PROPOSED WAREHOUSE LAYOUT
AND PROCESSES EVALUATION

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ABSTRACT

The main objective of the study is to implement a variety of tools necessary for the design of an effectiveness warehouse for company X. The first two phases (warehouse activity profiling and warehouse design) are finished. The proposed warehouse design for company X has two floors, which are ground floor and mezzanine. Bin-shelving area, pallet and floor storage area, shipping area, and receiving area are put in the ground floor. The pallet and floor storage area is further divided into four zones: Pallet rack, Floor storage zone, Special pallet zone, and Heavy pallet zone. The shipping area of 4,784 square feet will have five shipping doors which includes the staging area in front of the docks. The receiving area requires approximately 4,000 ft². Class C SKUs according to viscosity will be put in the mezzanine area which utilizes the vertical space of the building. This area is accessible from forklifts using a spiral corridor close to the receiving area. The warehouse processes will include batch order picking in improving labor hour utilization and high viscosity SKUS shall be placed in the most convenient location of the warehouse.

Keywords: viscosity, SKU, mezzanine, ground floor, ABC Analysis

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INTRODUCTION

A warehouse is one of the necessary entities in most operations in any manufacturing business. It is designed to store either raw material, work-in-progress, and/or finish goods. Why warehouse is built as part of manufacturing system? To consolidate product to reduce its transportation costs and provide an excellent customer service; to realize economies of scale in manufacturing or purchasing; to reduce response time; to provide value-added processing, for instance, light assembly in response to a postponement.

Company X is a distributor of wholesale office products with thirty six distribution centers throughout the United States. Its business begins when an order arrives. Orders are accepted until 5 p.m. and typically shipped in the “same night”. It is a challenge for this company to be able to keep up its aptitude to have the same night delivery service while maintaining an acceptable level of operation costs. Thus, it relies on extraordinary intensity of efficiency in the whole processes, especially in the order completion.

There are four phases in constructing a Greenfield design which supports the current warehouse activities and improves the overall performance and order fulfillment process: warehouse activity profiling, design of the warehouse areas, proposal of the warehouse layout, and discussion of the proposed warehouse layout. The first two phases are completed. A quick measurement is taken which chose D-11, one of the company X’s warehouses, as the main reference because it has the highest annual total number of picks per area of the warehouse. It was concluded in the first phase that the design of fast-pick area was unnecessary due to the low rate of pick/day on average. Therefore, batch picking will be used for order picking procedure and a special pallet picking area is designed. The information obtained from the second phase will be used in designing and evaluating the proposed layout and its processes.

DISCUSSION

Warehouse activity profiling measure and analyze the warehouse activity statistically. It is a crucial first step to almost any significant warehouse project, to understand the customer orders which drive the system (Skinner, 1988). The next step in designing a warehouse is to layout a storage area or a piece of equipment for which the costs to pick from any location are all roughly equal and the restocking costs for any locations are all approximately identical. Common storage modes are carousels, pallet rack, bin-shelving, and flow rack. The difficulty in designing any warehouse is in determining the number of slots to place along a shelf, the number of shelves needed, and the arrangement of the shelves (Ballou, 1999).

Bin-Shelving or Static Rack

Shelving is the least expensive and the most basic storage mode. The shelves are shallow where any significant quantity of a stock keeping unit (SKU) must spread out along the pick-face which reduces SKU-density and pick density, increase travel time, and reduce picks/person-hour. A typical pick rate from bin-shelving is 50-100 picks/person-hour (Bartholdi, 2002).

As the bin-shelving area becomes larger, more SKUs can be put in, which means more pick savings, less restocking at the expense of the savings per pick due to the additional walking. Based on the fluid model, assume each SKU is treated as incompressible and continuously divisible fluid. Suppose that every SKU will be represented in the bin-shelving area of volume V and the
rate at which pick savings decreases at rate (Bartholdi, 2002). Thus, the optimum size of bin-shelving area is given by

$$V^* = \frac{\sum_{i=1}^{n} \sqrt{f_i}}{\sqrt{S \sum_{i=1}^{n} p_i}}$$

where, $f_i$ is the annual flow of each SKU

$p_i$ is the annual number of picks of SKU $i$

$S$ is the rate of pick savings decrease as a function of the size of the area

Space allocation for each SKU; to minimize total restocks over all SKU’s $j = 1, \ldots, n$, each SKU $i$ should be stored in the amount

$$v_{i}^* = \left( \frac{\sqrt{f_{i}}}{\sum_{i=1}^{n} \sqrt{f_{i}}} \right) \cdot V$$

where $v_{i}^*$ is the optimal volume to store each SKU $i$ and $f_i$ is the annual flow of each SKU

Viscosity measures the work needed to pull a given amount of physical volume through the warehouse. The most viscous SKU should be placed in the most suitable for the best storage locations in order to generate the largest net benefit the space they consume (Chopra, 2004). The viscosity of a SKU $i$ that is stored in less-than-pallet quantities is

$$Viscosity\ of\ SKU\ i = \frac{p_i}{\sqrt{f_i}}$$

ABC Classification; one of the first things to know about any warehouse is which SKUs matter. A simple ranking of the SKUs using various criteria helps in revealing the contours of the economic terrain within the warehouse. ABC analysis is derived from the Pareto’s law which suggesting the “important few” be given separate treatment from the “less important many” (Hopp, 2000). ABC analysis simply classifies SKUs as A (the small fraction of SKUs that account for most of the activity, the top 20%), B (moderately important, the next 30%), or C (the bulk of the SKUs but account only for a small portion of the activity, the last 50%) (Nahmias, 2005). In any warehouse operation, ABC analysis should be used to see the extent each SKU consumes resources such as labor or space.

Pallet storage; pallet is the largest unit of material within the warehouse. The simplest way of storing pallet is floor storage, which is typically arranged in lanes and each lane is reserved for a single SKU. Pallet/floor storage can be used for bulk storage, to support full-case picking, oversized dimensions and volume SKUs, or for replenishment. For pallet storage used for replenishment, the number of pallets needed to be stored for each SKU can be calculated as follow:

$$No. \of \ pallets\ needed\ for\ SKU(i) = \frac{\left\{Volume\ needed\ per\ replenishment\ period\ for\ SKU(i) - Volume\ allocated\ in\ bin-shelving\ area\ for\ SKU(i)\right\}}{Pallet\ volume}$$

Where,

Volume needed per replenishment period for SKU $(i) = \frac{Maximum\ volume\ needed\ for\ SKU(i)}{No.\ of\ replenishments\ per\ year}$
Mezzanine area; vertical space is free. However, on the pick-face, horizontal space is generally more valuable than vertical space because most labor is devoted to traveling horizontally. Vertical movement is slower than horizontal movement.

Data Analysis

First, proposed warehouse layout. The design of the warehouse will be separate into two sections; the ground floor (figure 1) and mezzanine (figure 2). The ground floor will have a height 419 feet in width and 303 feet in length. The height of the warehouse will have an approximate of 25 feet. For the mezzanine, it will have a width of 143 feet and length of 303 feet. The height of the mezzanine will be 10 feet high. The layout is classified in color with Class A SKUs in red, Class B SKUs in green, and Class C SKUs in blue. The heavy pallet storage is colored in purple and the special pallet is colored in yellow.

Second, receiving and shipping areas. For the ground floor design of the warehouse layout, the receiving and shipping docks were put at the same side because company X has a strong ABC skewness for its SKUs. About 20% of the SKUs are picked 80% of the time. Hence, it is appropriate that the most convenient locations (occupied by the class A SKUs) be made more convenient. Another reason is that this design provides dock flexibility. In the case that either receiving or shipping experiences a need for surge in activities, the warehouse can make use of the additional doors from the other function.

Third, put-away area. For the put-away section of the warehouse, floor storage and pallet racks were used. Floor storage is used to stack up SKUs that come in standard containers, and it is the cheapest form of storage available in a warehouse. SKUs that were specified to be larger than the pallet dimensions and stackable (after looking at the description of the SKUs for suitability) were put at the floor storage area. For the rest of the SKUs, they were put away to the pallet rack, which serves to replenish the bin shelves.

The floor storage and the pallet rack areas were located near the receiving area for easy put-away, and ranked according to their viscosity, with the highest value of viscosity nearest to the receiving docks. In addition, the floor storage and the pallet racks are 3-tier high and single deep for easy retrieval of SKUs. For the lane width, it is equal to a length of two forklifts’ widths plus some safety space (8 feet) to enable two forklifts to travel together on the same aisle.

![Figure 1 Ground Floor Layout](image-url)
Fourth, bin-shelving area (ground floor). For the bin-shelving area, there are two main zones; one contains the broken-case SKUs and the other contains light bulk (full case) SKUs with the broken-case SKU region at the top of the bin-shelving area and full-case SKU at bottom. SKUs with class A or B will be placed in the ground floor to ensure minimum order combinations required between mezzanine and ground floor.

The SKUs were also ranked according to their viscosity, with the highest ranked located nearest to the shipping docks. The narrow aisles (4.5 feet) were used for single person width, because in this region, with batch picking being implemented, the pickers can cover most of the region in one run without the need for backtracking, and also to pick from both sides of the aisles.

Fifth, bin-shelving area (mezzanine). The bin-shelving area in the mezzanine is used to store slow moving SKUs, class C SKUs. All class C SKUs will be stored in the mezzanine and restored from the temporary staging area on the mezzanine. Similarly, the narrow aisles design for faster picking, broken and full-case storage, and ranking of SKU’s viscosity is also implemented in the mezzanine.

Sixth, special pallet rack. One area of the pallet racks termed as the special pallet rack was put nearest to the receiving docks and between the pallet racks and bin shelves. These special racks are single tier high, and they contain SKUs that are high in number of units shipped and relatively high in number of picks. These SKUs are not replenished to the bin-shelving but instead just directly sent to the shipping docks.

Seventh, heavy pallet rack. The heavy pallet is used to stored heavy class A and B SKUs that are original stored in the bin-shelve area. These SKUs are extracted out of bin-shelve and put them into pallets to assist pickers picking more efficiently as well as to distinguish the light-bulk SKUs and heavy-bulk SKUs.
Eight, sorting and packing area. After picking, the carts are brought to the sorting area, which is between the shipping and the fast-moving bin-shelving areas. The sortation is near the shipping area so that completed goods take a minimum time to be sent there. Over here, tables are placed for sorting manually. Once the orders are completed, the boxes are placed on the conveyors, which are very near to the tables, to be sent to the shipping area.

Ninth, shipping area. A circular conveyor was implemented due to the uncompleted orders from the mezzanine, which are bypassed by the human checkers at the five roller conveyors. The items of the uncompleted orders rotate to the sorting and packaging area of the ground floor, where the orders are completed. Then the orders are placed back onto the conveyor for new sortation. The conveyor speed should be about 1 mile/ hour, which enables the human sorters to have sufficient time to retrieve the completed orders without many errors. Because the volume of SKUs picked from the mezzanine is not too high per day, the likelihood of congestion at the start of the merging of conveyors is not too big, which can be further reduced by a human stationed there to ensure a smooth flow of traffic.

Roller conveyors were used for each lane because they are cheaper, and can also perform the tasks of bringing the completed orders to the staging area of the shipping area. The staging area was divided into five lanes of three waves. It is assumed that each slot consists of one route with many destinations. The first wave is for the destinations of the farthest distance from the warehouse.

Tenth, office and balcony on mezzanine. An office and balcony style edge is designed to be on the left side of the mezzanine. This location will provide the managers and supervisor the whole overview of the warehouse for the ground floor. This help assist the manager to have simple overview of its employee at all time.

**Warehouse Processes**

![Figure 3 Warehouse Process](image)

First, receiving. Every morning, vendors deliver the supplies and the SKUs will be put onto the staging area on pallets to be put-away.

Second, put-away. Using a basic Warehouse Management System (WMS), the SKUs will be forklifted to their corresponding zones according to their pre-determined viscosity (i.e. A, B or C). The SKUs that are stored in the floor storage will be put directly in the bin shelves area or in
the pallet racks. However, the SKUs that are too heavy for pickers to carry will be stored in pallet racks in heavy pallet storage zone. All C class SKUs will be put to the mezzanine directly by forklifts on a ramp (spiral corridor) connecting the receiving staging area to the mezzanine staging area. The WMS will automatically alert whenever the bin-shelving in the picking regions need to be replenished. Replenishment of products from the locations can be done throughout the day.

**Third**, replenishment. At the ground floor, the SKUs in the regular pallet storage zone will be used to replenish the bin shelves for both broken and full-case picking. Since the SKUs stored in the pallet will also be stored by ranking according to their viscosity, the time to replenish the SKUs of the same viscosity from the reserve storage to the bin shelves will be minimized. Replenishment of SKUs in heavy or special pallet storage is replenished directly by pallets. For the mezzanine, C class SKUs at the staging area will be used to replenish the bin shelves.

**Fourth**, Order-picking. Batch picking will be used to fulfill the orders in the warehouse, both at the ground floor and the mezzanine level. The pickers will push a cart around the bin-shelving in single direction, following a pick path optimized by the WMS system. Three separate types of batch picking techniques will be used to pick for each class SKUs; ground floor (Class A and Class B) and mezzanine (Class C). In this manner, the time to finish a batch picking process in the zones will be shorter as compared to without any zones. In the pick list, the SKUs are also categorized according to the lane in which they will end up at the shipping area, as well as the wave they belong to in that lane.

Typically, a batch-picking process in company X can fulfill up to fifty orders, as most of the orders (≈75%) received by them contains only one or two lines. Batch picking can fulfill up to a maximum of 128 orders and 51 orders per batch in broken and full-case picking respectively. After picking, the carts will be brought to the packing area to be sorted into the different orders at the ground floor.

In the mezzanine, the carts will be pushed to a similar initial sorting and packing area. After the initial sorting and packing process at the mezzanine, the boxes will be transported down to the ground floor using a spiral slide. A spiral slide is used because the total number of orders received in the mezzanine per day is only about 500. With batch picking, the number of times a picker visits the bin shelves area in the mezzanine will be approximate seventeen times a day with a maximum of 30 orders per batch. The average weight per order and average volume per order is approximate 9.17lbs and 1.16 ft³, respectively. This average weight and volume is not high enough to justify the use of a conveyor system to transport the SKUs downstairs. For SKUs in pallet storage and floor storage, forklifts will be used to transport them directly to the shipping area either in pallet picking or unit-load picking.

**Fifth**, Packing. In the packing areas in the ground floor or the mezzanine, a color sticker will be put outside to indicate which lane a completed order will go to later in the shipping area. Another sticker with a number will also be put onto the box to indicate which wave the box belongs to. Then they will be sealed up and sent to the shipping area. For incomplete orders in the mezzanine, the SKUs will be put into partitioned boxes and covered up without sealing to be ready for transporting downstairs. These SKUs will be only packed and sealed when they are combined with other SKUs at the packing area in the ground floor. The percentage of incomplete orders from the mezzanine is less than 10%.

**Sixth**, shipping. At the ground floor, a conveyor will be used to bring the boxes from the mezzanine to the packing and shipping areas from the spiral slide. There will be 5 roller conveyors extending out of a circular conveyor system linking to the 5 shipping docks. Two people will be stationed at each roller conveyor to roll the completed orders onto the roller conveyors. For
incomplete orders, they will continue to the other side of the circular conveyor and be brought onto the packing tables for combining with the other SKUs to complete the orders. This will be coordinated by comparing the same order sheet attached on each box. Upon completion, the completed orders will be put onto the conveyors again, where they will be sieved out by the people at each roller conveyor.

At the end of the roller conveyor, the completed orders will be brought down to be placed on pallets. These pallets will be brought to the staging area, where they will be placed according to their lane and wave. These pallets will be loaded into the trucks when the wave is complete. For floor storage and pallet racks where the SKUs are sent to the shipping area, they will be forklifted directly to the staging area to be shipped.

Warehouse Evaluation

From the proposed warehouse layout and process, several conclusions can be drawn regarding the efficiency and performance of the warehouse. First, bin shelves comparison in ground floor (class A and B) and mezzanine (class C), can be seen on Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Ground Floor: Class A</th>
<th>Ground Floor: Class B</th>
<th>Mezzanine: Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick/day</td>
<td>2416.012</td>
<td>1705.752</td>
<td>569.472</td>
</tr>
<tr>
<td>Travel Length (ft)</td>
<td>1596</td>
<td>1680</td>
<td>4900</td>
</tr>
<tr>
<td>Pick Density (pick/ft)</td>
<td>1.514</td>
<td>1.015</td>
<td>0.116</td>
</tr>
<tr>
<td>Weight/Day (lbs)</td>
<td>6489.759</td>
<td>8899.827</td>
<td>4332.825</td>
</tr>
<tr>
<td>Order/Day</td>
<td>1117.7</td>
<td>949.95</td>
<td>472.7</td>
</tr>
<tr>
<td>Weight/Order (lbs)</td>
<td>5.806</td>
<td>9.369</td>
<td>9.166</td>
</tr>
<tr>
<td>Volume/Order (ft³)</td>
<td>0.395</td>
<td>0.986</td>
<td>1.162</td>
</tr>
<tr>
<td>Cart Volume (ft³)</td>
<td>50.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Order/Batch</td>
<td>128</td>
<td>51</td>
<td>30</td>
</tr>
</tbody>
</table>

Second, number of orders completed in the mezzanine area and ground storage area. Based on the purposed layout, number of orders that can be completed separately on the mezzanine area and the ground storage area was calculated. Table 2 gives the percentage of orders that need to be combined.

<table>
<thead>
<tr>
<th>Order Needed to be combined</th>
<th>4,789</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Order in Warehouse</td>
<td>51,332</td>
</tr>
<tr>
<td>% Need to combine in total order</td>
<td>9.33%</td>
</tr>
</tbody>
</table>
Fourth, cost analysis. Several reasons in explaining the decision of using a gravity chute instead of conveyor to transport products from the mezzanine to the ground floor are (1) Gravity chute cost less compared to conveyors while performs similar function; and (2) Products obtained from the mezzanine are approximately 1,000 orders per day. Thus, the downward rate is not enough to justify the need for conveyor. Furthermore, the cost for gravity flow rack is higher than the cost for bin shelving and the total picks per day experienced by SPR is not big enough to justify the usage of gravity flow rack. Thus, bin shelving is used considering its cost effectiveness while performing similar function.

CONCLUSION

The main objective of the project is to implement a variety of tools necessary for the design of an effectiveness warehouse for company X. Because DC-11 has the highest pick density, data analysis is performed by using DC-11 as main reference. Once a particular DC is determined, the workload is divided into four phases: warehouse activity profiling, design of the warehouse areas, proposal of the warehouse layout, and discussion of the proposed warehouse layout. During these phases, intensive data analysis, design for each warehouse area, and combination of all results to build the complete warehouse layout for company X are conducted. Finally, evaluation for the operational issues of the proposed layout is calculated.

The proposed Greenfield design gives several advantages, which are (1) No fast-pick area, which means more cost effective; (2) The old method of put away by vendor categorization is not efficient and the storing of the SKUs by viscosity is adopted instead. This is because order-picking become more efficient and this process should be improved as it contributes the highest operational costs in a typical warehouse; (3) Batch order picking improves the utilization of labor hour; (4) High viscosity SKUs are placed in most convenient location of the warehouse, approximately over 50% of pick done in that location; and (5) Achieved economical design. Minimum usage of conveyors, no usage of gravity flow rack, and utilization of vertical space.

REFERENCES


