A MATHEMATICAL PROGRAMMING MODEL TO DETERMINE A SUITABLE PALLET STORAGE SYSTEM TO IMPROVE STORAGE SPACE UTILIZATION

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ABSTRACT
Currently many Fast-moving consumer goods companies are chasing towards in producing and delivering goods to their consumers on time thereby keeping enough stocks in the inventory, wherein the food and beverage companies, the necessity of storing enough stock in the warehouse is becoming more challenging as the rise of different types of brands, different Stock Keeping Units, fast and low moving brands, safety factors in storing of goods, etc. continues to increase. To improve the warehouse pallet storage with efficient utilization of floor space area for conducting picking and storing of goods, a suitable pallet storage system is proposed using push-back rack to improve their storage capacity. The process to determine an optimal pallet storage area and number of maximum number of pallet stock in each lane depth is found mathematically using linear programming model. The proposed mathematical programming model is solved using Excel Solver software because of the computational complexity for the given table calculation method for each product packages. This proposed pallet thus reduced product damages and increased efficiency in volume space utilization as well as floor area utilization. The result shows that for the chosen pallet storage system, maximum number of pallets to be stored and effective use of warehouse area and volume space was thus improved.

KEYWORDS: pallet storage, inventory management, supply chain management, warehouse operations

1. INTRODUCTION
The latest trends in food and beverage production business sectors are moving towards in achieving cost effective and efficient supply chain management system. A major role played in supply chain management system is the warehouse operations as it deals with the inbound and outbound goods shipped from the plant to distribution center and from distribution center to customers [1]. The main goals of warehouse operations and layout design is by having optimized and effective solutions of storage space utilization as discussed by [2] plus maintaining the safety of all products. In accordance to supply chain principle management system, numerous dominant companies and industrial sectors are trying to achieve assigned targets for increase in product volume in terms of both production and distribution [3] [12], in turn making use of minimized inventory stock throughout the items delivered to the warehouse. Approaching towards this scenario is encouraging the need for warehouse management system. The important end result is to implement a new pallet storage system which is a floor storage into a push-back rack system, to accommodate more products each having at least 2-3 SKUs, to utilize maximum use of space in terms of height and also, be able to find maximum number of pallets for each package.

2. TYPES OF PALLET STORAGE SYSTEM
2.1 Block stacking (Floor storage system)
Block stacking of storing unit loads is one of the optimal storage method obtained in many facilities dealing with supply chain. Block stacking is also known as Floor storage. The concept of this storage system is stacking unit loads on top of each other and placing them on the warehouse floor with storage lanes (blocks), generally 2-12 loads deep. With several layers high depending on the type of materials being stacked, the clearance area can shoot up to various heights.
Block stacking, does not require any type of storage equipment which is racks hence considered as a form of palletized storage system. All the pallets to be loaded are placed directly on the floor and built up in stacks to a maximum stable storage height. Each lane is designed to ensure there is adequate access to the dissimilar SKUs for each material types.

When removing loaded pallets from the storage lanes, often it results in creating space that remains unused until the entire lane has been vacant thus, resulting in ‘Honeycombing’. In order to avoid honeycombing, the warehouse operators need to carefully plan both the lane length and depth to determine storage capacity and in achieving a high level of utilization of each line considering future and current stock output levels for each SKU is required.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Less capital costs</td>
<td>Limitation on stack height which can restrict the use of building height to its maximum.</td>
</tr>
<tr>
<td>2.</td>
<td>No need for extra storage equipment’s</td>
<td>Causes Honeycombing which reduces storage capacity</td>
</tr>
<tr>
<td>3.</td>
<td>Makes good use of area however not necessarily in terms of height</td>
<td>Not a strict FIFO</td>
</tr>
<tr>
<td>4.</td>
<td>Very simple to control</td>
<td>Only free access is given to pallets at the top of each row.</td>
</tr>
<tr>
<td>5.</td>
<td>Suitable for high throughputs</td>
<td>Risk of fire</td>
</tr>
</tbody>
</table>

![Fig. 01: Block stacking in the warehouse (Source: Super Rack, all storage solutions)](image)

### 2.2 Drive-In Rack and Drive-Thru Rack

The term Drive-In Rack is often used interchangeably with Drive-Thru racking. In some scenarios, it is often appears the same. Typically, Drive-In racking necessitates an operator to drive the loaded pallet into the racking system from one side and remove pallets from the same entry point or a wall or otherwise closed at the opposite end. The products are rotated in a Last-In, First-Out inventory routine because of the single entry or exit point. The Drive-In rack system has precise efficient storage concentration. Each loaded pallets are stored back-to-back without the presence of aisles for dense storage. A Drive-In Rack is simply identified from its LIFO (Last-In-Last-Out) inventory management. This type of system is an efficient solution for product that is not venerable to duration, or for fast moving pallets that are exchanged frequently.

Extreme care must be taken by Drive-In Rack operators to not damage the pallet racking body structure. Besides this, the driver must enter the pallet racking system carefully with only a small clearance on either side pallets because
the pallets are stored very compactly. Hence, a Drive-In Rack system must be periodically checked for any damages caused by forklift drivers. As soon as the base of pallet rack damage is noticed, it must quickly be informed and properly repaired or replaced to prevent any further mishaps in the future. Lastly, a strict safety code of conduct should and must be adhered with a Drive-In rack system.

**Table 02: Drive-In Rack System advantages and disadvantages**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maximum pallet storage</td>
<td>Prone to misuse of rack structure.</td>
</tr>
<tr>
<td>2.</td>
<td>Unlimited depth of storage</td>
<td>Requires a rack which is reliable, sturdy and strong in order to last</td>
</tr>
<tr>
<td>3.</td>
<td>Virtually limited aisles, resulting in more efficient use of space</td>
<td>Uses a LIFO racking aspect where old products will not be used before new products are added</td>
</tr>
<tr>
<td>4.</td>
<td>Cost-effective storage strategy</td>
<td>Not suitable for sensitive items</td>
</tr>
<tr>
<td>5.</td>
<td>Utilizes density over selectivity</td>
<td>Requires experienced forklift operator with good judgment to load the pallets.</td>
</tr>
</tbody>
</table>

**Fig. 02: Drive-In Rack Side view (Source: Super Rack, all storage solutions)**

### 2.3 Pallet flow rack

Pallet flow rack is also known as “Gravity flow”. It follows a FIFO (First-In-First-Out) storage system for moving through warehouse. High density storage is achievable in Pallet flow rack while maintaining a FIFO retrieval order and efficiency in product handling. Apart from this, it also, maximizes the actual storage space by minimizing aisles. They can also, be designed to hold up to 20 pallets deep in one lane and allow fast and effective inventory turnover. The Pallet flow rack systems are easily customizable and offers manufactures multiple types of rollers to meet the demand of individual users’ pallets and products. Some manufactures can even customize their pallet flow racks with speed controller capacities that are uniquely designed for users’ product weight ranges.

During stacking the pallets are loaded into the storage path from the loading aisle and gravity fed towards the release aisle and move via roller track to the opposite end. The pallets are first set onto rollers whereupon which the pallets effectively flow towards the front of the rack system. Once they’ve glided to the front of the system, the pallets lay on pallet prevents until they’re emptied from the pick face. As pallets are removed or unloaded from the system, each of the pallets that were behind them “stream” into the next position through gravity. Pallet speed is controlled by the
kind of rollers and brakes designed into the system. Some of the type of Pallet flow rack lanes are Full-width rollers, Magnum (Poly) Wheel Rollers and Skate Wheel Rollers.

Advantage of Pallet flow rack system:

- Space-saving, high density storage
- Customized, tailor-made design and layout
- Fast access to every product
- Very versatile and well-suited to refrigerator or freezer storage applications
- Practical, efficient and Operation-friendly
- Time-saving and less maintenance

![Fig. 03: Pallet flow rack system (Source: Toyota Equipment)](image)

2.4 Push-back rack

One of the high-density storage systems is Push Back Pallet Racking. Up to six pallets deep configurations possible using the heavy-duty carts. During loading the pallets are loaded front to back onto rolling carts, which get pushed back as additional pallets are added. As pallets are moved, the gravity assists to advance the remaining ones forward so that the front pallet position is constantly filled. Hence, it follows a FIFO and LIFO storage system. In the case of high product variety this system is ideal, as the forklift can access each flow lane easily. However, the pallets must all be around the similar size, unless you have a cart cover. This system comprises of carts and rails set within a supporting structure. Pallet halts are at the end of the carts to ensure that the pallet does not move when it shouldn’t. The capacity of the carts can be up to six pallets deep, and move along the rails.

Design of Push-back pallet rack systems are such as to store pallets on wheeled carts that rest on rails enabling forklift operators to load and unload pallets onto the carts, as well as drive them back as the next pallet is loaded. During unloading, the pallet being unloaded acts as a brake for the pallets behind and once the pallet is removed, the pallet from behind will now be placed at the pick face for unloading. There are numerous benefits of Push-back pallet rack compared to its disadvantages which is clearly shown in Table 2.3. This makes it the best choice for proposing it to this proposed model as it is matches most of the company regulations.

### Table 03: Push-back rack system advantages and disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows high-density storage of multiple SKUs</td>
<td>No load overhang on front or back of pallet</td>
</tr>
<tr>
<td>Fast operation and better utilization of accessible pallet space than general capacity of storage system</td>
<td>Not suitable for FIFO (first in first out) inventory</td>
</tr>
<tr>
<td>Minimized need for aisles hence saves more space</td>
<td></td>
</tr>
<tr>
<td>Allows storage of more SKU’s</td>
<td></td>
</tr>
<tr>
<td>Easy &amp; fast loading and unloading of pallets</td>
<td></td>
</tr>
<tr>
<td>Customizable pallet carts, usually color-coded</td>
<td></td>
</tr>
<tr>
<td>No Rack damage since Forklifts never enters the rack</td>
<td></td>
</tr>
<tr>
<td>Reduces honeycombing effect compared to drive-in rack systems</td>
<td></td>
</tr>
</tbody>
</table>
3. LITERATURE REVIEW

Some literatures showed by [4,5] on hierarchical design method and step method along with solved examples and assumptions were studied for design of warehouse storage. According to author in [9] has utilized genetic algorithm for transportation cost and distance. Several researches have been done using mathematical programming method along with algorithm for warehouse design and storage and space allocation some to mention: heuristic algorithm [12], harmony search algorithm [13], and genetic algorithm [9]. The authors for warehouse space assignment with problem in space operational limitation proposed that [12] using heuristic algorithm and linear programming they were able to solve the decentralization of products in storage locations with better inventory control. Besides this, they developed a software for industrial usage with the focus on auto industry.

In line with the research, another author developed an application based on harmony search algorithm using MATLAB to solve the logistics knapsack problem. A knapsack problem is a combinative optimization problem wherein for a given set of data each having different sets of volume and value, it aims at finding the most important set of data that fits the knapsack fixed volume or values. The authors were able to find and develop a bandwidth operator aiding with convergence with the support of basic algorithm. The result of this authors work is shown in Fig. 2.9 below; this result was formed after feeding the harmony search algorithms in MATLAB using static parameters [13].

![Fig. 04: Push-back racking system 4-Deep (Source: Super Rack, all storage solutions)](image)

![Fig. 3.1 The result of logistic knapsack problem with harmony search based MATLAB application](image)

Another author used genetic algorithm for solving supply chain problem which is facility location. They were able to develop an application for denoting the facility location status. They also made use of linear programming method for improving the efficiency of facility location problem for the 6 customers in the Jiande area of China. By using linear programming method and genetic algorithm program the optimized result showing total turnover for the facility location
was obtained seen in Fig 2.10 [9]. The x-axis denotes the demand of the products in terms of weight (kg) whereas the y-axis denotes the maximum distance for distribution (km) of the products to be delivered to the 6 customers in the Jiande area. They assumed that the maximum distribution range was less than or equal to 50km. The graph shows that as the demand of product increases the distance for distribution of these products decreased, thus obtaining a minimum transport turnover quantity to meet the their most distant delivery distance customers.

![Fig. 3.2 Optimized Total transport turnover quantity for product demand and distribution distance](image)

However, this case study will solely be concentrating on linear programming method as it is not dealing with large constraint variables and also because of the computational complexity for the given table calculation method for each product packages. Moreover, the above research papers were related to supply chain management and warehouse operations.

4. PROPOSED PALLET STORAGE SYSTEM

As mentioned above the pallet storage system currently used in the warehouse is floor storage system; This pallet storage system is made to maintain a FIFO (First-In-First-Out) method wherein, the products which are manufactured first are stocked and sold out first. The racking storage system is divided to accommodate the three packaging categories; CANs, PETs and NRBs as per the company’s regulation. Each of these packages have a certain degree of condition that must be maintained throughout the daily operation carried out in the warehouse. Some of conditions for product stored in floor storage system are stated as follows:

- Each package comes in various product sizes
- Different product weight
- Number of cases in each pallet for each package
- Clearance height of warehouse
- Load stability, strength and pallet conditions
- Safety limits for each product packages.
- Safe temperature environment certain package must be maintained
- Maintaining a safe distance between each pallet lane.
- Providing appropriate distance for forklift and walkway access.
The drawbacks in floor storage system is greatly reduced by underutilization of warehouse space, wherein when an entire storage lane is cleared, resulting in honeycombing, ventilation of products is poor, limited to low density storage space that is only few SKU can be stored, in intensive case it requires large area to store large quantity of stock and often restricted in maintaining safe height and load weights. There is also limitation in the itself; the height of the warehouse restricts the need to stored pallet 2 to 3 layer in height. The NRBs can be stacked up till 2 layers since these products are more susceptible to damage, but their ever-growing demand needs to be fulfilled by allocating more of these products. The CANs have the capability of stacking 3 layers and PETs can stack up till 2 layers each. If floor storage method is continued then pyramid stacking operations needs to be maintained.

By keeping in mind all the drawbacks of the current warehouse pallet storage system, a push-back racking system was proposed to the beverage company. Benefits of push-back racking pallet storage system is that it allows pallets to be stored 3 to 6 pallets deep, in doing so, provides a higher storage density when compared to other racking system. The operation done by the forklift during pallet loading in 6 deep push-back rack is by placing the first pallet on the first cart, then while loading the second pallet on the second cart, it simply pushes the first pallet cart back behind one position and making space for the second pallet. This operation continues until all the 6 pallets are filled deep; the last pallet is placed on the rail without the cart, this helps in locking.

Krummell, John VR, and Kenneth invented the [6] a push-back racking system having 4 Deep; this was developed with intentions for warehouse having large capacity of items. During unloading operations, the remove a pallet, the fork truck driver lifts the pallet off, reverses slowly and the next pallet comes forward and into the front position. This operation is repeated until the lane is empty. Moreover, the benefits of this system provide allocating high storage density in inventory stock, no need for buying new forklift as existing forklifts can be used as long as the max. height is attainable. They are very suitable for keeping more than 7 pallets per SKUs; Stock rotation and order picking is conducted faster and large products can be stored at different level when compared with other storage system. Since the pallets come to the aisle easily, the loading and unloading is also increased. Damage to the product and the rack us also reduced and lastly, the racks provides better ventilation of air circulation for the items. Any variations in this system is omitted as the work is solely based upon the requirement of the company and their standardization.

5. LINEAR PROGRAMMING METHOD ON EXCEL SOVER

Linear programming is a common method used to solve many problems such as commercial location selection model [9], facility location problem [10], and fleet routing problem [11]. Author Dantzig first published the linear programming problem using simplex method [11] for solving various problems. The research method used for this project, is the linear programming method. This method is used to calculate and solve the optimum pallet count in each storage area for each beverage packages, by using simplex method present in the EXCEL solver software. The metaheuristic method was implemented to be made use in the warehouse pallet storage for evaluation of push-back rack storage system. The research work in this field of research project by using LP is carried out very little. However, the research seems to find a clear viewpoint for introducing to such environment. The aim of this project was to identify the current operations and standards followed in the warehouse, identify the flaws in the existing system and identify the possible solution to the upcoming issues.

The beverage products come in three packages, CAN, PET and NRB. Each of these have separate allocation of their products in the chosen push-back racking system. The aim is to find the optimum pallet count following operations were conducted:

- Decision variables
  The input data values of the amount of pallet count for each packaging type present in the warehouse is provided.

- Objective function
  In the range B7:E7, we referenced the number of pallet count and in B8:E8 we input the per pallet storage area for each available packaging variable. After this, we computed the total allocated pallet per area for all the package in the cell B10 with the following formula

\[ B7*B8 + C7*C8 + D7*D8 \]

- Constraint variable
  The values for obtaining the desired result, the conditions needed to match were that for warehouse area of 2178 m², a minimum number of total pallet storage area of 2000 m², 30 SKUs, 9 lane depth and lane height of 3. Using the
formula “=SUMPRODUCT (B7:D7, B14:D14)” is used to calculate the total value for each constraint parameters stated. For the given decision variables, objective functions and constraint variables, the required minimization formula can be obtained for the calculation done through EXCEL Solver. The input value is seen in Table 3.1. This will be used as set parameters for optimization by executing through simplex method.

Table 5.1 Current situation of pallet count.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CAN</th>
<th>PET</th>
<th>NRB</th>
<th>Required value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallet count</td>
<td>294</td>
<td>521</td>
<td>91</td>
<td>2000</td>
</tr>
<tr>
<td>Total warehouse area</td>
<td>2178 m²</td>
<td>2178 m²</td>
<td>2178 m²</td>
<td>2178 m²</td>
</tr>
<tr>
<td>Total pallet storage area</td>
<td>254 m²</td>
<td>244 m²</td>
<td>71 m²</td>
<td>2000 m²</td>
</tr>
<tr>
<td>Number of SKU’s</td>
<td>15</td>
<td>20</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Lane depth</td>
<td>15</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Lane height</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

According to the above data in table 4., the objective function and the constraints were established as follows:

\[
\begin{align*}
\text{Min } Z &= \sum b_i x_i \quad ; \ i = 1, 2, \ldots n \geq 0 \\
\text{s.t.} \quad & x_{11} + x_{12} + x_{13} = 2178 \text{ m}^2 \\
& x_{21} + x_{22} + x_{23} = 2000 \text{ m}^2 \\
& x_{31} + x_{32} + x_{33} = 30 \\
& x_{41} + x_{42} + x_{43} = 9 \\
& x_{51} + x_{52} + x_{53} = 3 \\
& x_i \geq 0, \ i = 1,2,3,4
\end{align*}
\]

Before on the start of optimization, a spreadsheet is created, wherein the decision variable consisting of pallet count for each package is inputted (this variable will the one where optimal pallet count will be changed during optimized solving), followed by inputting and calculating the objective function. This function acts as the deciding factor for minimizing of storage area through reduction in pallet count. Lastly, the constraint variables are fed into the spreadsheet to formulate the total outcome from the desired values. Once this is done, the addition of minimization or maximization constraint is inputted which is determined from each required value. Once all the necessary field of data need for linear programming solving is entered, the solver from the EXCEL is added via “add ins” and is found on toolbar “Data”. Upon selecting and opening the solver, a dialog box of “solver parameter” will be opened. The solver parameter is used for describing and solving the optimization situation through EXCEL. Upon opening certain parameters can be seen, for this research project the set objective is used here is the pallet count per pallet storage area. This parameter is then set to Min as our formula states so. The changing variable cells is the decision variable which will be changed after solving and this will be the pallet count. After, optimization the maximum storage area, maximum pallet count, lane depth and lane height is outputted.
6. RESULT ANALYSIS

The result of optimized pallet count for each package is shown in Table 4.1. It was found that, the optimum pallet count for accommodating CANs is 525; the optimum number for accommodating PETs is 510; and the optimum number for accommodating NRBs is 375. The total pallet storage showed 77.6% increase in pallet storage area compared to 65% with existing situation in the warehouse. A total of 1410 pallets were able to store in the warehouse if Push-back racking system is installed. The difference between the previous record and the optimised record of number of pallets for each CAN was 231, for PET was 11, and for NRB it was 284. The rise in pallet count with suitable lane height and depth for each package type and the choice of racking system, I was able to fulfill the objectives for this project work.

Table 6.1 Result for optimum pallet count.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CAN</th>
<th>PET</th>
<th>NRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum pallet count</td>
<td>525</td>
<td>510</td>
<td>375</td>
</tr>
<tr>
<td>Total warehouse area</td>
<td>2178 m²</td>
<td>2178 m²</td>
<td>2178 m²</td>
</tr>
<tr>
<td>Total pallet storage area</td>
<td>630 m²</td>
<td>612 m²</td>
<td>450 m²</td>
</tr>
<tr>
<td>Number of SKUs</td>
<td>15</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Lane depth</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Lane Height</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

![Optimum pallet count vs Number of SKU](image)

Fig. 6.1 The result obtained after simulation between pallet number and SKU

The graph above Fig. 4.1 represents the comparison of optimum pallet count verses number of SKU. From this we can clearly notice a decrease of total number SKU from CAN to NRB which is complements the actual data of the company inventory result. The actual company inventory result could not be shown here in this report due to privacy concern.
The current warehouse with proposed Push-back racking system could store SKUs with around 1410 pallets in total. A graph for this was produced and shown in Fig. 4.2; Considering the company works 6 days per week. So, on the first week, it showed an increase in number of pallets about 1402 pallets for 108255 daily SKU inventory in cases for day 2. However, a decrease was followed soon after day 3. As the week passed by during the last few days of week end there was always a decrease of pallet count of about 800 pallets. This shows that a rise and low of inventory is either due to inventory coming from the plant to the warehouse or due to more number of stocks being ordered.

The KPI (Key Performance Indicator) graph for the warehouse was produced, Fig. 4.3. Its denoted that a 83.5% rise in Warehouse utilization for the week 4 showed the warehouse operation activity was increased and the overall activity with the necessity for installing Push-back rack thus shown proven outcome.
Concentration of this project was solely done for utilization in storing maximum number of pallets for each area, since the company sole issue was finding effective use of space for storing goods. Push-back rack storage system which is chosen storage system for the warehouse could accommodate the required pallet count in their racks thus showing increased efficiency in space utilization.

Issues regarding the storage showed some proven success in allocating and utilizing the maximum space for warehouse usage. Moreover, from the above result the company was ready to invest in push-back racking storage system, as the result showed that with the given lane depth and optimum values of pallets, the racks could accommodate their numerous SKUs for each product, high storage density, and upkeep FIFO standard. Linear programming method by EXCEL Solver, showed that with the given constraints and objective values, it could calculate the maximum number of pallets, hence, making efficient use of storage space. Finally, the damage on the rack was shown to be significantly reduced, reason being the operator need not have to drive in to the rack to remove and place the pallets.

7. CONCLUSION

The implementation of installing the proposed push-back rack pallet storage system for the warehouse of the beverage company clearly provides solution to their large storage capacity. The problem regarding large SKUs for each product items in the inventory, storing of all three different types of packaging method: can, PET and NRB was solved using linear programming method. By calculating the optimum number of pallets for each package with the given constraints, Maximum warehouse storage space could be utilized as provisions for pallets with specific product packages were given its maximum pallet storage space. Allocating of such items shown to reduce even the cost of renting in extra external warehouse during peak seasons. The chosen pallet system showed improvements in reduced product damages and increased efficiency in volume space utilization as well as floor area utilization. The proposed pallet storage system for the warehouse ensured improvement in better effective use of storage space, easy access to all storage places, increased flexibility, accessibility and mobility for the forklift maneuvering, maintaining FIFO; Also, improved daily activities and operations carried out in the warehouse was clearly noticed. Nevertheless, as the complexity of warehouse distribution business sector becomes more and more hectic, further studies can be done to reduce the cost of products stored verses the cost of warehouse capacity under dynamic conditional factors. Also, future optimization application methods can be developed in this research area.

REFERENCES


