

3.2 Categorizing inventory into ABC groupings

The next step of the improvement plan is to reprioritize products to be stored. The movements of products were observed by analyzing batch sizes and their circulation frequency. For that reason, some products may have been excluded as disqualified products that is exceed the decisive criteria because their flow is very less likely to happen. By applying ABC analysis technique, the products in group A items are classified as the most frequent in movement which next-day supply is required. Items in group B shift out less frequently which has to be delivered in a few days, and items in group C are more likely to stay longer that means the products are stored for more than 3 days. From ABC approach, led to result in eliminating some products that need not to stock up, reducing to only 38 lists from previously 69 in total. Some of 31 items are dead stock and some of them have very slight movement which quantity is less than a pallet. Depending on the company policy, some dead stock items can be put on sales promotion or given to customers as complementary products. The dead stock and very slight movement items can be returned to keep in the main warehouse, 150 kilometers from case study distribution center, which has more space. Otherwise, only small portions of these items should be kept and observe future movement trend.

Table 1 presents the 38 qualified products on categorizing by movement frequency. Table 2 presents the quantities by group. The result shows that the chosen products in group A are approximately 18.42% from all kinds but contain up to 77.47% of all traffic. Products in group B are about 23.68% of roughly 18.60% traffic. The products in group C are the rest 57.89% that only conduct 3.93% traffic. Hence, those products in group A are worth monitoring closely and supposedly to be located in the most convenient zone for storing and releasing when compare to the products in group B and group C.

Table 1 ABC analysis result.

Product type	No. of pallet	%Movement	%Accumulated	ABC group
Beer#1	49,704	37.89	37.89	A
Spirit#1	14,872	11.34	49.22	A
Spirit#2	12,155	9.27	58.49	A
Beer#2	6,922	5.28	63.77	A
Whiskey#1	6,563	5.00	68.77	A
Water#1	5,711	4.35	73.12	A
Beer#3	5,702	4.35	77.47	A
Spirit#3	4,162	3.17	80.64	B
Spirit#4	3,938	3.00	83.64	B
Beer#4	3,528	2.69	86.33	B
Beer#5	3,282	2.5	88.83	B
Whiskey#2	2,963	2.26	91.09	B
Whiskey#3	2,197	1.67	92.77	B
Water#2	2,116	1.61	94.38	B
Whiskey#4	1,157	0.88	95.26	B
Whiskey#5	1,062	0.81	96.07	B
Spirit#5	740	0.56	96.63	C
Water#3	718	0.55	97.18	C
Soda#1	624	0.48	97.66	C
Spirit#6	605	0.46	98.12	C
Beer#6	365	0.28	98.40	C
Soda#2	311	0.24	98.63	C
Spirit#7	306	0.23	98.87	C
Beer#7	301	0.23	99.10	C
Whiskey#6	300	0.23	99.32	C
Soda#3	270	0.21	99.53	C
Spirit#8	234	0.18	99.71	C
Whiskey#7	172	0.13	99.84	C
Spirit#9	120	0.09	99.93	C
Whiskey#8	32	0.02	99.96	C
Whiskey#9	23	0.02	99.97	C
Spirit#10	8	0.01	99.98	C
Whiskey#10	8	0.01	99.99	C
Spirit#11	6	0	99.99	C
Spirit#12	6	0	99.99	C
Whiskey#11	4	0	100	C
Whiskey#12	3	0	100	C
Whiskey#13	1	0	100	C

Table 2 ABC analysis re-categorized by group.

Group	SKUs	% SKUs	No. of pallet movement	% Movement	Movement type
A	7	18.42	101,629	77.47	Fast
B	9	23.68	24,405	18.60	Medium
C	22	57.90	5,157	3.93	Slow
Total	38	100	131,191	100	

3.3 Calculating proper safety stock inventory

After re-categorizing by ABC analysis the products that remained for stocking, the new safety stock inventory is required in order to compare if this improvement process is feasible and in the right direction. Due to the wide spectrum of product types, the company developed a unique procedure to handle safety stock, called CVD Target technique; ‘CVD’ is an abbreviation for ‘Cover Day.’

The CVD Target technique is the formula that the company created for turning safety stock from quantity of products to be reserved into how many days the company can supply customer's demand to ensure the maximum customer satisfaction. A new prearranged CVD Target rate is calculated from conditioned safety stock (unit: pallet) divided by estimated daily demand (unit: pallet/day). In addition, the conditioned safety stock is the result of applying the formula when lead time is constant at 1.25 days (mandatory, set by the company) but demand is variable. The variable *z* represents the service level. The higher the value of *z*, the higher the safety stock and the cycle-service level should be. To reach the aimed highest level of customer satisfaction, the service level is assigned to each product group as following: 100% for items in group A, 95% for those in group B, and items in group C is lower. The estimated daily demand is an average demand over the past year.

The results in Table 3 show the previously calculated versus the present one of CVD Target on each product. It can be seen that the previous CVD is categorized by product category which is 5 storing days for beers, while the others are stored for 15 days. However, each product has different movement rate, therefore it is inappropriate to use the same CVD which resulted in holding overstock inventory. The improvement can be applied by having each product's CVD in order to calculate the proper stock of each one. There were significant drops on all new CVD Targets which were, by category: 31.43% in beer products, 66.11% in spirit products, 62.22% in whisky products, 84.44% in water products, and 62.22% in soda products. Therefore, the new CVD Target represents a 59.46% reduction when compared to the old one. By optimizing the inventory amount of each product, the new CVD has proved to be favor the more efficiency flow.

Table 3 CVD Target comparison.

Product type	Old CVD (day)	New CVD (day)	% Reduction
Beer#1	5	3	40
Beer#2	5	2	60
Beer#3	5	4	20
Beer#4	5	3	40
Beer#5	5	5	0
Beer#6	5	4	20
Beer#7	5	3	40
Spirit#1	15	3	80
Spirit#2	15	4	73
Spirit#3	15	4	73
Spirit#4	15	5	67
Spirit#5	15	5	67
Spirit#6	15	2	87
Spirit#7	15	4	73
Spirit#8	15	3	80
Spirit#9	15	8	47
Spirit#10	15	6	60
Spirit#11	15	8	47
Spirit#12	15	9	40
Whisky#1	15	4	73
Whisky#2	15	5	67
Whisky#3	15	5	67
Whisky#4	15	5	67
Whisky#5	15	5	67
Whisky#6	15	5	67
Whisky#7	15	9	40
Whisky#8	15	4	73
Whisky#9	15	5	67
Whisky#10	15	4	73
Whisky#12	15	7	53
Whisky#13	15	10	33
Water#1	15	2	87
Water#2	15	2	87

Product type	Old CVD (day)	New CVD (day)	% Reduction
Water#3	15	3	80
Soda#1	15	10	33
Soda#2	15	3	80
Soda#3	15	4	73

3.4 Redesigning warehouse layout

For making the space utilization more resourceful, the pattern of storage location needed to be redesigned. Since each warehouse environments are different in terms of the building size and shape, the number of products, the number of pallets, product activity and so on, there are no guidelines for warehouse design that provide overall designs that perform well. The simplest layout for order picking is to modify an existing storage area which might include stacking height, location of goods relative to outbound docks, and bay size [12].

The warehouse of this case study is 22 meters wide and 146 meters long. The warehouse layout before improvement is shown in Figure 4. The top right is an office area, the bottom 15 sequence-rectangular blocks represent the 15 docks, the far-inside area from those docks at the top left is the sloped ceiling in which comprises a limited stack height by its eaves. The rectangular blocks inside area represent storage locations. One specific location will locate one specific product. As the ABC analysis shown each product movement rate, the storage locations on the bottom left and right which currently keep low movement products in a small volume can be removed for opening more area for pallet stacking. Moreover, since the current warehouse has too many spaces that has been reserved to be the forklift path, the proposed layout limits the forklift paths to its minimum requirement in order to gain space for storage area. These lead to an increase of storing number of pallets per location. However, the progress is conditioned by the warehouse's rules, which mandated that the 1.2 meters of the pallet be left on the either side that is reachable by the forklift of each storage row to enable easier movement; the forklift's path needs to be at least 4.5 meters wide, while the hand-lift's path needs to be a minimum 1.6 meters wide; and the fully loaded pile of pallets need to be reachable in three directions. According to these conditions, each rectangular shape that was placed inside the layout represented the storage location which already included the entailed space for conveying pallets. The proposed warehouse layout is shown is Figure 5.

Furthermore, since the CVD recalculation could reduce number of stocks to be kept, therefore the size of location in term of width can be reduced which lead to gaining more locations for storage. The formed patterns of pallets is shown in Figure 6. The pallet's stack-ability is limited to 3 layers maximum, while the base or 1st layer can be 2, 3, or 4 pallets at most. The 1st and 2nd layer are stacked at the same amount of pallet while the top is less 1 pallet. Thus, this order will set the patterns into 2-2-1, 3-3-2, and 4-4-3. The products that contain big lot indication can store up to 4 pallets wide to maximize their utilized space.

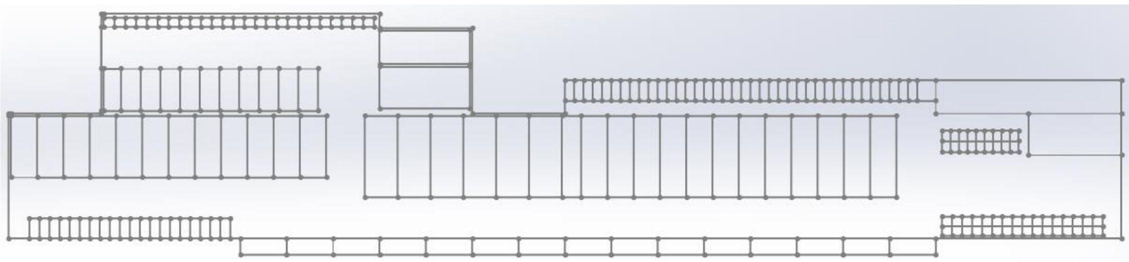

Figure 4 Current warehouse layout.

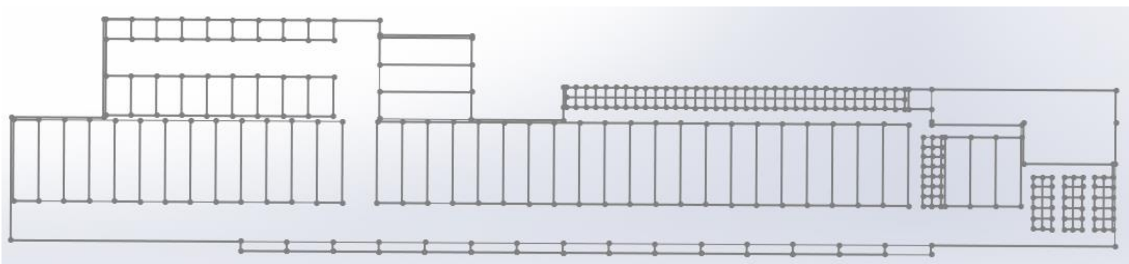

Figure 5 Warehouse layout after redesign.

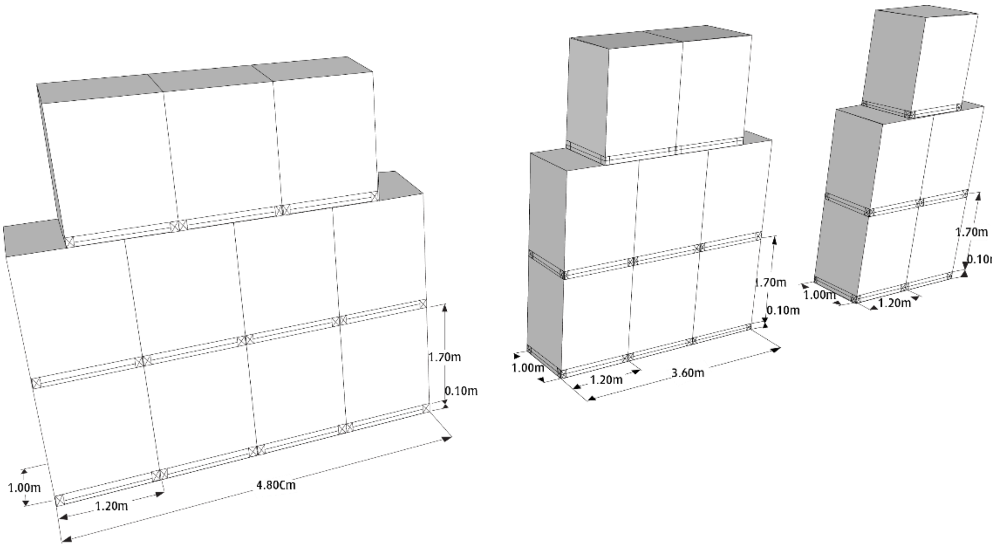

Figure 6 Patterns of pallet.

After rearranging storage location and redesigning stack pattern in accustomed location, the new adjustment was able to store up to 3,024 pallets. This is 365 pallets more when compared to the previous maximum capacity of 2,659 pallets, representing an increase of 13.73%. It is important to point out that the proposed layout design is not necessarily a suitable final layout. However, it is a basis for evaluating other design which incorporate other considerations apart from expected distance traveled.

3.5 Assigning products to storage locations

The decision as to where the products are to be located in the warehouse needs to be made after proper amount of inventory is determined and after layout for storage is defined. The warehouse layout model, which its solution procedure for designing a warehouse layout illustrated in previous section, was applied in order to determine the expected distance traveled between each storage locations and the docks. Previously, only four docks were able to open as other docks were blocked by stockpiles. The fixed limited entries increased the distance from the point of entering the warehouse to the point of storing goods accordingly. Therefore, all possible routes needed to be enabled, and 15 docks had to be kept open in working hours. On the assumption that all item movement in and out of storage is from/to one of all 15 docks with each dock equally likely to be used. Thus, probability of travel in/out of storage from/to each dock (p_{01}-p_{15}) is equal to 1/15. Suppose storage location B05 as an illustration of the computation of an f_k value. The rectilinear distance from the centroid of storage location B05 and each of the 15 docks gives $d_{1,\mathrm{B05}} = 39.3$, $d_{2,\mathrm{B05}} = 33.3$, $d_{3,\mathrm{B05}} = 27.3$, $d_{4,\mathrm{B05}} = 24.6$, $d_{5,\mathrm{B05}} = 25.8$, $d_{6,\mathrm{B05}} = 10.2$, $d_{7,\mathrm{B05}} = 16.2$, $d_{8,\mathrm{B05}} = 22.2$, $d_{9,\mathrm{B05}} = 28.2$, $d_{10,\mathrm{B05}} = 34.2$, $d_{11,\mathrm{B05}} = 40.2$, $d_{12,\mathrm{B05}} = 46.2$, $d_{13,\mathrm{B05}} = 52.2$, $d_{14,\mathrm{B05}} = 58.2$, $d_{15,\mathrm{B05}} = 64.2$. Hence,

$$
\begin{aligned}
f_{B05} &= \sum_{i=1}^{15} p_i \, d_{iB05} \\
&= p_1 d_{1B05} + p_2 d_{2B05} + p_3 d_{3B05} + p_4 d_{4B05} + p_5 d_{5B05} + p_6 d_{6B05} + p_7 d_{7B05} + p_8 d_{8B05} + \\
&\quad p_9 d_{9B05} + p_{10} d_{10B05} + p_{11} d_{11B05} + p_{12} d_{12B05} + p_{13} d_{13B05} + p_{14} d_{14B05} + p_{15} d_{15B05} \\
&= \left(\frac{1}{15}\right) * (39.3 + 33.3 + 27.3 + 24.6 + 25.8 + 10.2 + 16.2 + 22.2 + 28.2 + 34.2 + \\
&\quad 40.2 + 46.2 + 52.2 + 58.2 + 64.2) \\
&= 34.82
\end{aligned}
$$

The calculation result of the expected distance traveled between each storage location and the docks (f_k) are shown in Figure 7. The products in group A items are firstly assigned to the storage locations having the lowest, the next lowest and so on f_k values. Then group B and C were respectively assigned to storage locations in ascending order of f_k values. However, some of the products were rearranged to other locations as the company has a policy to allocate products in the same category near each other in the warehouse. Therefore, the storage locations assigned to beer in group A items include B01-B16. Spirit in group A items is assigned to location A05-A13 and C08-C09, while group B items is assigned to location A02-A04 and C07. Beer in group B items is assigned to B17-B21 and G01-G03. Whisky in group A items is assigned to D01-D02 while group B items is assigned to C03-C06 and E04-E07.

Since the company case study is distribution center which the focus is more on order fulfillment, the data of order picking is collected in order to calculate the travel distance to see if the proposed solution for warehouse improvement is feasible. Using 3 months data set of product categories beer and spirit in group A and B, the travel distances of the products is presented in Table 4. It can be seen that the total distances decrease after adopting the new assignments. The distance of beer is reduced by 49.73% while spirits were also cut by 6.41%. In total, the activities in the warehouse have successfully eliminated 80,935.48 meters on their trips, a 42.32% reduction after the development plan has been applied. It represents that an effective storage location assignment can reduce the travel times for storage/retrieval and order-picking.

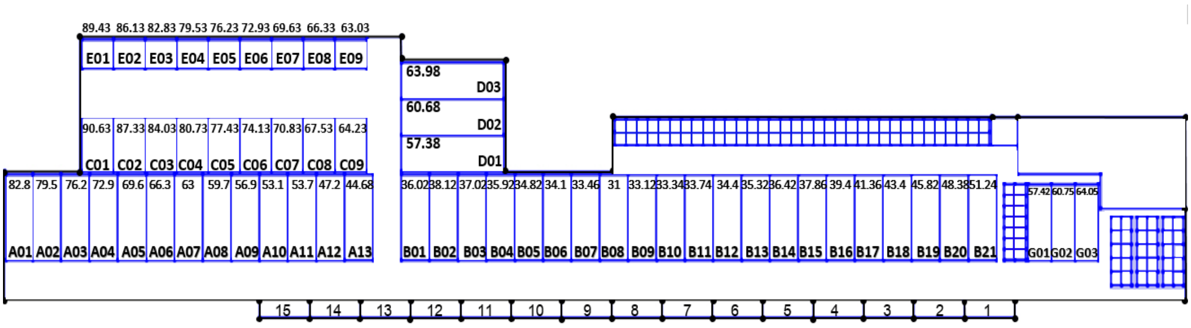

Figure 7 Expected distance traveled between each storage location and the docks (meter).

Table 4 Comparison of total distance.

Product	Before improvement (m)	After improvement (m)	Decrease (m)	% Reduction
Beer	158,549.80	79,710.75	78,839.05	49.73
Spirit	32,717.43	30,621.00	2,096.42	6.41
Total	191,267.23	110,331.75	80,935.47	42.32

4. Conclusion and recommendations

This research investigated the problem area of interest in making warehouse management more effective by reducing inventory levels, rearranging storage location and redesigning stack pattern in accustomed location, and determining storage location assignment. The results have satisfied the arranged intention. First, the average CVD of safety stock decreased significantly by 59.46% when compared to the data collected in the prior year. Second, relocating the layout on stocking increased the storage capacity by 365 pallets. Third, the combination of ABC analysis and Warehouse Layout Model has also notably reduced the delivery distance by 42.32%. The trait effect of products being stored outside the proper area was also completely eliminated. It can be concluded that proper planning of inventory management and storage location assignment, which determine amount and location of products to be stored, can be improved the overall warehouse performance. A reduction of total inventory levels while guaranteeing customer satisfaction not only reduce inventory and warehousing costs, but also improve efficiency of the operations within the warehouse. Furthermore, an effective storage space planning can minimize the total travel distance for storage and retrieval products. Since fast moving items are up front close to the docks and slow movers are in back of the warehouse, congestion may also be reduced leading to increasing the throughput capacity.

As this research was based on constant lead time and variable demand; the following conditions may effect the above outcomes:

- Promotions
- Unachievable production plans
- Irrelevant product volume and transportation capacity
- Renewing production policy
- Adjusting prices

The above conditions would cause demand, lead time, or both demand and lead time to be variable, and it is likely that the applied approach would be no longer valid. On the other hand, there is still further improvement recommendation if this trial succeeds appropriately. Since more alternative paths become available from opening all possible entrances, the critical path method is recommended. Likewise, the simulation model would be highly useful if there are any variables adding up because it can handle many variables at once.

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