Improving Material Flow by Developing New Warehouse Layout

Senior Design Project Report

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Executive Summary

Duncan Ticking, a reseller of ticking supplies, has a distribution facility located in Fort Worth, Texas. In order to relieve congestion in the current warehouse due to growing demand in the past few years, Duncan Ticking is building a third warehouse adjacent to their two existing buildings. A Senior Design team from the School of Industrial Engineering and Management at Oklahoma State University team has analyzed the current warehouse operations and developed three alternate layout and material handling recommendations to efficiently utilize the new space and lower picking times. These three recommendations include alternate layouts, material handling devices, picking efficiencies, implementation costs, and operating costs.

The current warehouses are highly congested, with a mixture of floor staking and racks used to organize materials. Aisle space ranges from one to six feet, and material storage and retrieval operations are difficult in many areas of the warehouse due to this congestion. In order to store excess material, Duncan Ticking is currently renting 26 trailers to supplement warehouse storage. Rental costs of these trailers amount to over $56,000 annually. Of the 22,400 rolls at the facility in November 2019, more than 25% was stored in the trailers. An ABC analysis of the current material based on annual consumption revealed more than 1,200 rolls of inactive material currently being stored in the warehouse. Picking is handled by four long-term employees and five to fifteen temporary contract labor workers, varying from month to month based on demand. These workers currently perform all picking and retrieval by hand. In 2019, each roll of ticking material cost Duncan Ticking an average of $1.94 in labor costs. Duncan Ticking spent a little more than $170,000 on labor. Storage costs amount to just over $6 per roll annually. Total storage costs amounted to $156,000 in 2019, including the rental costs of the trailers.

The goal of the new warehouse is to lower the current facility congestion and increase operational efficiency at the Fort Worth distributor. Three recommendations have been developed, utilizing alternate layouts and material handling devices for varying levels of utilization, picking efficiency, implementation cost, and operating cost. All three recommendations have similar layouts with minor differences. Each has the required minimum aisle space and storage rack designs to accommodate the corresponding materials handling equipment. Recommendation one utilizes ergonomic carts and floor stacking on wooden pallets. Of the three recommendations, it has the lowest implementation cost, but also the lowest utilization level, highest picking times, and highest operating cost. Recommendation two utilizes three levels of cubbies to store material, and an order picker for material handling. Recommendation two has the second lowest implementation cost, highest space utilization, second lowest operating costs and picking efficiency. Recommendation three uses a forklift and racks to store material on three levels of shelves within the new facility. It has the highest implementation cost, second highest utilization level, and features the best picking efficiencies and lowest operating costs, among the three alternatives.

With the new warehouse replacing the trailer storage, annual storage costs will decrease to $125,000 annually, and operating costs will decrease as well, varying based on the chosen recommendation. Total costs, including depreciation, has been calculated for all three recommendations and compared to the current operation. Overall, implementation of the new warehouse and storage recommendations will save Duncan Ticking anywhere from $104,000 to $165,000 annually.

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1.0 Introduction

Duncan Ticking is a reseller of ticking material. The company purchases ticking materials, which comes in rolls, from international suppliers and resells them to domestic manufacturers. Duncan Ticking is building a new warehouse adjacent to the two existing ones, hoping to relieve some of the congestion and improve the storage and flow of goods. They are seeking assistance in designing a facility layout for the new warehouse and request recommendations for the proper shelving and supporting material handling devices (MHDs) to support that layout.

The goal of the project is to develop a layout for the new warehouse and determine appropriate shelving and supporting material handling processes as well as devices for efficient storage and retrieval of materials. The primary objectives are to minimize the travel of material and personnel within the warehouse and ensure that the incoming and outgoing orders are processed efficiently and effectively. Time permitting, an inventory analysis will also be conducted throughout the current warehouses along with a plan to implement new storage policies, disposal of unused equipment and materials that are more than three years old, along with a cost-benefit analysis of our recommendations.

The team will develop and present three alternate recommendations based on implementation cost, operating cost, picking efficiency, and warehouse utilization. The short-term and long-term costs as well as the benefits for each alternative will differ. Methods, processes, and space utilization for each alternative will also differ. The team has performed a detailed cost-benefit analysis of each of the alternatives and presented the results.

2.0 Project Methodology

The team has followed the steps outlined in the three phases below to successfully achieve the project objectives.

2.1 Phase 1: Initiation & Research

1. Visited Duncan Ticking warehouse and discussed observations made at the Duncan Ticking warehouse with team members and facility staff.
2. Collected data on current state (e.g., photos, drawings, blueprints, inventory management data).
3. Visited client offices and interacted with sales and inventory staff.
4. Researched shelving solutions.
5. Researched material handling strategies and equipment.
6. Researched layout options.

2.2 Phase 2: Development

1. Determined shelving and material handling devices in the low, mid-range, and high cost categories.
2. Developed warehouse recommendations for shelving and material handling devices.
    a. Recommendation 1: lower investment cost/higher operational cost.
    b. Recommendation 2: medium investment cost/medium operational cost.
    c. Recommendation 3: higher investment cost/lower operational cost.
3. Created space and safety requirements for each option.
4. Developed three corresponding warehouse layout recommendations through AutoCAD based on the corresponding shelving and material handling recommendations.
    a. Created layout for Recommendation 1.
    b. Created layout for Recommendation 2.
    c. Created layout for Recommendation 3.
5. Developed material handling processes and for each recommendation.

2.3 Phase 3: Analysis & Calculation

1. Calculated space utilization for each layout option.
2. Estimated picking efficiencies of material handling processes.
3. Conducted cost-benefit analysis of each alternative layout recommendation.
    a. Determined cost of holding inventory in the current warehouse to forecast changes in storage costs with each alternative
    b. Determined the implementation cost of each option.
    c. Determined time and cost benefits of MHD investment alternatives (e.g. forklifts, carts)

3.0 Current State Analysis

Currently, the demand forecast for imported products is based on sales history. However, as customer preferences of styles and patterns change, some products no longer sell at the anticipated volumes and Duncan Ticking is left with the excess inventory for these products, which are stored at a location in Fort Worth. This location has two warehouses, both of which are at capacity with high levels of inventory of ticking materials. Because the available space exceeds the volume of inventory carried by Duncan Ticking, the company stores additional inventory in 26 rented trailers located on the property as seen in Figure 1.

Figure 1: Rented Trailer Storage

While a majority of the ticking material are stored inside the warehouses on shelves (Figure 2), some are block stacked on the floor (Figure 3). The materials stored on some of the shelves protrude into the aisles, making the latter narrow and the materials difficult to access. Thus, it is difficult to store, retrieve or access some of the materials, leading to congestion in the warehouse aisles (Figure 4). Due to the afore-mentioned factors, more time is spent searching for products. Storing and retrieving materials in the warehouse in a safe and efficient manner is also hindered.

Figure 2: Shelf Storage

Figure 3: Block Stacking

Figure 4: Narrow Aisles

3.1 Labor and Material Handling Analysis

The labor pool at the Duncan Ticking warehouse currently consists of four long-term employees and five to fifteen temporary contract workers. Duncan Ticking currently utilizes their contract labor to transport materials manually in the warehouse. Figure 5 illustrates the contract labor expenses in 2019. These expenses change significantly each month based on the movement of incoming and outgoing materials.

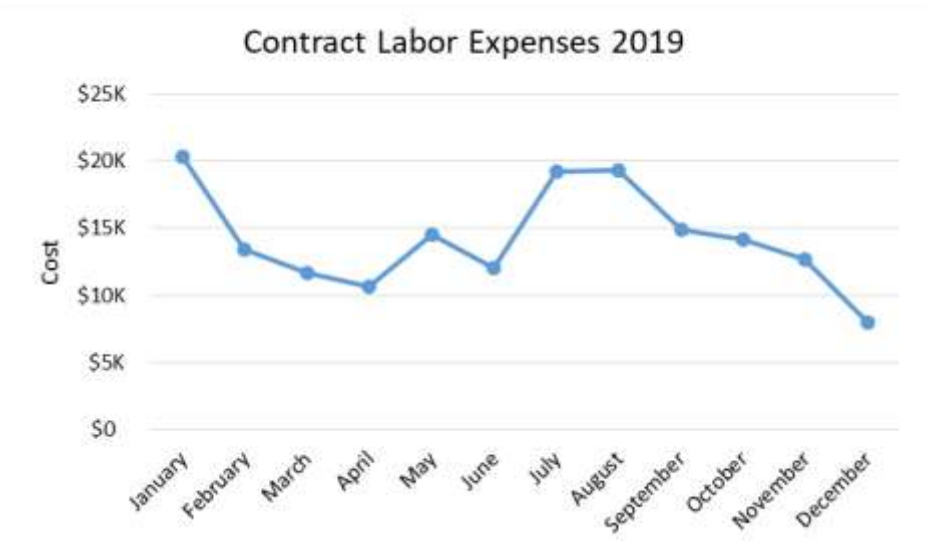

Figure 5: Contract Labor Expenses

Figure 6 shows the amount of material, in yards, that Duncan Ticking received versus the amount of material they sold to customers in 2019. The materials sold is relatively constant through the year. However, the amount of materials received varies based on the seasons and factors relative to the factory – high volume of production, quantity discounts, factory closures, etc. Because of the variability in receipt of raw materials, Duncan Ticking prefers to hold at least three months of inventory.

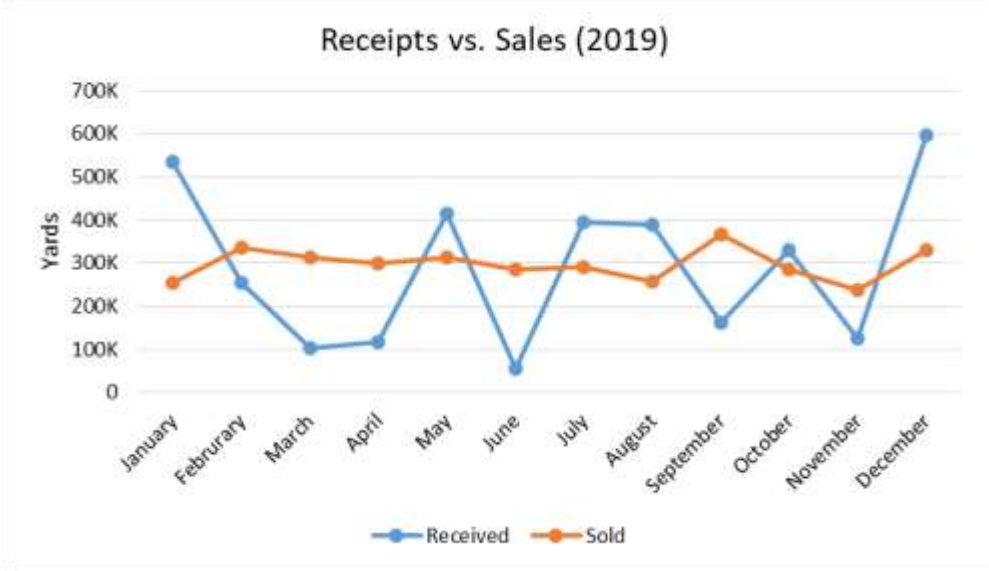

Figure 6: Receipts vs. Sales

From the analysis of monthly contract labor expenses compared to total receipts and sales per month, an average material handling cost has been calculated. Duncan Ticking has indicated that each roll contains an average of 80 yards of ticking material. Therefore, by converting the total yards of material handled to an average number of rolls and dividing by the average overall contract labor expenses in 2019, it is estimated that the cost of material handling is $1.94/roll handled. This material handling cost is considered when discussing recommendations for the new warehouse material handling processes.

3.2 Inventory and Storage Analysis

As of November 2019, Duncan Ticking held about 22,400 rolls of ticking that are stored in their two warehouses and rented storage trailers. The warehouses are separated into six sections. Figure 7 shows the number of ticking rolls within the stated locations as well as the storage trailers as of November 2019. During this time, Duncan Ticking stored 5,651 (25%) of the 22,400 total rolls in the storage trailers.

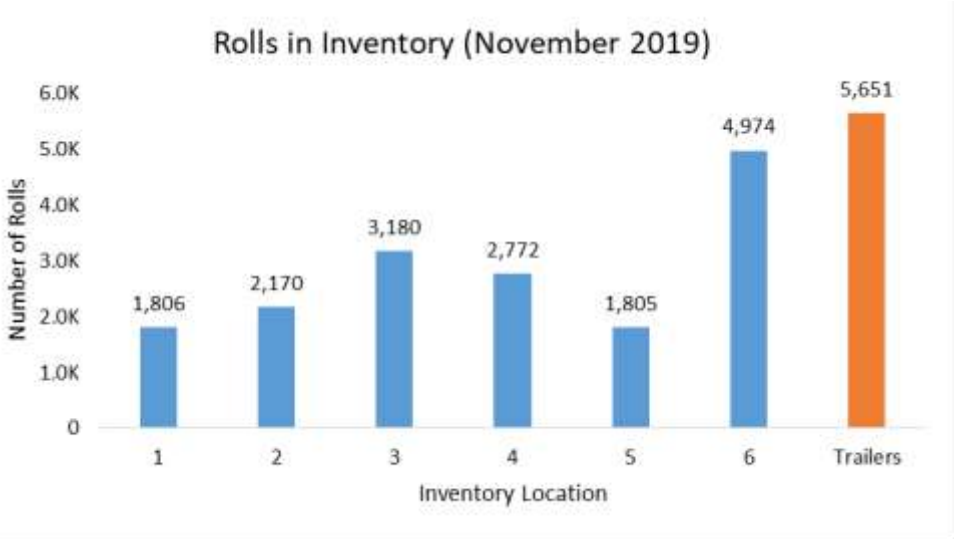

Figure 7: Rolls in Inventory by Location

Considering the fixed cost to run the warehouse in 2019 and the overall inventory stored on the property each month, an average storage cost was calculated. Fixed costs include expenses such as rent, maintenance, and utilities. They do not include variable expenses such as salaries for full-time employees and contract labor expenses. By taking all fixed costs per month and dividing by the average inventory held per month, it is estimated that the average cost to store one roll of ticking for a month is $0.51. This results in a cost of $6.08 to store one roll for an entire year. This is further analyzed in Benefits and Costs.

Figure 8 compares the usage and cost of inventory storage in the warehouse with inventory storage in the rented trailers. Like Figure 7, the roll count is taken from the inventory as of November 2019. The data displays that the amount of inventory in the warehouse is much higher than in the trailer, but the rental cost per month for the warehouse space is $1,000 more than for the trailers. This verifies that storing ticking in the rented trailers is not cost effective for Duncan Ticking.

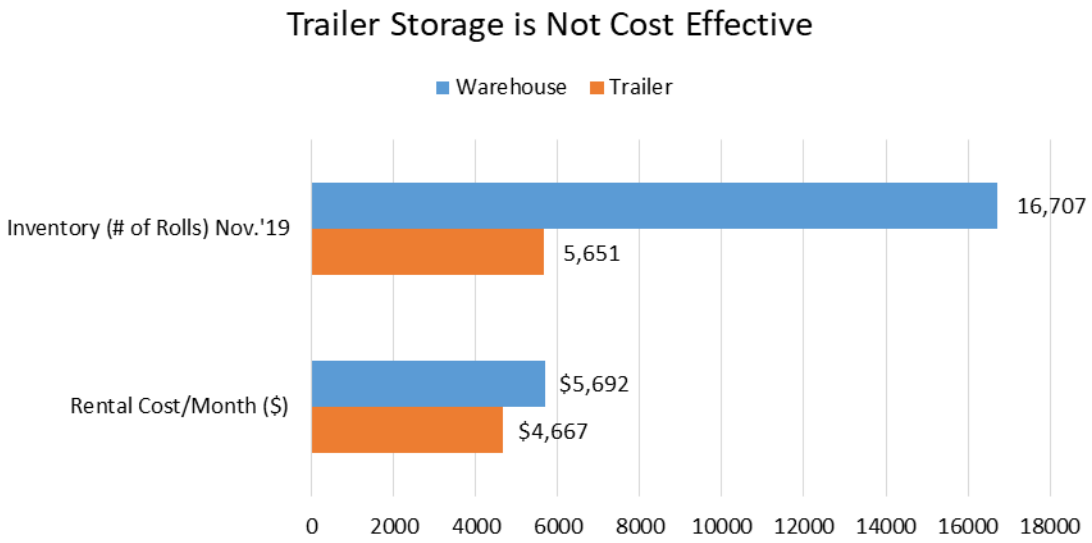

Figure 8: Warehouse vs. Trailer Storage and Costs

3.3 ABC Analysis: Inventory Categorization

In further analysis of the inventory kept in the warehouse, an ABC analysis was conducted to categorize products by annual consumption value. ABC analysis is an inventory categorization technique where inventory is assigned one of three "classes" – Class A, Class B, or Class C [i]. Class A includes the fastest moving items, while Class C includes the slowest moving items, and Class B includes the items in between. In this analysis, only products sold in 2019 by Duncan Ticking were considered, resulting in a total of 357 SKUs. Products were ranked in descending order by annual consumption and assigned a class based on cumulative percentage of consumption. The cumulative percent of ticking product by SKU and annual consumption is displayed in Figure 9.

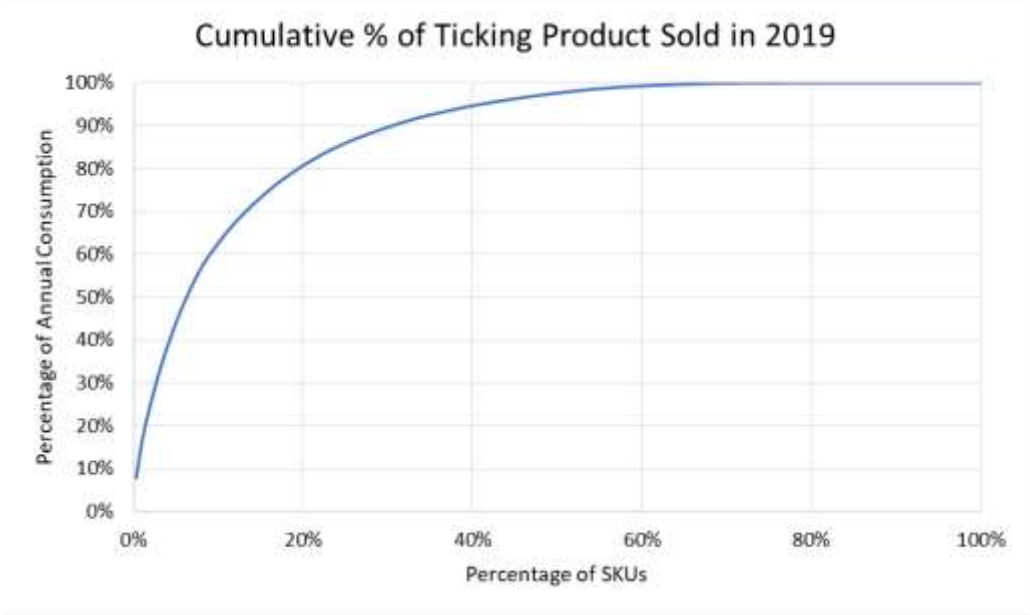

Figure 9: Ticking Product Sold in 2019

It is determined that the SKUs in the top 75% of annual consumption value of products are in Class A, the mid-20% of the annual consumption value are in Class B, and the remaining SKUs are in Class C. Table 1 shows the distribution of products by class, annual consumption and percent of SKUs, along with a total count of SKUs in each class.

Table 1: ABC Analysis – Class Distribution

	% Consumption	% SKUs	SKU Count
Class A	75%	16%	57
Class B	20%	25%	89
Class C	5%	59%	211

This ABC analysis was compared to given inventory data to determine how many rolls of each class were being held in inventory as of February 2020. The products that are held in inventory that have not been sold in the last year are assumed to be inactive. Figure 10 shows the number of ticking rolls available in inventory within each product class.

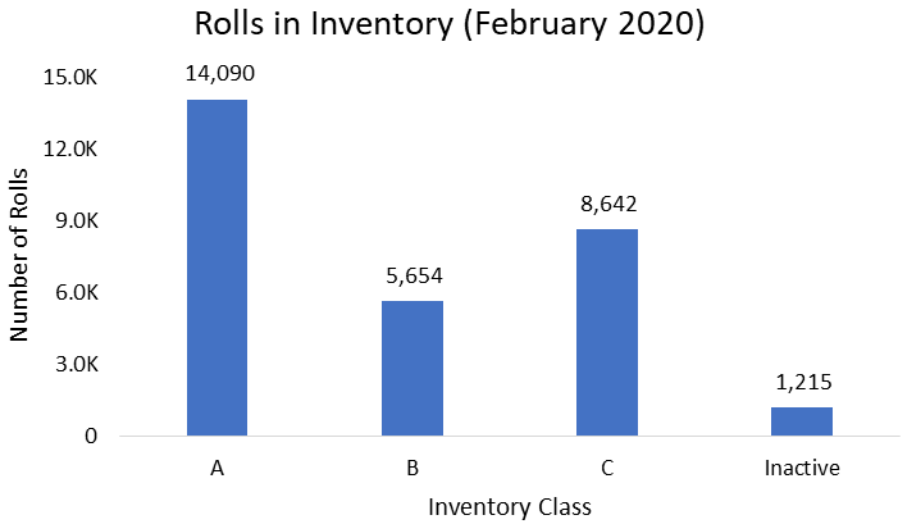

Figure 10: Rolls in Inventory by Class

4.0 Solution Alternatives

4.1 Material Handling and Shelving Alternatives

Duncan Ticking has requested three alternate material handling and shelving solutions as well as corresponding warehouse layouts. The team explored alternatives for these solution by considering various material handling devices (MHDs) that can be used to transport materials throughout the warehouse. Table 2 displays the MHDs in consideration and the parameters with which they were evaluated. Significant parameters include cost, efficiency, and feasibility with a weight of 3, maneuverability and vertical usability with a weight of 2, and desirability with a weight of 1. These weights were chosen based on the importance of the factors by the team on a scale of 1 to 3. The alternate MHDs were then scored on a scale from 1 to 5 by how well each MHD fit these parameters. The team made a subjective evaluation based on knowledge of material handling systems. From this analysis, it was concluded that the MHDs to be the basis of the recommendations are the Ergonomic Cart, the Standing Forklift, and the Order Picker.

Table 2: MHD Decision Matrix

Parameter	Weight	Manual Labor	Ergonomic Cart	Standard Forklift	Standing Forklift	Conveyors/ Rollers	Crane	Order Picker	Automated System
Cost	3	5	5	3	3	4	2	3	1
Desirability	1	1	1	4	4	1	2	5	5
Efficiency	3	1	2	3	3	2	3	4	5
Feasibility	3	5	5	3	4	2	1	4	1
Maneuverability	2	1	5	3	4	2	2	5	5
Vertical Usability	2	1	1	4	4	1	3	5	5
Weighted Scores		**38**	**49**	**45**	**50**	**31**	**30**	**58**	**46**

After decisions were made for the recommendation MHDs, shelving suitable for each type of MHD was considered. The shelving options for each material handling device were limited because of industry practices, usability, and availability of shelving materials and designs. Because the ergonomic cart has no vertical usability, stacked shelving is not a suitable option for this type of MHD. Due to possible dampness of the concrete floor in the warehouse, there must be insulation between the ticking fabric and the floor. Wooden pallets are therefore more suitable and cost-effective in individual storage locations for the placement of the product instead of a single layer of shelving.

Common shelving used in ticking warehousing when using forklifts are stackable pallet racks. These racks are commonly stacked directly on top of one another, resulting in a last-in-first-out (LIFO) storage method. Duncan Ticking currently has more than 500 active SKUs with many having a turnover rate of less than one month, so it is necessary to avoid stacking the racks directly on top of one another. These pallet racks will instead be placed in storage locations provided by stacked shelves for this MHD alternative.

Using an order picker is also a common practice in ticking warehousing while using carpet storage cubbies for shelving. When using an order picker, the operator travels vertically along with the product being moved. Using the cubbies results in ease of loading for the operator by sliding the ticking rolls into the storage location. Cubbies also help maximize the utilization of vertical storage space.

4.2 Layout Alternatives

When designing the respective layouts for each of the recommendations, aisle widths were determined based on the requirements of the corresponding material handling devices. For the recommendation including the ergonomic cart, the aisles were assumed to be 9 ft. in order for the 7.5 ft. rolls lying on the cart to be able to rotate within the aisles. The aisle width for the recommendations including the standing forklift and the order picker were set to 11.5 ft. following the MHD manufacturer recommendations. It has also been determined that the aisles will be perpendicular to one another, making the aisles and storage locations a grid. The usable height of the warehouse is limited to 25 ft. In order to effectively use the vertical space of the warehouse while also allowing appropriate vertical height for shelved storage location, shelving will be stacked three levels high at 7ft. tall when applicable. This results in the most cost effective storage while allowing sufficient storage space for individual SKUs.

4.2 Storage Alternatives

When material is received, it must be decided where each SKU will be stored. The new warehouse allows for a variety of storage options. Each SKU will only be stored in one of the three warehouses. Specific to the new warehouse, it is recommended that fast moving SKUs (high turnover rate) be placed on bottom tier shelves so that they are easily accessible. Medium turnover rate SKUs should be placed on the second tier shelves. Finally, any SKUs that do not move often should be stored on the top tier shelf of the new warehouse. Of course, the afore-mentioned solutions apply only to Recommendations 2 and 3, because Recommendation 1 (using utility carts) cannot be used to access shelves more than 6 feet.

4.3 Material Handling Processes and Alternatives

The material handling processes recommended help achieve maximum picking efficiency. Each process was chosen so as to minimize the distance material is moved and to move material infrequently. These processes are meant to be followed to maximize flow of materials from inventory to shipping, and receiving to inventory.

We recommend that the new warehouse be filled with mostly new products that are forecast to have higher turnover rates compared to older products that have relatively less turnover. The older products should be stored in the old warehouses that will have no access to the MHDs because the turnover rate is expected to be low. The decision of where to store each product should be determined before the usability of the new warehouse so that there is no confusion of product storage locations.

5.0 Recommendations

As stated in the Solution Alternatives, Duncan Ticking has requested three alternate recommendations for the new warehouse that is being constructed. These recommendations include material handling devices, appropriate shelving, implementation cost, corresponding warehouse layouts, and material handling processes and will differ from each another in implementation cost and potential benefits. Also included are recommendations to implement new storage policies and dispose of unused equipment and outdated materials.

5.1 Recommendation 1

Recommendation 1 utilizes ergonomic carts to assist manual labor (contract workers). Ergonomic carts prevent workers from completely leaning over to the ground to pick up heavy rolls. They are capable of moving 4 to 5 rolls per load. The material will be dead stacked on top of wooden pallets placed on the ground level of the warehouse. This is to protect the material from absorbing moisture in the concrete. The ergonomic cart and dead stacking pattern are pictured in Figure 11.

Figure 11: Ergonomic Cart Example [ii] and Dead Stack Pattern

Materials needed for purchase include two ergonomic carts which cost about $500 per cart and 308 wooden pallets which cost about $5 per pallet. The total implementation cost for this recommendation is estimated to be $2,540 as shown in Table 3. For this recommendation, the implementation cost is relatively low, but operational cost is relatively high because of the labor component. Picking efficiencies are also relatively low because of the time required for material handling.

Table 3: Recommendation 1 Implementation Cost

Material to Purchase	Quantity	Cost/Material	Total Material Cost
Ergonomic Cart	2	$500	$1,000
Standard Wooden Pallet	308	$5	$1,540
		Total Implementation Cost	**$2,540**

The developed layout for this recommendation includes perpendicular 9 ft. aisles and 77 storage locations on the ground level. Each storage location is 9 ft. wide and 7.5 ft. deep with four wooden pallets at the base. The layout for Recommendation 1 is pictured in Figure 12.

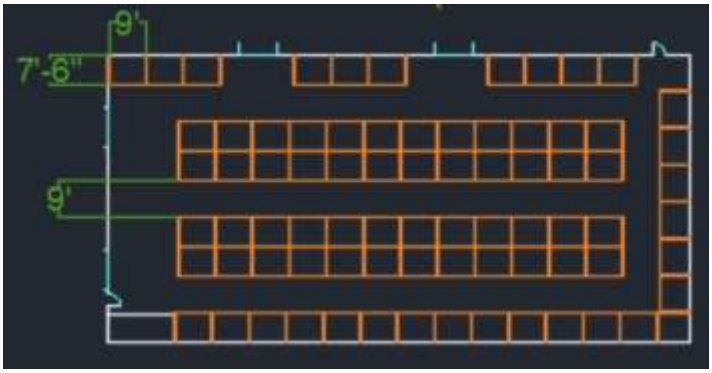

Figure 12: Recommendation 1 Layout

The material handling process of unloading and storing products for Recommendation 1 is as follows:

1. Truck arrives at Duncan Ticking.
2. Material is unloaded manually and placed in staging area.
3. Products are loaded on cart by SKU when ready for storage.
4. Material is transported to its desired location by cart.
5. Material is deposited in its storage location.
6. Cart is returned to staging area and the above process repeats for other receipts and withdrawals.

The material handling process of retrieving and loading product for Recommendation 1 is as follows:

1. Cart is taken to storage location of desired SKU.
2. Material is loaded onto cart.
3. Material is taken to staging area and staged.
4. Material is loaded into truck for shipment.

5.2 Recommendation 2

Recommendation 2 consists of using an order picker for material handling. An order picker allows operators to carry materials on the device from the staging area to the storage area as well as utilize vertical space by lifting the material above ground level. Like Recommendation 1, ground level storage will consist of dead stacking material on top of wooden pallets placed on the floor of the warehouse. Material will also be stored overhead in two levels of cubby-like shelving in order to maximize the amount of material able to be stored. As stated in the solution alternatives, the operator travels vertically along with the material and is able to transfer the ticking rolls into the storage location. The order picker is estimated to move 5 to 6 rolls per load. Figure 13 illustrates a common order picker device along with the cubby storage style.


Figure 13: Order Picker Example [iii] and Cubby Style Storage Example [iv]

Materials needed for purchase include an order picker which costs approximately $30,000, 134 shelves at $22 per shelf, 73 shelving racks, or uprights, at $170 per upright, and 268 wooden pallets at $5 per pallet. The installation of shelving is estimated to be equivalent to the cost of the shelving. Thus, the total implementation cost for this recommendation is estimated to be $62,056 as shown in Table 4. The implementation cost for this recommendation is significantly higher than that of Recommendation 1, but operational cost is estimated to be significantly lower because of the reduced labor and time required for material handling.

Table 4: Recommendation 2 Implementation Cost

Material to Purchase	Quantity	Cost/Material	Total Material Cost
Order Picker	1	$30,000	$30,000
Shelves	134	$22	$2,948
Shelving Racks/Uprights	73	$170	$12,410
Shelving Installation			$15,358
Standard Wooden Pallet	268	$5	$1,340
	Total Implementation Cost		**$62,056**

The developed layout for this recommendation includes perpendicular 11.5 ft. aisles and 67 storage locations for each level of storage available. Like Recommendation 1, each storage location is 9 ft. wide and 7.5 ft. deep. Ground level storage will include four wooden pallets placed in each storage location. The layout for Recommendation 2 is illustrated in Figure 14.

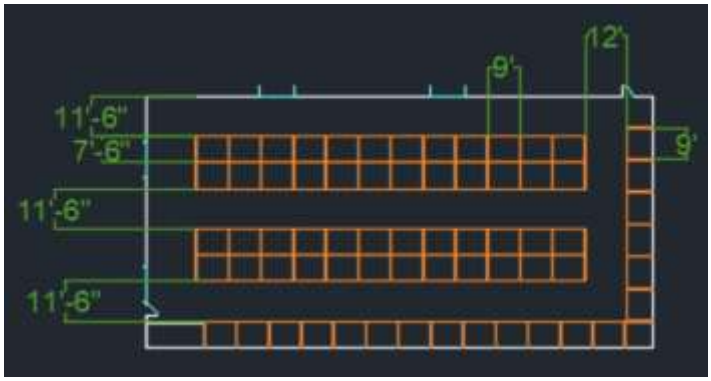

Figure 14: Recommendation 2 Layout

The material handling process of unloading and storing product for Recommendation 2 is as follows:

1. Truck arrives at Duncan Ticking to be unloaded.
2. Material is unloaded manually and placed in staging area.
3. Products are loaded onto order picker by SKU when prepared to store.
4. Material is transported by order picker to its desired storage location.
5. Material is deposited in its storage location.
6. Order picker is returned to staging area and the above process repeats for other receipts and withdrawals.

The material handling process of retrieving and loading product for Recommendation 2 is as follows:

1. Order picker is taken to storage location of desired SKU.
2. Material is loaded onto order picker.
3. Material is taken to staging area and staged.
4. Material is loaded into truck for shipment.

5.3 Recommendation 3

Recommendation 3 utilizes a standing forklift for material handling. The forklift will transport stackable pallet racks holding rolls of ticking to and from the product's shelving location and the staging area. This allows operators to store bins on three levels of shelves, which results in higher space utilization for the warehouse. As previously stated in the solution alternatives, the pallet racks will not be stacked directly on one another. The pallet racks will instead be placed on the ground level and on overhead shelves throughout the warehouse. Each shelving space will hold two stackable pallet racks, with each rack holding one SKU of ticking material. The pallet racks are estimated to hold 6 to 7 rolls each. Figure 15 illustrates a common standing forklift along with pallet racks for storage.

Figure 15: Standing Forklift Example [v] and Stackable Pallet Rack Storage Example [vi]

Materials needed for purchase include a standing forklift which costs around $40,000, 134 shelves at $22 per shelf, 73 shelving racks, or uprights, at $170 per upright, 402 pallet racks at $150 per rack, and 268 wooden pallets at $5 per pallet. Like Recommendation 2, installation of shelving is estimated to be equivalent to the cost of the shelving. Total implementation cost for this recommendation is estimated to be $131,016 and is shown in Table 5. The implementation cost for Recommendation 3 is the highest of the three recommendations, but the operational cost is estimated to be the lower than the previous two recommendations because of the limited manual labor and the time saved during material handling.

Table 5: Recommendation 3 Implementation Cost

Material to Purchase	Quantity	Cost/Material	Total Material Cost
Standing Forklift	1	$40,000	$40,000
Shelves	134	$22	$2,948
Shelving Racks/Uprights	73	$170	$12,410
Shelving Installation			$15,358
Pallet Racks	402	$150	$60,300
	Total Implementation Cost		**$131,016**

The developed layout for this recommendation is identical to Recommendation 2, including perpendicular 11.5 ft. aisles and 67 storage locations for each level of storage available. Each storage location is 9 ft. wide and 7.5 ft. deep. The layout for Recommendation 3 is pictured in Figure 16.

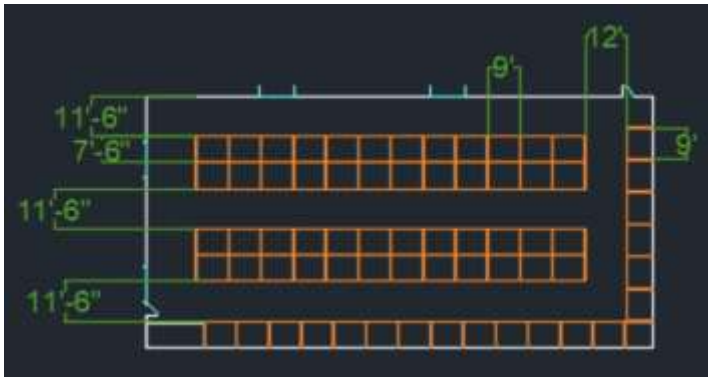

Figure 16: Recommendation 3 Layout

The material handling process of unloading and storing product for Recommendation 3 is as follows:

1. Truck arrives at Duncan Ticking to be unloaded.
2. Material is unloaded manually and placed in staging area.
3. Pallet racks are placed near staging area via forklift.
4. Products are loaded into pallet racks by SKU when prepared to store.
5. Pallet racks containing SKU are taken to desired storage location via forklift.
6. Pallet racks are placed into storage location via forklift.
7. Above process repeats for other receipts and withdrawals.

The material handling process of retrieving and loading product for Recommendation 2 is as follows:

1. Forklift is taken to desired material storage location of SKU.
2. Pallet rack is removed from storage location and move to staging area via forklift.
3. Material is unloaded from pallet rack and loaded into truck for shipment.
4. Pallet rack is returned to storage location for shipment.

5.4 Storage Policies and Disposal Plan

The implementation of new storage policies in the warehouses will result in storing material in a more effective way. This includes decreasing congestion in the warehouse and increasing picking efficiencies and flow of goods. As previously discussed, an ABC analysis has categorized products by annual consumption. Product class should determine storage placement throughout the warehouses in order to assure that the highest moving products are the most easily accessible throughout Duncan Ticking. Table 6 lists the new storage policies for each warehouse.

Table 6: Storage Policy Recommendations

New Warehouse Storage	Old Warehouse Storage
• Floor level of storage should be filled with the highest consumption value (Class A) products. • If racking is implemented, second and third level of storage racks should be filled with the next highest consumption value (Class B) products.	• Remaining Class A products should be placed in the most accessible areas of the old warehouses. • Remaining Class B products should be placed in the next most accessible areas of the old warehouses. • Class C products should be placed in the remaining and least accessible areas of the old warehouses.

In order to utilize all available space within the warehouse, disposal of unused equipment and inactive products in the warehouse is recommended. Disposing unused equipment and products will result in additional available space in the warehouses to hold more inventory of products with a higher annual consumption. Table 7 displays a step by step implementation of the recommended disposal plan. This disposal plan should be implemented annually or when there is limited available storage space in the warehouse.

Table 7: Product Disposal Plan

Duncan Ticking: Product Disposal Plan	
Step 1:	Ticking product should be disposed of if the product SKU meets the following criteria: • Product SKU is classified as product type “Zample”. • Product SKU is classified as product type “Close Out” or “End of Life” and has been determined inactive.
Step 2:	Ticking product that is classified as product type “Close Out” or “End of Life” but has been determined as an active SKU should be sold until the product is no longer available or determined inactive.
Step 3:	Ticking product that is classified as product type “Standard” or “Specific to Customer” but has been determined as an inactive SKU should be reevaluated.
Step 4:	A method of disposal should be determined for products. Methods of disposal include listing products on sale, donating products, or throwing products away.
Step 5:	Unused equipment in the warehouse, such as the mattress machine, should be restored and either used, sold, or donated.

6.0 Benefits and Costs

To evaluate the three recommendations presented, the team conducted a cost-benefit analysis. This analysis considers the benefits resulting from the space utilization levels and picking efficiencies of each material handling process and corresponding layout. It also considers the costs resulting from the implementation and depreciation of the equipment and installation for each recommendation.

6.1 Space Utilization Benefits

Space utilization is a measure of how much cubic warehouse space is occupied by material storage. Additional warehouse space is required for doors, shelving, aisle space, and staging areas. As shown in Table 8, the warehouse is 145 feet by 72 feet, with 25 feet of usable vertical space, allowing for a maximum storage capacity of 261,000 cubic feet. The standard roll size is 12 inches in diameter and 90 inches in length, or about 7.5 cubic feet per roll. Based on these calculations, the new warehouse has a maximum capacity of 34,800 rolls.

Table 8: Maximum Warehouse Storage Capacity

Usable Warehouse Space		145 x 72 x 25	261,000 ft^3
Space per Roll	7.5 ft^3	Max. # of Rolls	34,800

Table 9 displays the number of roll locations for each layout alternative, as well as the percent utilization of the layout alternative with respect to the maximum storage capacity displayed above. Industry standards [vii] indicate that maximum picking efficiencies occur at around 22-27% utilization. Although utilizing more than 27% is acceptable, it will generally indicate lower storage and retrieval efficiencies within the operation. Using less than 22% of the maximum capacity will just result in poor utilization with little change in picking efficiency.

Table 9: Warehouse Alternative Space Utilization

Storage Type	# Storage Locations (7.5 ft^3)	% Utilization
Cart & Dead Stack	5,544	**15.93%**
Order Picker & Cubbies	12,060	**34.66%**
Forklift & Pallet Racks	9,648	**27.72%**

The three recommendation alternatives range from 15.93% to 34.66% storage utilization. The low space utilization for Recommendation 1 is primarily due to the vertical space not being utilized. With no material handling device to allow the usage of shelving, dead stacking is only viable to a height of about eight feet. Recommendation 2 features the highest level of space utilization, due to the cubby system utilizing the maximum amount of vertical space possible. Recommendation three also utilizes vertical space, but the bins used for storage take up a large amount of space on the shelves and require more clearance to be stored and retrieved than directly hand loading and unloading.

In the current state, there are twenty-two rented trailers of 3,895.5 cubic feet each and four rented trailers of 3,528 cubic feet each being used for storage, totaling 99,813 cubic feet of storage space. As of November 2019, 5,651 rolls of ticking were stored in trailer storage, so it is estimated that each trailer has an average space utilization level of about 42%. Considering this estimation and the space utilization levels calculated for each recommendation, Recommendation 1 will hold fewer rolls than currently stored in the trailers, while Recommendation 2 and Recommendation 3 will hold significantly more.

6.2 Storage Cost Savings

As mentioned in the current state analysis, an average storage cost was calculated by dividing all monthly fixed costs for the warehouse by the average inventory held per month. This resulted in a storage cost of $0.51 to store one roll of ticking for a month or $6.08 for the entire year of 2019. Average storage costs for 2019 are shown in Table 10. A large contribution to this cost are the rental fees involved in storing rolls of ticking material trailers, but once the new warehouse is built and used for storage, there is an expected change in fixed overhead costs. This will result in a change in average storage cost.

Table 10: Fixed Costs and Storage Costs (2019)

Total Fixed Cost (2019):	$156,101.15
Fixed Cost/Month (2019):	$13,008.43
Cost to Store 1 Roll for 1 Month:	$0.51
Cost to Store 1 Roll for 1 Year	**$6.08**

Previous fixed costs have included expenses such as rent, maintenance, and utilities. In order to calculate an updated fixed cost after the implementation of the new warehouse, the trailer rental fees have been taken away from the previous fixed costs, and an annualized depreciation expense for the warehouse has been added. It is determined by the IRS that the depreciation period for commercial real estate is 39 years [viii], so the annualized depreciation expense will be considered for a 39 year period. Given a total construction cost of $775,000, the annual depreciation expense over 39 years is $19,872. Additionally, it is assumed that the average inventory per month will remain constant. It is also assumed that the change in utility costs for the warehouse will be negligible, so these cost changes are not being included in the calculations. With these considerations in place, it is estimated that the average cost to store one roll of ticking for a month will be $0.41. This results in a cost of $4.87 to store one roll for an entire year. Updated average storage costs are shown in Table 11.

Table 11: Updated Fixed Costs and Storage Costs

Updated Fixed Cost:	$125,078.68
Fixed Cost/Month:	$10,423.22
Cost to Store 1 Roll for 1 Month:	$0.41
Cost to Store 1 Roll for 1 Year:	**$4.87**

From the above analysis, it is reasonable to assume that the average storage cost per roll will be similar for all three recommendations. This cost can be slightly higher than estimated based on if the volume of material currently stored in the rented trailers is able to be stored in the new warehouse. For each recommendation, if the number of rolls of material that can be stored in the new warehouse is greater than or equal to the number of rolls stored in the trailers, then the storage cost remains at the estimated $5.60. This will be the case for Recommendation 2 and Recommendation 3. If fewer rolls are able to be stored, like in Recommendation 1, then the cost of storage may change to be slightly higher. This could be due continuing to keep the remaining product in storage trailers or storing the remaining product in a disorganized way. Storing a similar volume of material in the new warehouse as was previously stored in the rented storage trailers results in product being more visible, inventory being more organized, and a decrease in time looking for and retrieving material.

6.3 Annual Implementation and Depreciation Costs

As noted in the Recommendations, each material handling recommendation varies in the MHDs and shelving used and therefore, varies in overall implementation cost. Straight line depreciation has been calculated for the material needed in each recommendation in order to represent an annualized fixed cost for the implementation of each recommendation over the life of the new warehouse. This is shown in Table 12. The annualized cost also includes the installation cost of its respective recommendation over the life of the new warehouse. Salvage value and lifespan are estimated from sources provided. If a material has a longer lifespan than the expected lifespan of the new warehouse, the lifespan is 39 years.

Table 12: Annualized Implementation Cost

Rec.	Material Needed	Total Material Cost	Depreciation Period (Years)	Salvage Value	Material Expense/Year	Total Expense/Year
1	Ergonomic Carts	$1,000	10	$50	$90	**$398**
	Wooden Pallets [ix]	$1,540	5	-	$308	
2	Order Picker	$30,000	10	$7,500	$2,250	**$3,306**
	Shelves	$2,948	39	-	$76	
	Racks/Uprights [x]	$12,410	39	-	$318	
	Installation	$15,358	-	-	$394	
	Wooden Pallets	$1,340	5	-	$268	
3	Standing Forklift [xi]	$40,000	10	$10,000	$3,000	**$5,334**
	Shelves	$2,948	39	-	$76	
	Racks/Uprights	$12,410	39	-	$318	
	Installation	$15,358	-	-	$394	
	Pallet Racks	$60,300	39	-	$1,546	

Comparing the alternative recommendations, the annualized cost increases with the complexity of the recommendation. Recommendation 1 has the least and cheapest equipment needed, and therefore, has the lowest annualized cost per year. Recommendation 2 and Recommendation 3 include shelving and material handling devices, which increase the annualized cost.

6.4 Picking Efficiencies and Operating Cost Savings

Picking efficiencies for each material handling recommendation were estimated and compared by calculating the storage and retrieval times per roll. Storage and retrieval times were calculated based on multiple factors such as batch size, travel speed, load and unload time, and average distance traveled. Table 13 depicts the estimated picking efficiencies of each recommendation in comparison to the current state picking methods in the warehouses now and if these methods were to be used in the new warehouse.

Travel speeds are based on an average walk speed of 2.5 mph for moving material by hand, 3 mph moving material by cart (Recommendation 1), and 8 mph for moving material with a machine operated MHD (Recommendation 2 and Recommendation 3). Load time represents the time it takes to unload the ticking batch from the trucks and into their respective material handling devices and is a standard thirty seconds per roll, multiplied by the batch size for each item. Unload time represents the time is takes to unload and stack or store the batch and is twenty seconds per roll handled. The average distance traveled for the old warehouse operations is an estimated 240 feet per trip, while average distance traveled for the new warehouse is estimated to be 80 feet on average per trip for the methods with only one vertical level,

and 90 feet for the options with three vertical levels. The average travel times for each method are calculated and then doubled to account for both the storage and retrieval of each roll.

Table 13: Material Handling Picking Efficiencies

Storage Process	Batch Size	Travel Speed (ft./s)	Load Time (min)	Unload Time (min)	Avg. Distance Traveled (ft.)	Fatigue Factor	Storage and Retrieval Time/Roll (min)
Current State – Old Warehouse	1	3.67	0.5	0.33	240	0.50	**7.70**
Current State – New Warehouse	1	3.67	0.5	0.33	80	0.55	**4.35**
Rec 1 – Cart & Dead Stack	5	4.40	2.5	1.67	80	0.75	**2.38**
Rec 2 – Order Picker & Shelves	8	11.73	4.0	2.67	90	0.85	**2.00**
Rec 3 – Forklift & Pallet Racks	20	11.73	10.0	1.5	90	0.85	**1.37**

With the new warehouse being less congested, smaller, and easier to load and unload into, storage and retrieval times are estimated to be smaller than those for the current warehouse, even without utilizing the recommended material handling devices. Recommendation 1 and Recommendation 2 show significant improvement due to their utilization of MHDs to increase batch sizes, lower the number of trips needed per roll, and reduce the fatigue imposed on employees. With the use of the standing forklift and pallet racks, Recommendation 3 will operate at the highest rate of any recommendation. Resulting in an average storage and retrieval time of 1.37 minutes per roll, this process is more than 5.5 times efficient than the current warehouse operations.

Table 14 translates these storage and retrieval times into operating and labor costs to better reflect the cost savings of each recommendation. These figures represent operating costs if all material handled was processed through the new warehouse annually, based on the 7,045,404 yards of material processed in 2019. Due to this, the actual operating and labor costs per year will be slightly different than the calculations, as the old warehouse space will still be utilized for day-to-day operations.

Table 14: Operating Costs

Storage Process	Cost/Roll Processed	Operating Cost/Year
Current State – Old Warehouse	$1.92	**$169,441**
Current State – New Warehouse	$1.09	**$95,824**
Rec 1 – Cart & Dead Stack	$0.60	**$52,485**
Rec 2 – Order Picker & Shelves	$0.50	**$43,998**
Rec 3 – Forklift & Pallet Racks	$0.34	**$30,119**

The costs in Table 14 account for hourly employee wages for all operations and operating costs of the cherry picker and forklift in used recommendations two and three. The calculations for operating and labor costs accurately reflect the actual costs, as the current warehouse operations expense calculation of $169,441.49 is within 1% of the $170,884.51 total 2019 labor costs in the data provided to us by Duncan Ticking. All three recommendations show a significant decrease in operating costs compared to current operation methods, more than offsetting the implementation costs of each operation.

6.5 Cost Summary

From the previous analyses conducted for each recommendation and for current state alternatives, the variable costs (implementation and operating costs) and the fixed costs (construction and overhead costs) were studied and compared. A total annualized cost was calculated for each recommendation and alternative, as shown in Table 15.

Table 15: Annualized Cost Summary

	Construction Cost/Year	Implementation Cost/Year	Operating Cost/Year	Overhead Cost/Year	Total Cost/Year
Current State – Old Warehouse	-	-	$169,441	$156,101	**$325,543**
Current State – New Warehouse	$19,872	-	$95,824	$105,207	**$220,903**
Recommendation 1 – Cart & Dead Stack	$19,872	$398	$52,485	$105,207	**$177,961**
Recommendation 2 – Order Picker & Shelves	$19,872	$3,306	$43,998	$105,207	**$172,383**
Recommendation 3 – Forklift & Pallet Racks	$19,872	$5,334	$30,119	$105,207	**$160,531**

From these results, it is concluded that overall, building the new warehouse will save Duncan Ticking more than $104,000 a year without the implementation of any new material handling devices or processes. This is the result of conducting operations more efficiently, thus reducing labor, and decreasing the overhead cost by eliminating the monthly storage trailer fee. For the three material handling recommendations, it is observed that as the implementation cost increases, the operating cost decreases significantly. This leads to the conclusion that although Recommendation 1 seems to be the easiest to implement, it will result in lower efficiency and a higher labor requirement, and therefore will yield higher overhead costs per year. Recommendation 2, while having an implementation cost eight times higher than Recommendation 1, only saves about $8,000 per year in operating costs, resulting in a total cost per year of only $5,500 less than Recommendation 1. Recommendation 3, however, saves $11,852 more per year than Recommendation 2 and $17,430 more per year than Recommendation 1. In conclusion, implementing any of the material handling recommendation will decrease yearly overall costs for Duncan Ticking, but by implementation the material handling devices and processes involved in Recommendation 3, Duncan Ticking will save over $165,000.

Appendix A: Project Proposal

PROJECT PROPOSAL 1/30/2020

Improving Material Flow by Developing New Warehouse Layout

An Oklahoma State University
School of Industrial Engineering and Management
Senior Design Project
Spring 2020

Organizational Sponsor

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The OSU IEM team appreciates the opportunity to present a proposal to develop a layout and determine appropriate material handling equipment for Duncan Ticking in a new facility that is being constructed adjacent to existing warehouses. The primary goal is to design a layout, determine appropriate shelving to stock ticking inventory, and determine the material handling equipment that would be required to move the ticking materials into and out of the warehouse effectively and efficiently.

DUNCAN TICKING WAREHOUSE LAYOUT DESIGN

This proposal is organized in the following sections:

1. Background
2. Objectives and Scope
3. Anticipated Methodology
4. Anticipated Schedule
5. Anticipated Deliverables
6. Anticipated Benefits
7. Risks and Mitigation Strategy

1. Background

Duncan Ticking is a reseller of ticking material. The company purchases ticking materials, which comes in rolls, from international suppliers and resells them to domestic manufacturers. Demand forecast for imported products is based on sales history, but as customers change styles and patterns, some products no longer sell at the same volumes and Duncan Ticking is left with the excess inventory which is stored at a location in Fort Worth. This location has two warehouses, both of which are at capacity with high levels of inventory of ticking materials. In addition, Duncan Ticking stores additional inventory in eighteen trailers located on the property.

While a majority of the ticking materials are stored on shelves, some are block stacked on the floor. The materials stored on some of the shelves protrude into the aisles, making the latter narrow and the materials difficult to access. Thus, it is difficult to store, retrieve or access some of the materials, leading to congestion in the warehouse aisles. Due to the afore-mentioned factors, more time is spent searching for products. Storing and retrieving materials in the warehouse in a safe and efficient manner is also hindered.

To address the afore-mentioned problems, Duncan Ticking plans to build a new warehouse adjacent to the two existing ones, hoping to relieve some of the congestion and improve the storage and flow of goods. They are seeking assistance to design a facility layout for the new warehouse and request recommendations for the proper shelving and supporting material handling devices (MHDs).

2. Objectives and Scope

The goal of the project is to develop a layout for the new warehouse and determine appropriate shelving and supporting material handling processes as well as devices for efficient storage and retrieval of materials. The primary objectives are to minimize the travel of material and personnel within the warehouse and ensure that the incoming and outgoing orders are processed efficiently and effectively. Time permitting, an inventory analysis will also be conducted throughout the current warehouses along with a plan to implement new storage policies, disposal of unused equipment and materials for more than three years old, along with a cost-benefit analysis of our recommendations.

The team will develop and present three alternate recommendations based on implementation cost: low, mid-range, and high cost. In developing the recommendations,

different long-term values and benefits may be present. Each option consists of varying methods of material handling processes and space utilization of the warehouse. Thus, a detailed cost-benefit analysis of each of the alternatives will be developed and presented to the client.

The scope of our project is limited to developing three alternate layout recommendations for the new warehouse by providing corresponding shelving and MHD options for each. Per advice from the client, the project scope will not include inventory placement in the new warehouse.

3. Anticipated Methodology

We recommend the following steps for our project plan to successfully achieve our scope.

Phase 1: Initiation & Research

1. Visit Duncan Ticking warehouse and discuss observations made at the Duncan Ticking warehouse with facility staff
2. Collect data on current state (e.g. photos, drawings, blueprints, inventory management data)
3. Visit client offices and interact with sales and inventory staff
4. Research shelving solutions
5. Research material handling strategies and equipment
6. Research layout options

Phase 2: Development

1. Decide shelving and material handling devices in the low, mid-range, and high cost categories
2. Develop warehouse recommendations for shelving and material handling devices
    a. Create draft of low-cost option
    b. Create draft of mid-range cost option
    c. Create draft of high-cost option
3. Create space and safety requirements of each option
4. Develop three corresponding warehouse layout recommendations through AutoCAD based on previous shelving and material handling recommendations
    a. Create layout of low-cost option
    b. Create layout of mid-range option
    c. Create layout of high option

Phase 3: Analysis & Calculation

1. Calculate space utilization levels of each layout option
2. Calculate picking efficiencies of each layout option
3. Conduct cost-benefit analysis of each alternative layout recommendation
    a. Determine value of space in the warehouse
    b. Determine buy-now price of each operation
    c. Determine time and money saved by MHD investment (e.g. forklifts, carts)

DUNCAN TICKING WAREHOUSE LAYOUT DESIGN

d. Create a grand total cost-benefit for each of the three options for ease of comparison

4. Anticipated Schedule

The figure below shows an estimated timeline of the project.

Anticipated Schedule	Weekending Date											
	24-Jan	31-Jan	7-Feb	14-Feb	21-Feb	28-Feb	6-Mar	13-Mar	20-Mar	27-Mar	3-Apr	10-Apr
Phase 1: Initiation & Research												
Warehouse Visit												
Data Collection												
Office Visit												
Research												
Phase 2: Development												
Decide on Three Cost Options												
Shelving and MHD Cost Recommendations												
Space and Safety Requirements												
Layout Recommendations												
Phase 3: Analysis & Calculation												
Space Utilization												
Picking Efficiencies												
Cost Analysis of Implementation												
Benefit Analysis												

5. Anticipated Deliverables

Our anticipated deliverables are listed below in the order that they will be completed.

- Status reports - send bi-weekly reports to Duncan Ticking to update on project progress
- Shelving and MHD recommendations and corresponding AutoCAD layouts for warehouse
    - Recommendation 1 - low cost
    - Recommendation 2 - medium cost
    - Recommendation 3 - high cost
- Final Report- final layouts documented with Recommendations and benefit/cost analysis
- Presentation of Final Report

6. Anticipated Benefits

Based on our project scope and current methodology, these are the team's anticipated benefits that we plan on accomplishing by the completion of the project.

- Effectively utilize space within the warehouse to improve the storage and transportation of inventory.
- Reduce material storage and retrieval times
- Make warehouse operations safer
- Material Handling Device utilization

DUNCAN TICKING WAREHOUSE LAYOUT DESIGN

7. Risks and Mitigation Strategy

Below are the risks that we have acknowledged that might be encountered during our project.

Risks	Mitigation Strategy
If communication issues arise because of the distance between team and Duncan Ticking warehouse, then we could be without adequate data and knowledge needed for the project.	• Increase communication with Duncan Ticking team through bi-weekly updates. • Follow up after phone calls through email to assure information is communicated effectively.
If the team is only able to make one site visit to the Fort Worth warehouse, then the team may lack full understanding of the problem because of the frequent changes in the warehouse.	• Communicate with the warehouse manager to stay up to date on inventory fluctuations. • Utilize kickoff meeting in Fort Worth to meet with entire warehouse team and gather as much knowledge as possible on the issue at hand.
If the main point of contact, Linda and Peter Duncan, are unable to communicate with the team and/or Duncan Ticking offices because of traveling logistics, then the project and communications may be delayed.	• Establish set times for phone calls for meetings with Linda and Peter that are convenient for both parties (time zones). • Effectively communicate availability and plans ahead of time. • Plan for initial in-person meeting upon return.
If the scope is not fully understood by all points of contact, then scope creep could result in increased project load.	• Prioritize completing tasks in problem statement before "time permitting" tasks. • Communicate project scope to all parties involved.

DUNCAN TICKING WAREHOUSE LAYOUT DESIGN

Endorsements – Endorsement below acknowledges receipt and acceptance of the proposal of a Senior Design Team from Oklahoma State University's School of Industrial Engineering and Management. Project will be executed on a 'best effort' basis and no warranty is stated or implied. All modifications to this proposal shall be provided, in writing, to all signatories for approval and acceptance.

On Behalf of Duncan Ticking

Linda Duncan 02/01/2020

Linda Duncan

On Behalf of Senior Design Team

Derek Dixon

Macie Hull

Brett Mallon

Alex Cannon

2/10/2020

Date of Last Signature

Appendix B: Additional Figures and Tables

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crual Basis REVISED

Profit & Loss
January through December 2019 REVISED

	Jan - Dec 19	
Ordinary Income/Expense		
Cost of Goods Sold		
Warehouse Supplies- Incidentals		19,554.51
Total COGS		19,554.51
Gross Profit		-19,554.51
Expense		
Automobile Expense		
Gas & Oil 912 E. Vickery	20.00	
Total Automobile Expense		20.00
Contract Services		
Contract Labor		
Ft. Worth Contract Labor	170,749.51	
Total Contract Labor	170,749.51	
Total Contract Services		170,749.51
Dues and Subscriptions		295.00
Fort Worth Bills		
Trailer Fee	50,894.26	
Total Fort Worth Bills		50,894.26
Maintenance		
Lawn care	3,885.00	
Maintenance - Other	2,581.08	
Total Maintenance		6,466.08
Meals and Entertainment		13.47
Office Expenses		
Office Meals	52.90	
Office Supplies	636.90	
Postage	10.00	
Supplies for 915 E. Vickery	1,177.56	
Total Office Expenses		1,877.36
Payroll Expenses		
Payroll Taxes	13,978.53	
Salaries- Officers	0.00	
Salaries and Wages	187,061.54	
Total Payroll Expenses		201,040.07
Rent (warehouse)		68,300.00
Supplies		25.27
Taxes- Interest		0.12
Taxes-penalties		230.64
Travel Expense		326.42
Utility Bill for Fort Worth		
Electric Bill	3,062.96	
Gas and Water Bill	921.42	
Phone/DSI	3,604.59	
Trash Bill	1,187.87	
Total Utility Bill for Fort Worth		8,776.84
Total Expense		509,015.04
Net Ordinary Income		-528,569.55
Net Income		-528,569.55

Figure 17: Overhead Costs (2019)

AM
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rual Basis

Profit & Loss
January through December 2019

	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	TOTAL
rdinary Income/Expense													
Expense													
Contract Services													
Contract Labor													
Ft. Worth Contract Labor	20,313.80	13,428.62	11,675.49	10,641.38	14,526.68	12,047.15	19,229.05	19,306.58	14,917.28	14,138.48	12,653.38	8,006.62	170,884.
Total Contract Labor	20,313.80	13,428.62	11,675.49	10,641.38	14,526.68	12,047.15	19,229.05	19,306.58	14,917.28	14,138.48	12,653.38	8,006.62	170,884
Total Contract Services	20,313.80	13,428.62	11,675.49	10,641.38	14,526.68	12,047.15	19,229.05	19,306.58	14,917.28	14,138.48	12,653.38	8,006.62	170,88
Total Expense	20,313.80	13,428.62	11,675.49	10,641.38	14,526.68	12,047.15	19,229.05	19,306.58	14,917.28	14,138.48	12,653.38	8,006.62	170,88
let Ordinary Income	-20,313.80	-13,428.62	-11,675.49	-10,641.38	-14,526.68	-12,047.15	-19,229.05	-19,306.58	-14,917.28	-14,138.48	-12,653.38	-8,006.62	-170,88
Income	-20,313.80	-13,428.62	-11,675.49	-10,641.38	-14,526.68	-12,047.15	-19,229.05	-19,306.58	-14,917.28	-14,138.48	-12,653.38	-8,006.62	-170,88

Figure 18: Contract Labor Costs (2019)

Table 16: ABC Analysis – Annual Consumption

Product Name	Annual Consumption (Yards)	Cumulative % Consumption	Class
Waterfall White	282,085.23	7.89%	A
Gina Silver	133,858.00	11.64%	A
Navy Blue Suede	126,229.60	15.17%	A
MaryAnn Gold	97,408.08	17.90%	A
Sharon Grey	94,538.00	20.54%	A
Corsi Brown	80,594.50	22.80%	A
Jill Grey Metro	77,532.82	24.97%	A
Jute Border	76,897.40	27.12%	A
Mono Black	75,259.64	29.23%	A
Oxford Wide Navy Blue FR	69,281.90	31.17%	A
Cornell Grey	66,657.00	33.03%	A
Tencel Black	66,635.52	34.90%	A
Ellis Black	62,501.38	36.65%	A
Ebony Plaid	58,329.53	38.28%	A
Dorset Elite	56,664.41	39.87%	A
Ash Cooltex	55,838.40	41.43%	A
Denver White	53,571.00	42.93%	A
Waterfall Vanilla	53,560.00	44.43%	A
Tencel Grey	51,532.60	45.87%	A
Tarpaulin Green 39.5" FAB1169	47,696.27	47.20%	A
Tencel Brown	45,144.04	48.47%	A
Ashcroft	44,848.37	49.72%	A
Koala Bamboo Black	44,006.39	50.95%	A
Halie Black	42,429.20	52.14%	A
Stencil Grey	40,472.11	53.27%	A
Seattle Light Grey	40,023.30	54.39%	A
Slumber	37,846.91	55.45%	A
Timothy White	34,431.55	56.42%	A
Tessa Charcoal	33,478.77	57.35%	A
Jill Grey Nano	33,017.18	58.28%	A
Hush	32,072.10	59.17%	A
Oxford Wide Navy Blue	28,038.20	59.96%	A
Dallas White	27,184.00	60.72%	A
235 Stretch Knit	26,961.33	61.47%	A
Pollyana White	26,552.08	62.22%	A
Malcolm Black	26,070.10	62.95%	A
Oxford Wide Navy FR Lam HL	26,042.30	63.68%	A
Pillowtex Steel Grey	24,286.71	64.36%	A
Raw White Spacer Mesh	24,267.73	65.03%	A
Kale Charcoal	23,324.44	65.69%	A
Nova Blue	23,026.00	66.33%	A

Crayons Beige Narrow	22,490.36	66.96%	A
Oxford Paisley Backed	22,380.50	67.59%	A
FAB0482	21,725.00	68.20%	A
Doris White Print	20,437.00	68.77%	A
Royal Court Damask	20,000.00	69.33%	A
Alcott Dark Black	19,785.03	69.88%	A
Cambridge Navy Blue	19,447.64	70.43%	A
Aberdeen Black	19,233.13	70.96%	A
Dormlife New Gold	19,122.50	71.50%	A
Big Crest Brown	18,686.10	72.02%	A
Dallas Black	18,368.00	72.54%	A
Alcott Dark Navy	18,139.40	73.04%	A
Montgomery Stripe	17,313.80	73.53%	A
Tommy Silver	17,169.44	74.01%	A
Oxford Narrow Navy FR Lam HL	16,843.67	74.48%	A
Field Blown Ebony	16,487.00	74.94%	A
Fleur de Lis	16,227.06	75.40%	B
Emma Dot Cocoa	16,216.00	75.85%	B
Brussels Stitchbond FR	15,863.84	76.29%	B
Corsi Grey Nano	15,641.41	76.73%	B
Oxford Nylon NavyBlue FR Lam HL	15,300.50	77.16%	B
Steel Suede	14,883.14	77.58%	B
Beck Grey	14,660.53	77.99%	B
Ash Beacon	13,779.61	78.37%	B
Petite White	13,516.22	78.75%	B
Reserve	13,467.80	79.13%	B
Devon	13,294.51	79.50%	B
Crayons Beige Wide	13,268.48	79.87%	B
Circle Stitchbond Non-FR	13,126.20	80.24%	B
Lyla Grey	12,744.63	80.59%	B
Rocky Grey - FR	12,192.92	80.94%	B
Tiffany White	11,973.88	81.27%	B
Steel Beam	11,930.00	81.60%	B
Whitney Black	11,809.50	81.93%	B
Koala Bamboo Chocolate	11,696.87	82.26%	B
Alabaster Black	11,415.20	82.58%	B
Kale Grey	11,300.96	82.90%	B
FTV - 246	10,973.20	83.20%	B
Tim White	10,707.00	83.50%	B
LADAM Misty Grey	10,509.40	83.80%	B
Corsi Brown Nano	10,243.10	84.09%	B
Gunmetal Spacer	10,114.29	84.37%	B
Channe Dark Grey	9,386.75	84.63%	B
LADAM Diamond Queen	9,285.88	84.89%	B

Koala Bamboo Grey	9,220.47	85.15%	B
Blue Silver Stripe	8,932.98	85.40%	B
Kale Navy Blue 15 Pick	8,826.20	85.65%	B
Sheffield Black Plaid	8,766.20	85.89%	B
Aurora White	8,683.91	86.13%	B
Stellar Blue	8,641.95	86.38%	B
Whitney Blue	8,277.20	86.61%	B
Goodwill	8,081.00	86.83%	B
Richard Grey	8,058.19	87.06%	B
Beck White	7,715.00	87.28%	B
LADAM Diamond King	7,376.67	87.48%	B
Harry Gold 10	7,359.89	87.69%	B
WoodSmoke Suede	7,333.00	87.89%	B
Harley Grey	7,226.42	88.10%	B
Art White Border	7,151.20	88.30%	B
Corsi White Nano	6,897.12	88.49%	B
Carlisle Grey Check	6,885.27	88.68%	B
Nuelle Black	6,809.70	88.87%	B
Chadwick Organic Cotton	6,788.98	89.06%	B
Aloe Bright White	6,710.20	89.25%	B
Holder White	6,700.35	89.44%	B
Pillowtex White	6,576.60	89.62%	B
Circle Stitchbond FR	6,557.80	89.80%	B
Dinah Grey	6,551.20	89.99%	B
11990 White Nano	6,540.63	90.17%	B
Nora Grey	6,477.73	90.35%	B
Sheffield Blue Plaid	6,412.90	90.53%	B
MVSS 302 - Non/FR	6,233.76	90.71%	B
Laudon Light Grey	6,173.35	90.88%	B
Adler Grey	6,101.00	91.05%	B
Whitney Charcoal	5,913.60	91.22%	B
Stitchbond Light Grey	5,886.08	91.38%	B
MED Bright White	5,882.75	91.54%	B
Scalene Cool White	5,314.67	91.69%	B
Aloe Leaf Grey Stretch Knit	5,256.98	91.84%	B
Newcastle Beige	5,249.69	91.99%	B
Phelps Blk/Wt Spacer Mesh	5,114.93	92.13%	B
Hammond Grey	5,026.60	92.27%	B
Silk Silver Block	5,017.33	92.41%	B
Tara Blue	4,732.45	92.54%	B
Colorado Grey Warp	4,611.00	92.67%	B
Warrington Grey Squares	4,533.60	92.80%	B
W Black	4,505.00	92.93%	B
Rex	4,502.00	93.05%	B

Stitchbond Air Balloons	4,448.28	93.18%	B
American Flag	4,430.00	93.30%	B
Dallas Beige	4,394.00	93.42%	B
Stitchbond Air Balloons FR	4,360.00	93.55%	B
Cabot Brown	4,348.34	93.67%	B
Sheffield Charcoal Plaid	4,304.40	93.79%	B
Holder Shimmer Grey	4,275.64	93.91%	B
CoolSilk	4,142.80	94.02%	B
Alcott Dark Grey	4,134.70	94.14%	B
8HD409A	4,063.78	94.25%	B
Walcott Black	4,028.40	94.37%	B
Pillowtex Dark Grey	3,894.95	94.47%	B
Newcastle White	3,603.98	94.58%	B
Maddie Grey	3,547.35	94.67%	B
Webster Grey 200	3,543.60	94.77%	B
Edison Charcoal FR	3,466.80	94.87%	B
Ultracool Trilobal	3,459.59	94.97%	B
Slate Shadow	3,456.54	95.06%	C
Channe Dark Grey 500	3,454.61	95.16%	C
Mono Vanilla	3,442.00	95.26%	C
Tricia White	3,365.06	95.35%	C
Bamboo Brown	3,361.20	95.45%	C
Stitchbond Light Blue	3,301.88	95.54%	C
Lena Grey	3,289.24	95.63%	C
Jet Black Spacer	3,268.55	95.72%	C
Bethany Black	3,201.10	95.81%	C
Birmingham Light Grey	3,143.73	95.90%	C
Andrew	3,123.48	95.99%	C
Claire Diamond Black	3,118.39	96.07%	C
Mono Saddle	3,038.73	96.16%	C
LADAM New B	3,028.20	96.24%	C
Crayons White	2,930.00	96.33%	C
MX2013ZZ-2J-6B	2,927.80	96.41%	C
Stitchbond Beige FR	2,845.28	96.49%	C
MaryAnn Beige	2,829.74	96.57%	C
Whitney Laurel	2,821.59	96.64%	C
Barton White FR	2,819.38	96.72%	C
Liz Black	2,741.00	96.80%	C
Box Spring Cloth Vanilla Non-FR	2,732.10	96.88%	C
MaryAnn Navy Blue	2,721.10	96.95%	C
Bison Brown Suede	2,647.90	97.03%	C
Oxford Narrow Navy Blue	2,626.48	97.10%	C
2902-20 Silver Blue	2,615.78	97.17%	C
Koala Bamboo Navy	2,586.21	97.25%	C

LADAM Squares	2,501.51	97.32%	C
Sheffield Laurel Plaid	2,450.90	97.39%	C
MVSS 302 - FR	2,435.00	97.45%	C
Cooltex Hybrid	2,367.09	97.52%	C
Aurora Grey	2,338.81	97.58%	C
Ashley Butterfly	2,310.30	97.65%	C
Griffon Slate	2,308.10	97.71%	C
Saddle Suede	2,302.80	97.78%	C
LADAM Medallion	2,294.46	97.84%	C
Neil White FR	2,285.69	97.91%	C
ORGANIC COTTON	2,264.10	97.97%	C
Saturn Grey	2,216.27	98.03%	C
Renee White	2,199.43	98.09%	C
DT002	2,172.88	98.15%	C
Liz Steel	2,108.00	98.21%	C
Harris White - FR	2,039.06	98.27%	C
Savannah Black	1,968.15	98.33%	C
Channe Light Grey 300	1,954.44	98.38%	C
Trey Cooltex	1,878.29	98.43%	C
Savannah Grey	1,808.33	98.48%	C
Platinum Swirl	1,777.70	98.53%	C
Black Suede	1,734.10	98.58%	C
Momento New Gold	1,617.20	98.63%	C
London Grey	1,604.88	98.67%	C
Claire Diamond Gold	1,513.40	98.71%	C
Nadia Grey	1,494.10	98.76%	C
Angelina White	1,471.31	98.80%	C
Greyson Navy Blue	1,379.50	98.84%	C
Stratus Light Grey	1,369.78	98.87%	C
Beck Light Grey Trilobal	1,342.80	98.91%	C
Whisper Shield	1,289.00	98.95%	C
Wisteria Navy Blue	1,285.49	98.98%	C
Pillowtex Cream	1,276.51	99.02%	C
Cream Suede	1,191.80	99.05%	C
Ash Cooltex 220	1,191.05	99.09%	C
Devon Black	1,171.30	99.12%	C
Juliet Grey	1,133.40	99.15%	C
Bishop Classic	1,132.80	99.18%	C
Tencel Arbor White 240	1,055.70	99.21%	C
Mattress Tape 1.5" White Knit	1,050.00	99.24%	C
Big Crest Gold/ Natural	1,035.60	99.27%	C
Aurora Navy Blue	1,024.23	99.30%	C
Scott Grey Print	1,006.60	99.33%	C
Timothy Sonic Blue	991.80	99.35%	C

CoolSilk FR	971.80	99.38%	C
Flint Grey Spacer	896.74	99.41%	C
Ash Dot Charcoal	887.20	99.43%	C
Soft Green Vinyl w/ High Loft	861.03	99.46%	C
Desmond FR	839.31	99.48%	C
Webster Grey Print	790.80	99.50%	C
Samantha Grey	742.10	99.52%	C
Morgen Nickel	735.77	99.54%	C
Cambridge Beige	700.60	99.56%	C
Alabaster Charcoal	686.70	99.58%	C
Taylor Appleblossom	686.30	99.60%	C
Colorado Grey - FR	669.16	99.62%	C
Woodsmoke Suede Lam	660.80	99.64%	C
Channe Light Grey	625.11	99.66%	C
3D ROSES CREAM	620.21	99.67%	C
Claire Heather Grey	612.82	99.69%	C
Tarpaulin Green Wide	546.64	99.71%	C
Claire Diamond Green	545.17	99.72%	C
Greyson Pewter	533.70	99.74%	C
Duncan Grey Dot	493.50	99.75%	C
Wisteria Appleblossom	490.70	99.76%	C
Pillowtex Black	490.69	99.78%	C
Champagne 90"	416.63	99.79%	C
Pillowtex Bison Brown	411.00	99.80%	C
Greyson Bison Brown	404.90	99.81%	C
Dinah White	404.28	99.82%	C
Isabelle Pewter	404.00	99.83%	C
Dream Supreme	402.40	99.85%	C
Ellis White	367.20	99.86%	C
White Bed Bug Cover	365.00	99.87%	C
Pewter Suede	334.80	99.88%	C
Montgomery/Plain Weave	331.30	99.88%	C
Regina White	323.98	99.89%	C
Barkley	299.60	99.90%	C
Pillowtex Electric Blue	267.90	99.91%	C
Elle	221.80	99.92%	C
Harry Gold	219.80	99.92%	C
Bison Brown Suede Lam High Loft	215.80	99.93%	C
Fossil Grey Wave	215.80	99.93%	C
Cerise Ash Leaf	201.00	99.94%	C
Beck Navy Blue	195.13	99.95%	C
LADAM Outback Ebony	162.50	99.95%	C
Pillowtex Electric Pink	162.01	99.95%	C
White Dove Suede	158.57	99.96%	C

Memphis Organic Cotton	153.35	99.96%	C
White Hollow	132.37	99.97%	C
Ice Blue Suede	117.00	99.97%	C
11990 White Laminated	109.40	99.97%	C
Cooltex Copper	95.29	99.98%	C
Petite Grey	93.00	99.98%	C
Pillowtex Blue	57.00	99.98%	C
John Black Stripe	52.00	99.98%	C
Lucas Black	50.80	99.98%	C
Crofton Hampton	50.00	99.98%	C
Circle Grey	46.00	99.99%	C
ACA Blue Tick	30.00	99.99%	C
Hazel Grey	28.00	99.99%	C
Dahlia Blue	24.00	99.99%	C
Glen Black/Chocolate Brown Weav	20.00	99.99%	C
Adhesive Spray	20.00	99.99%	C
Boston White	18.00	99.99%	C
Reed Black	17.00	99.99%	C
Deanna Grey	17.00	99.99%	C
Nuelle Blue	16.00	99.99%	C
Jackson Navy - 10 pick	15.31	99.99%	C
Alabaster White	15.00	99.99%	C
H06	14.00	99.99%	C
Renee Grey	12.00	99.99%	C
Silver Blue Suede	11.00	99.99%	C
Dorset Shimmer Grey A	11.00	99.99%	C
Heather DIamond Grey	11.00	99.99%	C
Isabella Heather Grey	11.00	99.99%	C
Ashley Butterfly Brown	10.00	99.99%	C
Seattle Navy	10.00	99.99%	C
Black Jack	10.00	99.99%	C
Mark Plaid	10.00	99.99%	C
Checkers	9.00	99.99%	C
Dallas Cocoa	9.00	100.00%	C
Landry Grey	9.00	100.00%	C
Landry White	9.00	100.00%	C
Edging Thread Tape FR	8.00	100.00%	C
Gail	8.00	100.00%	C
Janela Pewter	7.00	100.00%	C
Rex Small Diamond	7.00	100.00%	C
Jackson Navy	7.00	100.00%	C
Burberry Plaid FR	6.00	100.00%	C
MaryAnn Sonic Blue	5.00	100.00%	C
BM1578A	5.00	100.00%	C

Shadow Grey	5.00	100.00%	C
Ace Diamonds	4.00	100.00%	C
Dark Grey Swirl	4.00	100.00%	C
Florence Light Grey	4.00	100.00%	C
Kelly White	4.00	100.00%	C
Charcoal Ribbon	4.00	100.00%	C
Monarch Grey	3.00	100.00%	C
Clarke Grey Plaid	3.00	100.00%	C
Aberdeen Tan	3.00	100.00%	C
Nadia White	3.00	100.00%	C
Cream Wave	3.00	100.00%	C
Brad Diamond Black 2013ZZ-9C-54	3.00	100.00%	C
Dorset Shimmer Grey	3.00	100.00%	C
Tommy White	3.00	100.00%	C
December Grey	2.00	100.00%	C
Mono Burgundy	2.00	100.00%	C
Valerie Viscose	2.00	100.00%	C
Paisley Print Black	2.00	100.00%	C
Corsi Green	2.00	100.00%	C
Stencil Navy Blue	2.00	100.00%	C
Dallas Brown	2.00	100.00%	C
Kris Platinum	2.00	100.00%	C
LADAM Brooke Charcoal	2.00	100.00%	C
Sandcastle Suede	2.00	100.00%	C
White Wave	2.00	100.00%	C
Lucas White	2.00	100.00%	C
Lyla Gold	2.00	100.00%	C
Element	2.00	100.00%	C
Beck White Trilobal	1.00	100.00%	C
Black Beauty	1.00	100.00%	C
Edison Charcoal	1.00	100.00%	C
Vida Purple	1.00	100.00%	C
ACA Blue Ticking FR	1.00	100.00%	C
Corsi Tan	1.00	100.00%	C
Crofton White	1.00	100.00%	C
Eden Grey	1.00	100.00%	C
Eden Navy Blue	1.00	100.00%	C
Green Leaf Suede	1.00	100.00%	C
Green Leaf Suede Laminated	1.00	100.00%	C
October Celeste	1.00	100.00%	C
Waves	1.00	100.00%	C
Waves Grey/Black PP	1.00	100.00%	C
Wilcox Small Diamond	1.00	100.00%	C
Copeland Navy	1.00	100.00%	C

Tommy Cool White	1.00	100.00%	C
Koala Bamboo Green W	1.00	100.00%	C
Kris Chocolate	1.00	100.00%	C
Silver Grey Wave	1.00	100.00%	C
Smoke Grey	1.00	100.00%	C
Soft Grey Vinyl w/ High Loft	1.00	100.00%	C
Seattle Charcoal	1.00	100.00%	C
Spring Leaf Green	1.00	100.00%	C

Appendix C: References

[i] ABC Analysis, Internet Source, https://www.invoiceberry.com/accounting-terms/abc-analysis, April 14, 2020.

[ii] Ergonomic Cart Example, Internet Source, https://www.globalindustrial.com/p/material-handling/trucks-carts/bar-pipe-lumber/ergo-bar-cradle-truck-24-x-36?infoParam.campaignId=T9F&gclid=CjwKCAiAgqDxBRBTEiwA59eEN376uaclTSFw8yJUhILvrcBFs-0y5AavAdIYgNH0k4AvVX7iwpLOmhoCIHkQAvD_BwE, March 31, 2020, Downloaded.

[iii] Order Picker Example, Internet Source, https://www.raymondcorp.com/news/2018/raymond-announces-5300-orderpicker, March 31, 2020, Downloaded.

[iv] Cubby Style Storage Example, Internet Source, https://www.stow-group.com/en/solutions/carpet-vinyl-rolls, March 31, 2020, Downloaded.

[v] Standing Forklift Example, Internet Source, http://forkliftlicenseguide.com/blog/179-stand-up-forklift , March 31, 2020, Downloaded.

[vi] Stackable Pallet Rack Storage Example, Internet Source, https://rackandshelf.com/product/storage-products/warehouse-racks/carpet-pad-racks/, March 31, 2020, Downloaded.

[vii] Industry Standard, Internet Source, https://www.camcode.com/asset-tags/how-to-calculate-warehouse-space-utilization/, March 31, 2020.

[viii] Commercial Real Estate Depreciation Period, Internet Source, https://www.fool.com/millionacres/taxes/depreciation/commercial-property-depreciation-what-real-estate-investors-need-know/, April 7, 2020.

[ix] Wood Pallet Usable Life Estimation, Internet Source, https://blogs.3ds.com/delmia/a-compelling-case-for-plastic-shipping-pallets-2/, April 14, 2020.

[x] Storage Racks and Pallet Racks Usable life Estimation, Internet Source, https://nextlevelstorage.com/2016/12/how-long-will-pallet-rack-last/ , April 14, 2020.

[xi] Used Forklift Price Estimation for Salvage Value and Useful Life, Internet Source, https://www.tmhnc.com/blog/how-long-will-a-forklift-last-and-forklift-average-use , April 14, 2020.