Georgia Institute of Technology

New Warehouse Design Proposal for a Home Improvement Retailer's DC

Supply Chain Engineering Capstone

ISyE 6341-42

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Finally, we would like to acknowledge John VandeVate, our academic advisor who provided us valuable guidance and assessment for us to have a successful, and educative Capstone experience.

Executive Summary

This is a facility planning and layout-oriented project. We worked with a home improvement retailer in Panama that operates 45 stores which are supplied by a single DC located in Tocumen. The DC currently has 3 warehouses, and they are planning to expand it by adding a fourth warehouse to receive, store and dispatch products from local suppliers that are currently received directly at stores and others that are received in warehouse 1.

This solution intends to increase visibility, security, and control over their replenishment strategies. The solution will also reduce the waiting and processing time at stores, since now the shipments sent would be more consolidated.

This project aims to design the layout for the new warehouse, propose and design a fast-pick area, allocate the areas within the warehouse, and propose technologies, strategies, and labor requirements for the operation.

To achieve this, we first determined that the main areas needed in the facility were a staging area, a home appliance floor storage area, a fast-picking area, and overstock. Next, a warehouse profiling analysis was performed to understand the characteristics and performance of the products and suppliers that will be received, stored, and dispatched from the new warehouse.

Then, we estimated the square meters needed for the staging areas using a probabilistic throughput simulation for the next three years. For the home appliances area, the square meters needed were estimated based on how many stacks can each product family support, and average volume expected to be stored at the facility, which we estimated to be 3 months' worth of inventory.

A fast-pick area supported by a picking module was designed to allocate fast-movers, small and medium size products to be picked in pallets and/or cartons with technologies such as carton gravity flow racks, pallet gravity flow racks and conveyors.

The remaining space was dedicated for overstock, which will consist of conventional pallet racks. For the home appliances area, we proposed 1000 square meters, for the picking module a total of 3 levels with conveyors which will have a total capacity of 858 pallet positions and 6600 cartons, and for the overstock area a total capacity of 2592 pallet positions.

Finally, with the assistance of our calculations and analyses, we draw a 3D layout to represent our proposal for the new warehouse and calculated the labor and equipment requirements needed such as forklifts, to successfully run the expanded operations.

Sponsor Overview

The sponsor is one of the biggest and most successful retail companies in Panama. They own two store brands, The first one is focused on construction and hardware, and the second one is focused on home improvement, furniture, appliances, and other product categories.

They operate 45 stores located throughout the country and sell through a website and app, so they are focused on traditional store retail, but their future strategy is towards omnichannel retail.

They receive thousands of SKUs from international and local suppliers in their distribution center that is in the eastern part of Panama City. Both store brands are served by the same DC.

Processes Overview

Distribution Center

The DC is made up of three warehouses (Galeras). Galera 1 receives medium size items from local and international suppliers. This warehouse is also used as a cross dock where items from local suppliers are received, verified, and later arranged on the floor near the docks instead of storing them on racks, so they can be picked quickly and consolidated on pallets the next day and sent to the stores.

FIGURE 1 GALERA 1 INBOUND STAGING AREA

Galera 2 is used to receive and store construction materials which are mostly bulky and large. Some examples include wood, sand, and cement. Most of the output from this warehouse is transported in pallets to stores.

Galera 3 has an AS/RS which is used to store small size items in totes. Goods that are not suitable to be stored in the AS/RS are stored in conventional pallet racks. The working flow in this warehouse starts in a fast-picking area that is made up of one level of carton flow racks and replenished from the conventional racks. Pickers place items in red totes that are later carried by conveyors to an area where other workers pick items from the totes that are stored in the AS/RS and transfer them into the red totes. The red totes are later carried to the outbound docks by conveyors to be sealed and loaded in trucks and taken to stores. This warehouse is also used to stack large home appliances on the floor.

All warehouses work with picking waves, so for a period of one hour and a half all workers focus on picking, and consolidating goods for a specific set of stores. Besides all the goods that are received, stored, and dispatched from the DC there are more than 200 suppliers that ship items directly from their facilities to the sponsor's stores.

Stores

We visited two stores to understand the receiving process of goods that come from the DC and from those suppliers that dispatch their goods directly from their facilities. We went to Store 03 which is one of the sponsor's bigger stores and to Store 06 which is one of the smaller ones. Both are in Panama City. The stores receive flatbed trucks loaded with pallets and box trucks loaded with red totes from the DC. Store 03 receives roughly 5-6 daily trucks from the DC while Store 06 receives 3-4 trucks. Products received in the red totes go through the most agile receiving process, since they are only scanned at the receiving ramp and taken directly to the sales floor, while products that are received in pallets are verified at the ramp before being taken to the floor.

Products that are received directly from suppliers' facilities go through a similar process that they go through at the DC, but at a smaller scale. Store personnel verify that the quantity delivered is the same as the quantity billed, and then the products are staged before being taken to the sales floor. Instead of delivering pallets, suppliers usually deliver cartons at the stores. On average 10-15 suppliers deliver to each store per day and due to space constraints workers can only serve one supplier at a time.

FIGURE 2 RECEIVING RAMP STORE 03

Opportunity Statement

Receiving goods from many suppliers directly at stores has led to an increase in waiting times and working hours at the receiving ramps which are costs to both suppliers and the sponsor. The verifying process for each of the suppliers can take up to one hour, and as was mentioned before, only one can be served at a time. By centralizing the receipt of those goods at the DC and sending more consolidated shipments to stores, the sponsor would have more security, visibility, and control over their replenishment strategies, alleviate waiting and processing times at stores and avoid stockouts. To support the scaled-up operations, they have decided to expand their DC and build a fourth warehouse.

This fourth warehouse will receive, store and dispatch goods from local suppliers that deliver directly to stores, and local suppliers that are cross docked at Galera 1, plus it will also have space dedicated to stack the large home appliances that are currently stacked at Galera 3. The shape of the building and placement of dock doors is already defined by the sponsor and is out of scope.

Goals, Deliverables and Metrics

Our objective is to propose a design for the new warehouse. The design must include space for cross docking or fast-picking goods, space to stack large home appliances and an overstock area with conventional pallet racks. We will decide how to allocate these areas prioritizing the cross dock/fast-picking area to maximize productivity. We will also propose technologies, strategies, and labor requirements to support the expanded operations. The design should be able to robustly support the expected throughput.

A significant number of SKUs that will be received in the new warehouse include high rotation items that are currently cross docked at Galera 1 or delivered directly from supplier's facilities to stores. For this reason, it is critical for the facility to have an area dedicated to efficiently storing, handling, and picking these items. While we will also recommend the spaces within the warehouse that are needed for large home appliances and overstock, our focus will be in the design of a crossdocking or fast-picking area dedicated to those high rotation items. Given the increase in suppliers that will be received at the DC it is also vital to have enough space to stage and verify pallets and boxes from suppliers before taking them to their preparation station or overstock area.

Metrics we propose the sponsor should measure to compare current operations with the solution that is being proposed are:

- Stockout levels of the goods from suppliers included in the study, before and after the centralization of deliveries.
- Processing times at the receiving ramps at stores with the more consolidated shipments.
- Productivity in the form of pick-lines per working hours at the cross dock/fast-picking area.
- Supplier fill rate, to examine if by centralizing deliveries the suppliers can fulfill better the orders placed by the sponsor.

Other intangible benefits of the solution will include better utilization of space dedicated to customers at stores. By increasing waiting times at the receiving ramps some suppliers had to wait to be served in customer parking spaces. Another benefit will be better utilization of working hours at stores. Instead of spending time verifying orders one by one from suppliers, store workers will be able to spend their time efficiently replenishing the facings at the sales floor and attending customers.

Methodology

Layout Considerations

As a first step in our facility planning, we defined the areas needed in the new warehouse. Once defined, we made a Muther's Relationship Chart to qualitatively represent the proximity needed between the different areas. Figure 3 shows the results.

	Areas	1	2	3	4	5	6	7	8
1	Inbound docks		A / 1	I / 2	U / -	X / 3	X / 3	U / -	U / -
2	Inbound staging	A / 1		A / 1	U / -	X / 3	X / 3	U / -	U / -
3	Fast-Picking and Sorting	I / 1	A / 1		E / 2	O / 4	U / -	U / -	U / -
4	Consolidation	U / -	O / 1	E / 2		E / 2	O / 4	U / -	U / -
5	Outbound staging	X / 3	X / 3	O / 4	E / 2		A / 1	U / -	U / -
6	Outbound docks	X / 3	X / 3	O / 3	U / -	A / 1		U / -	U / -
7	Overstock Area (Conventional Racks)	U / -	U / -	O / 1	X / 4	U / -	U / -		U / -
8	Floor storage (Home appliances)	U / -	U / -	O / 1	X / 4	U / -	U / -	U / -	

Value	Relationship
A	Closeness absolutely necessary
E	Closeness especially necessary
I	Closeness important
O	Ordinary closeness OK
U	Closeness unimportant
X	Closeness not desirable

Code	Reason
1	Minimize travel distance and time
2	Convenient to follow process flow
3	Inbound and picked product's mixture
4	Avoid mixing products from different stores

Figure 3 Muther's Relationship Diagram

Using the qualitative results obtained we assembled a block layout to have a schematic of how the areas should be placed to follow the process flow of the facility. Figure 4 shows the results.

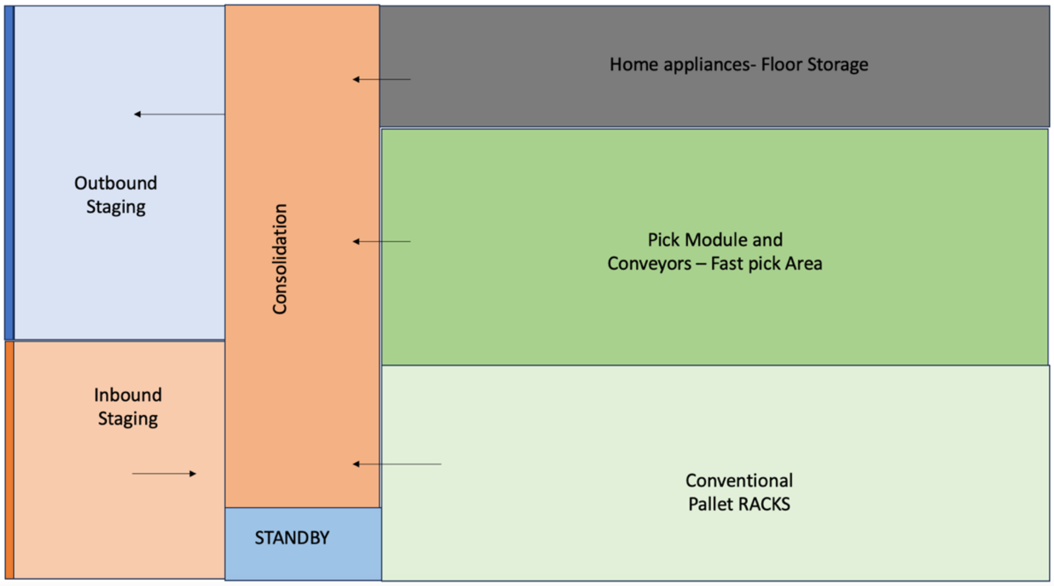

FIGURE 4 PROPOSED BLOCK LAYOUT OF THE FACILITY

First, goods will come in, usually in pallets, from supplier facilities and they will be verified in the inbound staging area. If there is an issue with the order then those pallets will be transferred to the Standby area to be checked by the purchasing personnel, but if not, they will be taken to their respective preparation station in the pick module or overstock position in the conventional pallet racks. Conventional pallet racks will be placed on the lower section of the layout because they can be placed against the wall taking advantage of the warehouse space, while the fast pick area which will consist of a pick module needs to be replenished with forklifts on both sides. To replenish those racks, there should be space in the middle of the facility for the forklifts to maneuver. Large home appliances will be stacked on the floor, and they can also be placed against the wall if needed to, so that area will be placed in the upper section of the layout. Once orders are received from stores, those items are picked and taken to the consolidation area where they will be consolidated in mixed SKU pallets or totes to be later staged in the outbound area, loaded in trucks, and taken to stores.

We will define the square meters needed to robustly support operations at each of the areas, but our focus will be designing the fast-picking or cross docking area.

In our meetings with the sponsor, they mentioned that it is indispensable for the new facility to have space to cross dock or fast pick the items that are currently cross docked at Galera 1 plus the items that are delivered directly at stores. We surveyed Galera 1 workers and the warehouse supervisor to have a better understanding of how that cross-docking process is currently done. They receive the pallets from local suppliers, and they are verified and staged near the inbound docks. Once orders are verified, the warehouse supervisor does a manual procedure in a spreadsheet to get the order in which the WMS will generate the picking lines and arrange the SKUs received in that same order on the floor. According to the warehouse supervisor this process can take up to half a working day with suppliers that bring a high variety of SKUs. Due to the manual component of this process and the space used for picking, which is currently on the floor, it will be highly inefficient to scale up this exact same process at the new warehouse.

After discussing the sponsor's needs, surveying Galera 1 workers and examining the volume of suppliers and goods they are going to receive and dispatch to stores, our team is proposing a picking module like the ones shown in Figure 5 to support the expanded fast picking operations in the new warehouse.

Figure 5 Picking Modules

By implementing a picking module with conveyors of this nature, the sponsor will be able to consolidate storage and operations vertically, conserving warehouse space. Currently, the warehouse workers arrange the goods that are cross docked in Galera 1 at the staging area to reduce travel, but by having conveyors in the picking module the travel component will also be reduced, and the flow of goods will be automated to the consolidation and shipping area. Most of the picking in the module will be made in flow racks which supports FIFO inventory rotation and reduces the risk of having goods in obsolescence or price erode. This type of pick module also enhances warehouse safety by having the picking area separated from the forklifts. It is also customizable and has various configurations that include sections with pallet flow racks, broken case picking, carton flow among others. On the next section we will perform a profiling analysis to decide how product categories should be picked from the module and how it should be designed.

Warehouse Profiling

The next step in our facility planning included analyzing historical data from the sponsor's suppliers and product categories that will be received, stored, and dispatched at the new warehouse. To obtain the list of suppliers we examined all local purchases received directly at stores, plus others that are currently received in Galera 1, but excluded food and some construction materials that according to the sponsor should not be included in the study. Our list ended up with 260+ suppliers.

Since most of these goods are not picked at any warehouse, we examined transactional data to see if there were any seasonality trends among the goods included in the study that we should consider in our capacity considerations. Usually there is a general spike in demand during December because of the holiday season, but other spikes we noticed appeared to be random. We discussed this with the sponsor, and they confirmed that they don't usually observe seasonal trends in demand.

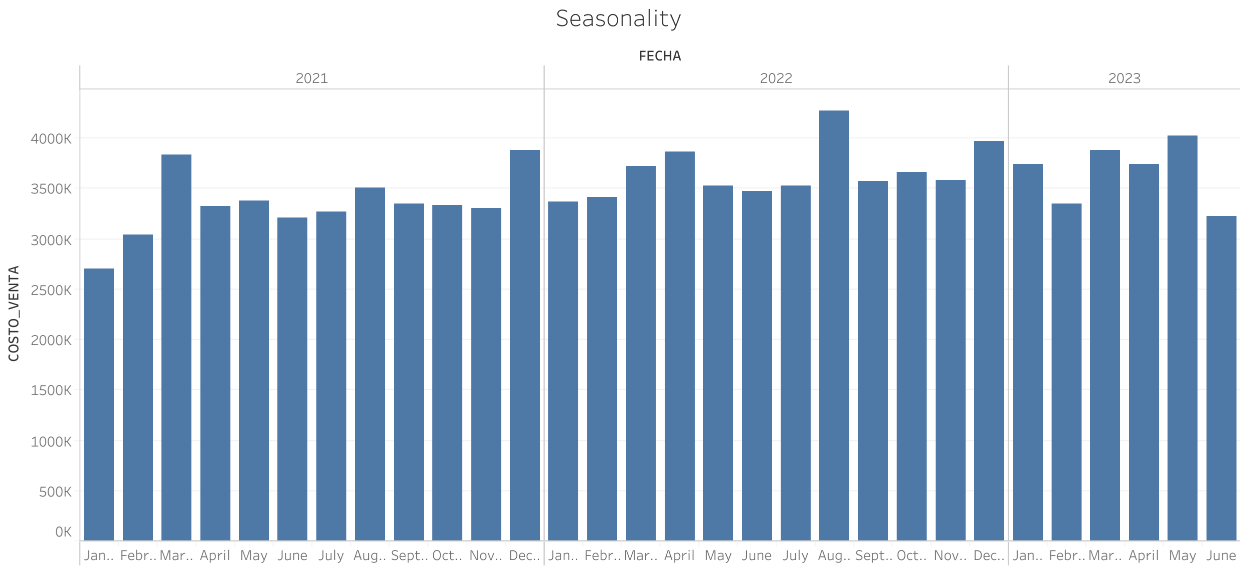

FIGURE 6 MONTHLY SEASONALITY

Next, we performed an ABC analysis of suppliers and product categories. This was done to identify the suppliers with high rotation SKUs, and with higher impacts on revenue. The analysis was done at the supplier level instead of SKU to simplify put-away and replenishment operations at the picking module and overstock area. All product arriving in a truck from a supplier facility should be assigned to the same region of the warehouse. Also, since suppliers usually dispatch similar products, storing them together leads to good space utilization. Results from this analysis are shown in figures 7 and 8.

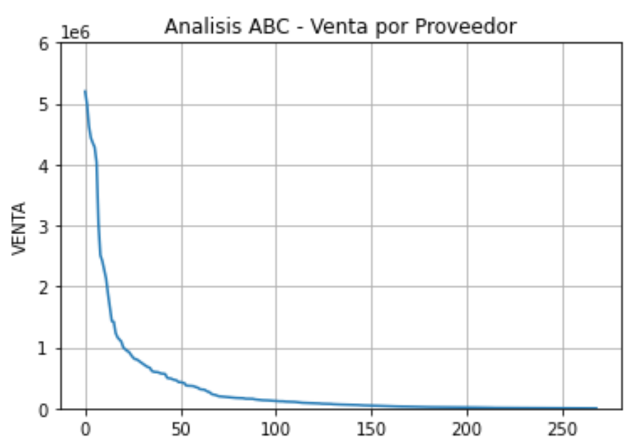

FIGURE 7 SUPPLIER ABC ANALYSIS

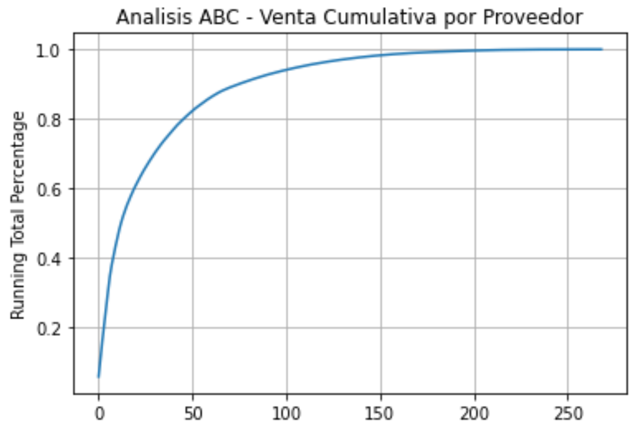

FIGURE 8 CUMULATIVE SUPPLIER ABC ANALYSIS

Figure 7 is non-cumulative and shows a “long-tail” graph, which means that a small percentage of suppliers represent a high percentage of the revenue and potential picking activity. Figure 8 on the other hand is cumulative and shows that around 20 suppliers represent 60% of revenue and potential picking activity. The same analysis was done by SKU and the results were similar. Most of the “prime” SKUs are supplied by “prime” vendors so handling inbound pallets by supplier instead of breaking them down by SKU decreases the complexity of the operation and you obtain similar results.

In our meetings with the sponsor, they mentioned that paint suppliers will continue delivering their products directly to stores, but eventually in a phase 2 of the project they will also centralize those deliveries at Galera 4. We repeated the same analysis, but included the paint suppliers which are only five. The results are shown in figures 9 and 10.

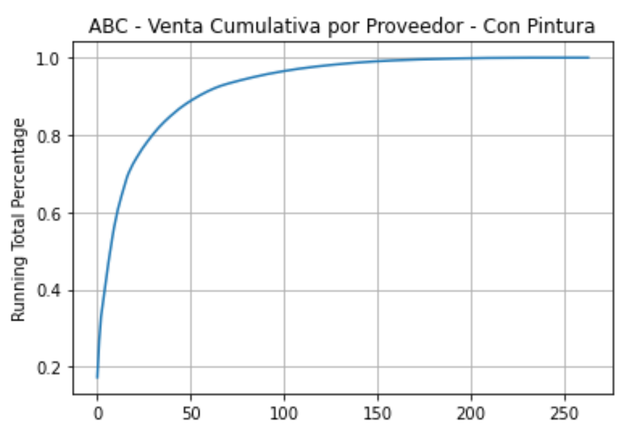

FIGURE 9 SUPPLIER ABC ANALYSIS (INCLUDING PAINT)

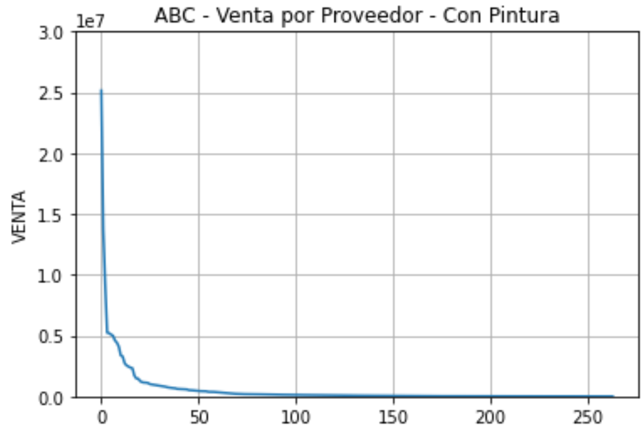

FIGURE 10 CUMULATIVE SUPPLIER ABC ANALYSIS (INCLUDING PAINT)

As it can be seen on the graphs, by only adding those five suppliers the results changed dramatically. Those five suppliers account for approximately 10% of the sponsor's total monthly revenue. Their paint products will most likely be picked in pallet quantities, so it makes economic sense to pick them directly from overstock. Also, their characteristics make it difficult for them to be hand-picked from the module (up to 5-gallon containers). They will not be considered in our picking module design.

As a last step in our profiling analysis, we set up a probabilistic throughput simulation considering growth for the next three years. For this simulation the paint suppliers were included because eventually they will be received at Galera 4, so they should be considered when examining the overall potential throughput used for the design of the warehouse. By obtaining the results as a statistical distribution we can have a broader understanding of the possibilities and robustly estimate the spaces needed for staging and overall capacity of the warehouse to ensure an efficient flow of goods. The parameters used for the simulation were average month-to-month growth of all the suppliers included in the study and their average COGS of the last 12 months. The results of the simulation are shown in figure 11 and table 1.

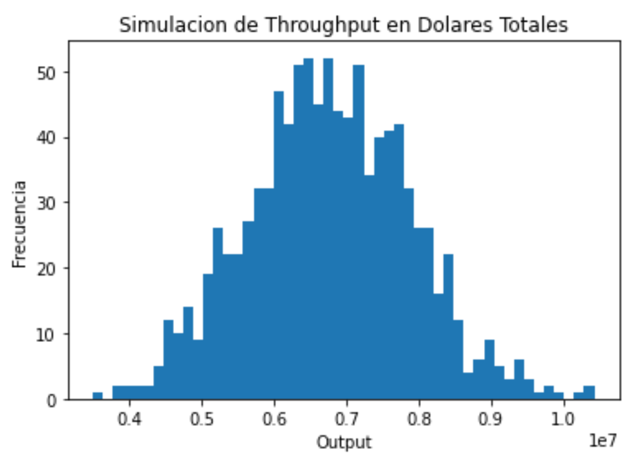

FIGURE 11 THROUGHPUT SIMULATION (1000 SCENARIOS)

Total Throughput Simulation	
Mean	$6.76 M
Std_Deviation	$1.12 M
Min	$3.50 M
Max	$10.43 M
99% Robustness	$9.46 M

TABLE 1 THROUGHPUT SIMULATION RESULTS

We estimate that on average monthly throughput will be between $6 and $7 million dollars in inventory, but to design staging spaces, and overall capacity that can robustly support most scenarios we should consider that monthly throughput can reach $9 to $10 million dollars. Given that the sponsor handles many SKUs that also vary greatly in value we had to estimate an average overall pallet value of $1200. Based on this rough estimation, a robust throughput will be close to 300 daily pallets.

Picking Module Design

After completing our profiling analysis, we designed the picking module that will be used as a fast-picking area at Galera 4. As we mentioned before, it is indispensable for Galera 4 to have an area designated to cross-dock or a fast-picking area. Scaling up the cross-dock operations exactly as they are done in Galera 1 would not be ideal, since that process consists in receiving pallets, breaking them down and then picking the goods directly from the floor. This leads to poor utilization of vertical space, and to congestion in the inbound staging area which limits the sponsor's capacity to receive shipments. The picking module proposed will be made up of three levels to take advantage of vertical storage space and conveyors at each level to reduce travel which is usually the most expensive component of order picking. To accommodate fast-moving categories and "prime" suppliers within the picking module we used the ABC analysis that was performed on the previous section.

The first level of the picking module will consist of pallet-gravity flow racks on one side and pallet racks on the other. This makes it appropriate to store high-rotation products that are received in pallets, but do not come in cartons. The second and third levels will have carton gravity-flow racks on one side of the conveyor and pallet racks on the other. All replenishment of racks that face the conveyor should be done from behind to not interfere with picking operations. Pallet racks can be replenished with forklifts and the carton gravity-flow racks will have a mezzanine where workers can replenish them with the help of pallet-jacks. On the other end of the mezzanine there will be another row of pallet racks that can be used as reserve for the carton gravity-flow racks. It was decided to have only one side of the module with carton-gravity flow because a mezzanine is needed to replenish them and having them on both sides of the module would lead to poor utilization of warehouse space.

Each level of the module will be divided in picking zones. By storing popular products in different zones, we can avoid congestion in picking and replenishment operations. Traveling to pick goods is not an issue because the module will be equipped with conveyors. Each zone will be made up of similar product categories to simplify put-away operations both at the warehouse and downstream at stores. For example, having cleaning supplies stored, picked, and packed together at the warehouse will lead to a more effective storage process at stores because they are usually placed together at the sales floor.

On our proposal we suggest having the first level dedicated to liquid and powder like products, since they are more likely to be picked directly from pallets and they are also usually the heaviest. Table 2 includes our proposal for each level and figure 12 shows a potential heat map of level 1. We turned in to the sponsor a detailed proposal for each zone based on the ABC analysis. A snapshot of the detailed proposal can be found in the appendix.

Level	Zone	Rack	Categories
1	1	pallet	Car Supplies
	2	pallet	Pet Supplies
	3	pallet flow	Cleaning
	4	pallet flow	Other (Silicone, Garden, etc..)
2	1	pallet	Cables and ropes
	2	pallet	Medium Appliances
	3	carton flow	Hardware
	4	carton flow	Electrical
3	1	pallet	Outdoors, BBQ and High Value
	2	pallet	Other
	3	carton flow	Plumbing, Bathroom, Kitchen
	4	carton flow	Lighting

TABLE 2 PICKING MODULE ARRANGEMENT PROPOSED

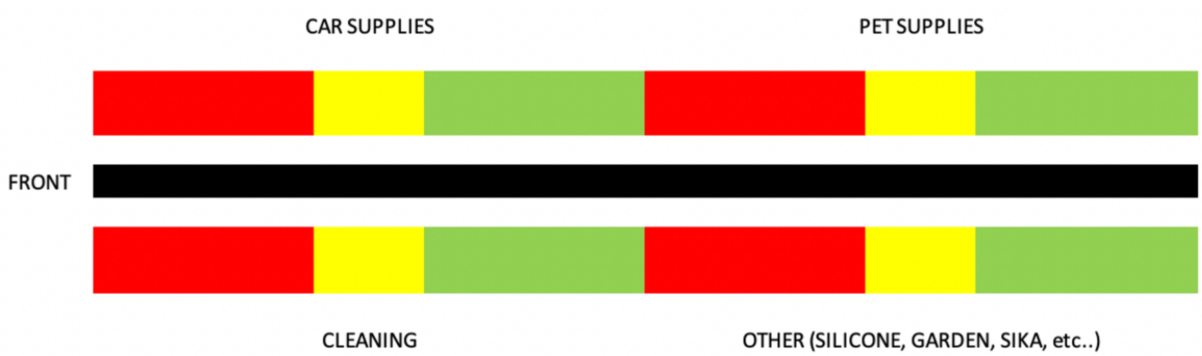

FIGURE 12 POTENTIAL HEAT MAP OF LEVEL 1

Replenishment of the picking module can be done directly from the inbound docks or from the overstock area. Goods that want to be pushed by the sponsor to stores will most likely be received and then placed directly on the module, so they can be picked and sorted. Other goods will be taken to overstock and then forklifts will pick them in bulk to replenish the module.

Results

Staging Areas

Since the number of suppliers received at the DC will increase it is essential to have an area that can robustly support the receipt of goods, and stage outbound pallets. To estimate the overall staging area needed at Galera 4 we used the robust throughput simulation results. With those results we calculated the space needed to support daily flow of pallets and considered space needed for forklifts to maneuver. The result obtained was 1262 squared meters. 526 squared meters will be dedicated to the inbound staging area and 736 squared meters to the outbound staging area since inbound processes tend to be quicker.

Home Appliances Area

Galera 4 will have an area dedicated to store large home appliances like refrigerators, washing machines, stoves, and others. These appliances usually come in standard boxes that are perfect for stacking, so it is not necessary to store them in racks to take advantage of vertical storage space or to help in retrieving operations.

Storage of these products should be dedicated by product family. This means that locations will be reserved for a specific family to store the most popular categories in convenient locations and so workers can learn the layout, which makes order-picking more efficient. Dedicated storage by SKU instead of product family brings an unnecessary degree of complexity to the stowing operations. To determine which are the popular or fast-moving categories that should be stored at convenient locations we examined sales data. Results are shown in Figure 13.

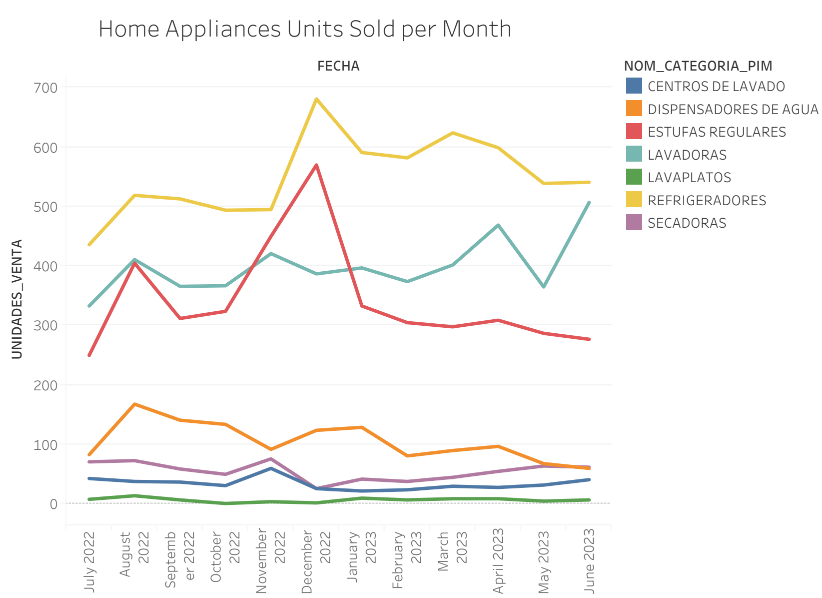

FIGURE 13 HOME APPLIANCES SOLD PER MONTH BY PRODUCT FAMILY

As it can be seen on the graph, refrigerators, stoves and washing machines are clearly the fast-moving categories while the other four can be categorized as slow movers. Those three categories will be stored closer to the docks to minimize traveling in stowing and picking operations. We also examined inventory data to understand how the sponsor handles the stock of these product categories. On average they have around 3 months' worth of inventory of each of the categories. Based on this we estimated the storage space needed for each category, also considering that refrigerators and washing combos can only support 2-boxes-high stacks due to their size, while all the other categories can support 4-boxes-high stacks. We estimate that 1000 squared meters are needed for the whole area that include two 4-meter aisles and pick faces on both sides. A schematic of the recommended layout is shown in Figure 14.

FIGURE 14 HOME APPLIANCES AREA PROPOSED LAYOUT WITH COLOR CODES

Order-picking of these products is typically done in eaches with the assistance of forklifts with clamps, so it is unnecessary to have cross-aisles in this area, since dual operations are highly unlikely.

Labor and Equipment Requirements

To estimate labor and forklifts needed we used basic deterministic capacity requirements. First, we calculated the required number of operators using the expected average throughput from our simulation.

For the processing time, we assumed that 1 person can pick all products in a pallet in around 20 minutes. This is based on what we observed in our visits to Galera 1. We also assumed that the operator should be available 7.5 hours per day. The result was that to support Galera 4 operations, the sponsor will need 40 daily operators. This includes order-pickers, receipt verifiers, stowers and supervisors.

The same methodology was applied for the number of forklifts, but instead of a processing time of 20 minutes we assumed 3 minutes on average for the resource to be used and be released for other activities. The result was 3 forklifts to be used in stowing and pick-module replenishment operations and 1 forklift with clamps to be used in the home appliances area.

Storage and Handling Capacity

The warehouse is designed to have 4 main sections, the fast-picking area, home appliances area, overstock, and staging. The fast-picking area which will consist of a picking module will have 3 levels. The first one will allocate pallets and the second and third will allocate pallets and cartons. It will also have conveyors, a spiral conveyor, pallet gravity flow racks and carton gravity flow racks.

Based on the design proposed, the storage and handling capacity for pallets and cartons throughout Galera 4 is shown in Table 3.

Storage Capacity		
Area	**Capacity**	**Units**
Picking module - level 1	462	Pallet Positions
Picking module - level 2	3300	Cartons (0.4 x 0.32 x 0.315)
Picking module - level 2	198	Pallet Positions
Picking module - level 3	3300	Cartons (0.4 x 0.32 x 0.315)
Picking module - level 3	198	Pallet Positions
Overstock Area	2592	Pallet Positions
Staging Area	166	Pallet Positions

Table 3 Galera 4 Storage Capacity

4-meter-wide aisles are being proposed to have enough maneuvering space for forklifts. We also are proposing a forklift highway of 3.5 meters width in the consolidation area to ensure that forklifts can safely travel from the docks to each one of the other areas in the warehouse.

3D Layout

All the estimations and analysis explained before were done to assist us in our layout proposal. We drew the layout using Sketchup to get a 3D result and to deliver a highly realistic representation of our recommendations. First, we created the dimensions of the warehouse (110 meters x 51.02 meters) defined by the sponsor, and we segmented this space by the areas proposed before. The staging area will be made up of 1,262 square meters to ensure a robust space to consolidate, receive, and dispatch pallets to stores. Figure 15 shows the staging area in our 3D drawing.

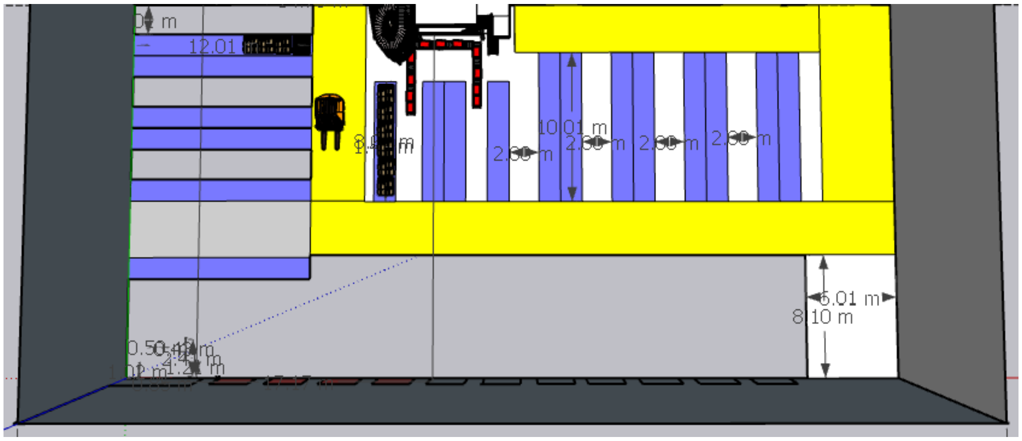

FIGURE 15 STAGING AREA

The home appliances area was designed with an area of 1000 square meters to stack products on the floor and two 4-meter aisles with pick faces on each side. Figure 16 shows the home appliances area in our 3D drawing.

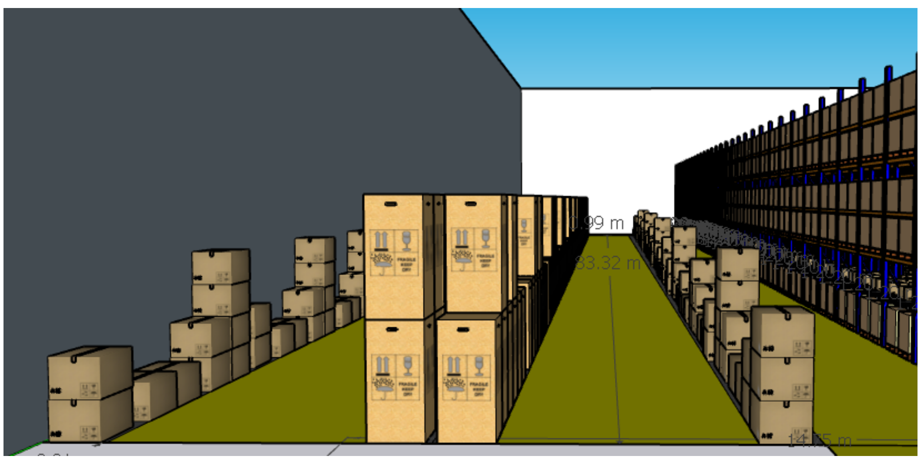

FIGURE 16 HOME APPLIANCES AREA

The fast-picking area, which will consist of a picking module was designed to allocate pallets and cartons. For this, we used Sketchup's 3D warehouse library to import predefined pallet racks, spiral conveyors, and normal conveyors. To transport items picked in upper levels to the first level we recommend a spiral conveyor which can also act as a buffer if there are peaks in demand in any given picking wave. We drew the carton gravity flow rack on level 2 and 3 of the fast-picking area and the pallet gravity flow rack on level 1. When we surveyed store workers, they told us that the easiest put-away operations were done with products that arrived at the store in totes. They usually just scan the totes and take them directly to the sales floor to place those items in the facings. Our suggestion is that the picking in the module should be done using collapsible totes with dimensions of 0.6 x 0.4 meters when possible. This standardizes pallet building, makes non-conveyable products conveyable and simplifies operations in stores. Figure 17 shows the picking module design proposed:

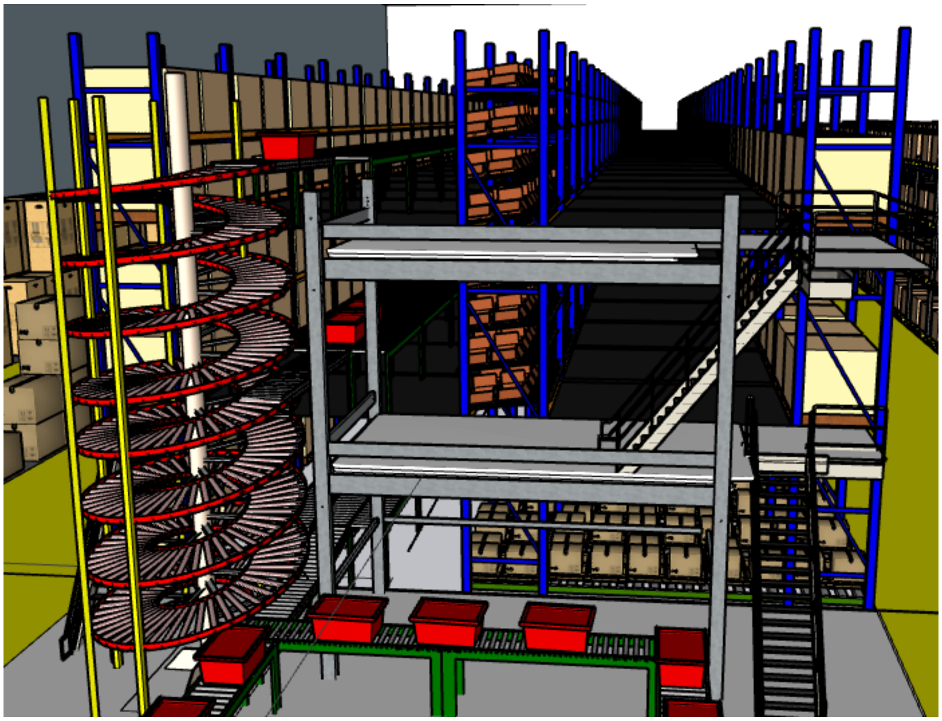

FIGURE 17 PICKING MODULE

Finally, we have the overstock area that is the rest of the space available in the warehouse and is made up of 4 rows of pallet racks and four 4-meter-wide aisles for forklift maneuvering. Since most of the picking in this area will be done in bulk to replenish the picking module, we recommend a shared storage strategy in this area, so no SKU will have a designated space. Once they are received and verified at the inbound dock, the WMS should assign them a free pallet position. Cross-aisles were also added in the middle of the overstock pallet racks. This is for forklifts or workers to cross through the facility without having to go all the way to the front. Figure 18 shows the overstock area.

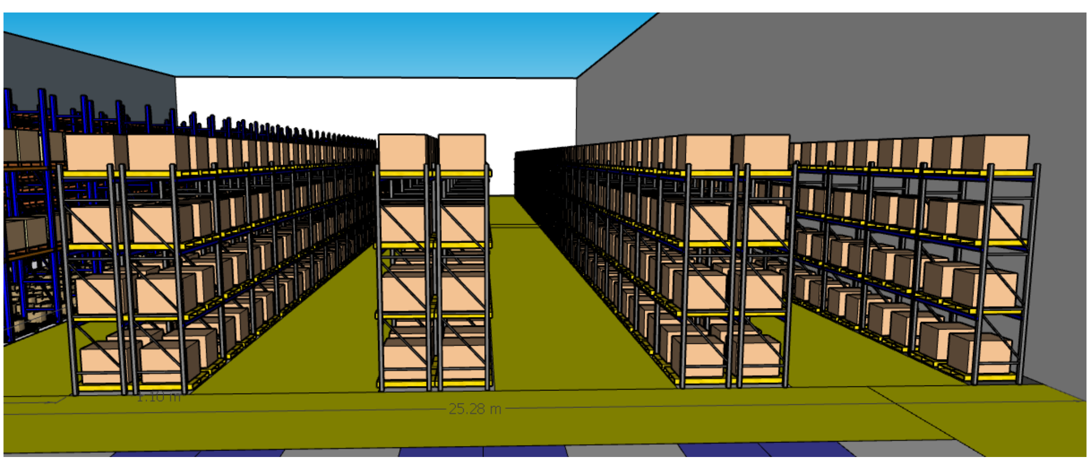

FIGURE 18 OVERSTOCK AREA

Lastly, figure 19 shows the whole layout from above.

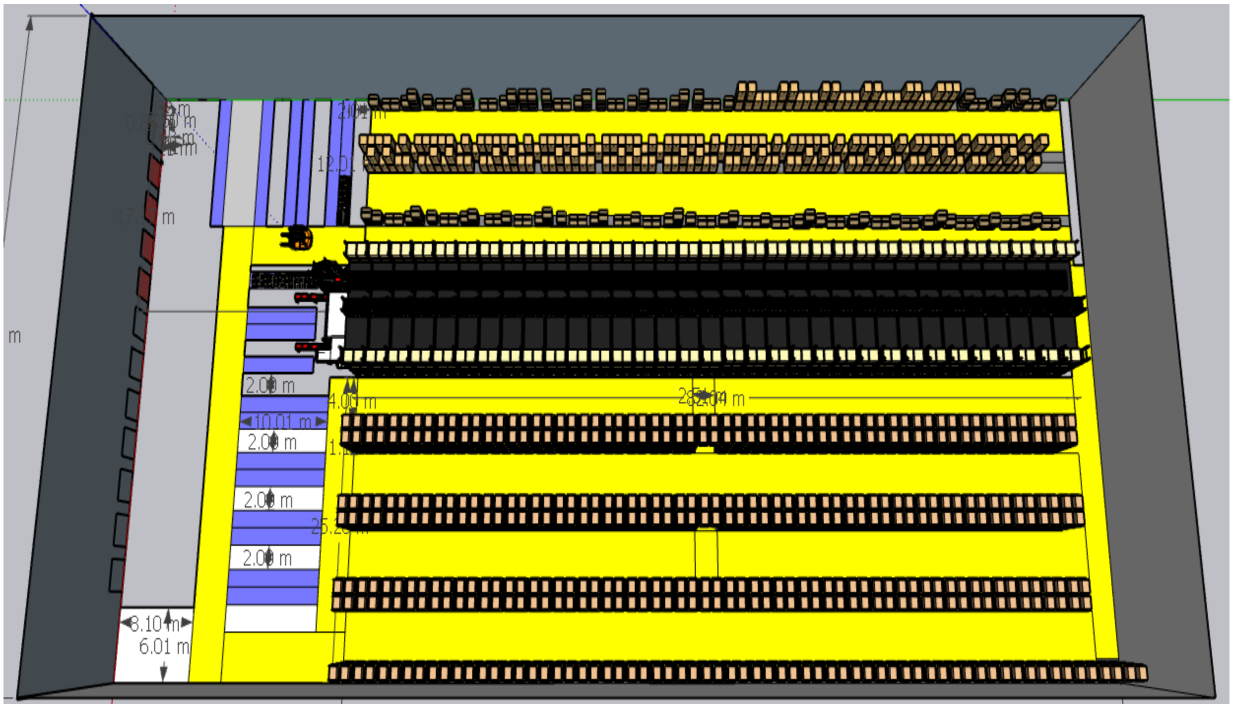

FIGURE 19 GALERA 4 FROM ABOVE

Recommendations

Facilities planning is essential for achieving an efficient layout and operations within a DC. Based on our planning we have the following recommendations for our sponsor:

- For staging areas, we recommend having 1,262 square meters to receive suppliers, consolidate shipments and stage outbound pallets. Also, in this space we proposed to have a forklift highway to ensure safe travel from the docks to other areas.
  It is good practice in the industry to have lanes in the consolidation area to group pallets with the same destination that are ready to be shipped. Since the picking is done by waves, the lanes can be set up by stores in a specific wave.
- We recommend three lanes for the home appliances area with its respective product distribution described in previous sections.
- A picking module is a structure that offers flexibility and scalability to the operation. Our sponsor being a retail company, handles a great deal of SKUs. For this case we are recommending a three-level module to handle pallets and cartons. Also, it gives us the opportunity of implementing a degree of automation by using conveyors. To facilitate consolidation and standardize pallet building, we recommend using pick-to-tote strategy to group products that will go to the same destination and have similar sizes. In the appendix we show the collapsible tote that we recommend of size (0.4 m x 0.6 m x 0.5 m).
- The spiral conveyor was proposed to carry products from upper levels to the first level to be consolidated and taken to stores. Spiral conveyors also act as a buffer if there are

peaks in traffic in the consolidation area. Also, it is an excellent alternative to move totes from the upper levels to the consolidation station on level 1 without wasting space.

- The overstock area is the area designated to store all the products that are not at the picking module. For this area we recommend having single-depth racks with 4 levels allocated as shown in the 3D Layout section with 4 aisles of 4 meters for forklift transit and three cross-aisle sections to facilitate movement between warehouse areas without having to travel all the way to the front of the facility.

Conclusion

A new warehouse represents expanded operations, new equipment, and hiring of new labor. Due to this, facility planning is an extremely important step to achieve overall efficiency. For this project, the shape of the building, overall space and placement of dock doors was out of scope. We proposed how areas should be arranged within the warehouse, and which technologies and strategies the sponsor should use to support their operations.

We proposed a picking module to be used as a fast-picking area. Picking modules are an excellent alternative, especially for retail warehouses. The direct clients of the warehouse are the 45 stores, and the sponsor can know in advance the orders and that gives them leverage in the module replenishment strategies.

Robust planning is essential, especially in capacity. In this case we used our robust results to plan for the staging areas to avoid congestion near the inbound and outbound docks.

Since the main reason to expand the DC is to centralize most of the deliveries that are currently done directly at stores, we made our best effort to design a warehouse free of bottlenecks, and that ultimately increases the overall efficiency of the sponsor's operations through the metrics that we defined.

References

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[2] Montreuil B. (2008), *Facilities Location and Layout Design*, Chapter 5 of Introduction to Logistics Engineering, Ed. G. D. Taylor, CRC Press, 2008

[3] Muther, R. & L. Hales (2016) *Systematic Layout Planning*, 4th Edition Cahners Books

[4] Sharp G. (2008), *Warehousing*, Chapter 8 of Introduction to Logistics Engineering, Ed. G. D. Taylor, CRC Press, 2008

Appendix

- ABC Parameters

```
# 3 categorias (A-60%,B-25%,C-15%)
def ABC_segmentation(RunPerc):
    if RunPerc > 0 and RunPerc < 0.6:
        return 'A'
    elif RunPerc >=0.6 and RunPerc < 0.85:
        return 'B'
    elif RunPerc >=0.85:
        return 'C'
```

FIGURE 20 ABC ANALYSIS PARAMETERS

- Collapsible Totes

FIGURE 21 COLLAPSIBLE TOTE

Specifications:

Available Heights (mm): 320, 400
Collapsed Height (mm): 77.5

Footprint (mm): 600 x 400
Capacity (liters): 63, 80
Stacking Ratio: 4:1, 5:1

- Deterministic Capacity Requirements

$$C = \frac{dt}{qare}$$

C: Capacity requirement
d: demand
t: processing time
q: quality
a: availability of the resource
r: reliability of resource (0-1 ratio)
e: efficiency of resource (0-1 ratio)

- Snapshot of detailed picking module proposal

NOM_PROVEEDOR	NOM_PLANOGRAMA	Priority Volume	ZONE
ABOLU S.A.	ACEITES, ADITIVOS Y LUBRICANTES	Medium	AUTO Y ACEITES
ABOLU S.A.	SILICONES, SELLADORES Y CINTAS PARA SELLAR	Medium	OTROS
REPRESENTACIONES IDEALES S A	QUIMICOS DE LIMPIEZA	Medium	LIMPIEZA
ADITIVOS DE PANAMA S.A.	SILICONES, SELLADORES Y CINTAS PARA SELLAR	High	OTROS
DIC S. A.	ACEITES, ADITIVOS Y LUBRICANTES	High	AUTO Y ACEITES
DIC S. A.	QUIMICOS DE LIMPIEZA	High	LIMPIEZA
FELIPE MOTTA, S.A.	QUIMICOS DE LIMPIEZA	High	LIMPIEZA
GLOBAL PRODUCTS AND LOGISTIC SERVICES INC.	QUIMICOS DE LIMPIEZA	High	LIMPIEZA
INTREP S.A.	SILICONES, SELLADORES Y CINTAS PARA SELLAR	High	OTROS
INVERSIONES BARRIA S.A.	ACEITES, ADITIVOS Y LUBRICANTES	High	AUTO Y ACEITES
JACKAL S.A.	QUIMICOS DE LIMPIEZA	Medium	LIMPIEZA
JACKAL S.A.	SILICONES, SELLADORES Y CINTAS PARA SELLAR	Medium	OTROS
LUBRICANTES Y QUIMICOS S.A.	ACEITES, ADITIVOS Y LUBRICANTES	High	AUTO Y ACEITES
LUBRICANTES Y QUIMICOS S.A.	QUIMICOS DE LIMPIEZA	High	LIMPIEZA
LUBRICANTES Y QUIMICOS S.A.	SOLVENTES Y REMOVEDORES	High	OTROS

FIGURE 22 SNAPSHOT OF DETAILED PICKING MODULE ARRANGEMENT