Senior Design Project:

Redesigning a Logistics Warehouse at Crowley

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Abstract

Crowley Maritime is a logistics, distribution, fuel & energy and marine solutions company among many other services. It provides its services worldwide and it is based in Jacksonville, Florida. Thanks to the agreement between this company and the ISE department of the University of Florida a group of students could perform a full study on one of their warehouses for their Senior Project Design Course.

The warehousing business unit of Crowley Maritime has been identified as an area to improve its profit margin. Specifically, the Crowley's 30th warehouse in Jacksonville (Florida) is losing money due to their current inefficient processes, lack of storage plans, absence of standardization and, most significantly, a large amount of temporary labor.

The overall goal of this project is to provide Crowley Maritime with suggestions to minimize their warehouse expenses through thorough examination and analysis of the system as a whole. To ensure the full coverage of all operations within the facility, the project was split into two divisions, each covering separate issues. Both sides of the project aimed to maximize the system's efficiency in facility processes, minimizing facility costs, and increasing potential revenue, but each focusing on isolated operations. The content of this report will cover a full summary of both groups analysis of the complex issues facing the Crowley warehouse, and our supporting proposed solutions to these issues. The first part of the project will look at the processes in the Pan American Grain rice warehouse, and the other part of the project will look at the processes developed in the Bed Bath & Beyond pool point warehouse and the FootLocker new pool point warehouse.

For the rice warehouse part of the project, we will address the problems within the Pick &Pack section as well as inefficiencies with communicating and handing off materials for processing pallets to load and unload. We attack these problems by recommending the reorganization of the Pick &Pack section and a consolidation board that eases the transition of pick sheets and labels needed for loading and unloading.

For the pool point part of the project, there is an inefficient allocation of temporary labor and a lack of standards. The inbound process can be greatly improved through the implementation of a set of standard procedures.

Through the implementation of our proposed solutions, the warehouse can reduce costs by decreasing temporary labor and reduce time by standardizing the processes. Furthermore, with a more efficient warehouse, profits are expected to rise due to the greater amounts of goods that can be cycled through the warehouses.

Chapter 1: Rice Warehouse

Introduction

The first focus of the Crowley Jacksonville warehouse project is on the Pan American Grain warehouse and distribution. As a third-party logistics company, Crowley rents out space in their warehouse to store pallets of rice. They employ forklift drivers to unload the rice delivered from the Jacksonville ports. They also load trailers that are heading to distribute pallets across Florida. Some pallets require a variety of different rice SKU's (Stock-Keeping unit) to be wrapped into one pallet manually. These are called a "Pick &Packs". There is a specific Pick &Pack area in the warehouse currently, where already opened pallets are stored so that forklift operators can grab single items and build a pallet with them.

After observing the process in the warehouse, it seemed obvious that the Pick &Pack section is the process with the most room for improvement. In addition to improving this process, there are other small, non-value added steps during the loading and unloading processes, such as walking to the office and back, waiting on pick sheets, and printing out labels that could be eliminated or improved so that the entire time of loading or unloading is reduced. Also, there were some clear opportunities for better use of space in the warehouse, either by rearrangement of current racks or adding more racks to space currently available.

Assumptions

The assumptions that were made during this project serve to focus on inefficiencies in the warehouse. All parts of the rice warehouse processes were observed, a noticeable theme in these assumptions is that the conclusions made will help to spend less time on parts of the process that are routine and functioning properly, thus allowing more time to focus on areas of concern.

The process for loading and unloading begins when a truck arrives, and it ends whenever the last pallet has been shelved or it has been placed on a truck. This assumption helps modeling purposes and waste identification purposes. Creating a solid end point helps to discern a discrete event simulation, as well as bringing a solid understanding of the process' end. The truck's departure time can be very sporadic and depends more on human factors. Thus, this part of the process cannot be changed, so this assumption stating that the process ends at the final pallet is needed.

For the simulation models, we assume a forklift speed will be 9.84252 ft/s (3m/s) (Burinskiene, 2015). This may be tweaked so that the base model more accurately matches the runtime of real loads and unloads. Furthermore, in the simulation models, it is assumed that a human walking speed will be 3 ft/s (Goetschalckx, et al. 2002).

Regarding the time it takes to load a pallet onto the shelf and to take a pallet off of a shelf, it is assumed that these processes follow the same distribution. This allows the model to have more data points for the racking and un-racking process and model its distribution with less variation. Additionally, the time it takes to load a pallet onto a truck and unload a pallet from a truck will be assumed to follow the same distribution. This allows us to have more data points for the picking up and dropping off pallets process and model its distribution with less variation in the same way.

Another assumption made was that small inventory location changes could be made to the warehouse. While a full-scale reorganization of the rice distribution room is out of the question due to being "very costly and time consuming, and would likely require guys to come in on the weekend" (Kevin Hart, 2019), we are open to ideas that switch a few specific pallets to improve travel times and, therefore, improve efficiency. This will specially help us with the Pick &Pack process.

In regard to how many operators and forklift drivers there will be on the floor, the assumption is that there will be just one forklift driver that will be loading and unloading each truck. Besides which, the amount of turns will not slow down a forklift driver, and forklift acceleration and deceleration is negligible. Our Arena model will not consider how many times a driver had to make a turn to get to a shelf. There is, as well, one gate that will be available for loading and unloading. While this is often the case in the warehouse, there have been days where there are two gates and two trucks being processed. Modeling only one gate will suffice since our improvements lie within parts of the loading and unloading process that are unaffected by the number of gates.

Attending the Pick &Pack area, it is assumed that there is a 1% chance of any request for a pallet being a Pick &Pack pallet. This is based off the assumption that there are about four orders of 24 pallets a day, and each order has a 25% chance of containing one Pick &Pack. So, out of these 96 pallets, one will be a Pick &Pack. We also believe that past customer behavior will predict future customer behavior. This is the theory that guides our Pick & Pack reorganization. Finally, it is assumed that there are no current problems with the way pick sheets are generated. Our model and solutions will not focus on pick sheet generation, but instead, the way by which pick sheets and other tangible pieces of information are facilitated.

Proposed Solutions/Changes

As stated before, when observing the rice warehouse, one of the most strikingly inefficient process is that of the Pick &Pack. As previously explained, a worker takes an empty or a full pallet, and begins either building from the bottom with various items or stacking on top of the full pallet. However, several other processes occur before or in between the actual stacking of various items. In order to better understand what all these motions are, a forklift driver was recorded building a Pick & Pack pallet, the entire process was timed as well as all of the intermediate processes. A breakdown of the time spent doing various activities is shown below, in Figure 1.1.

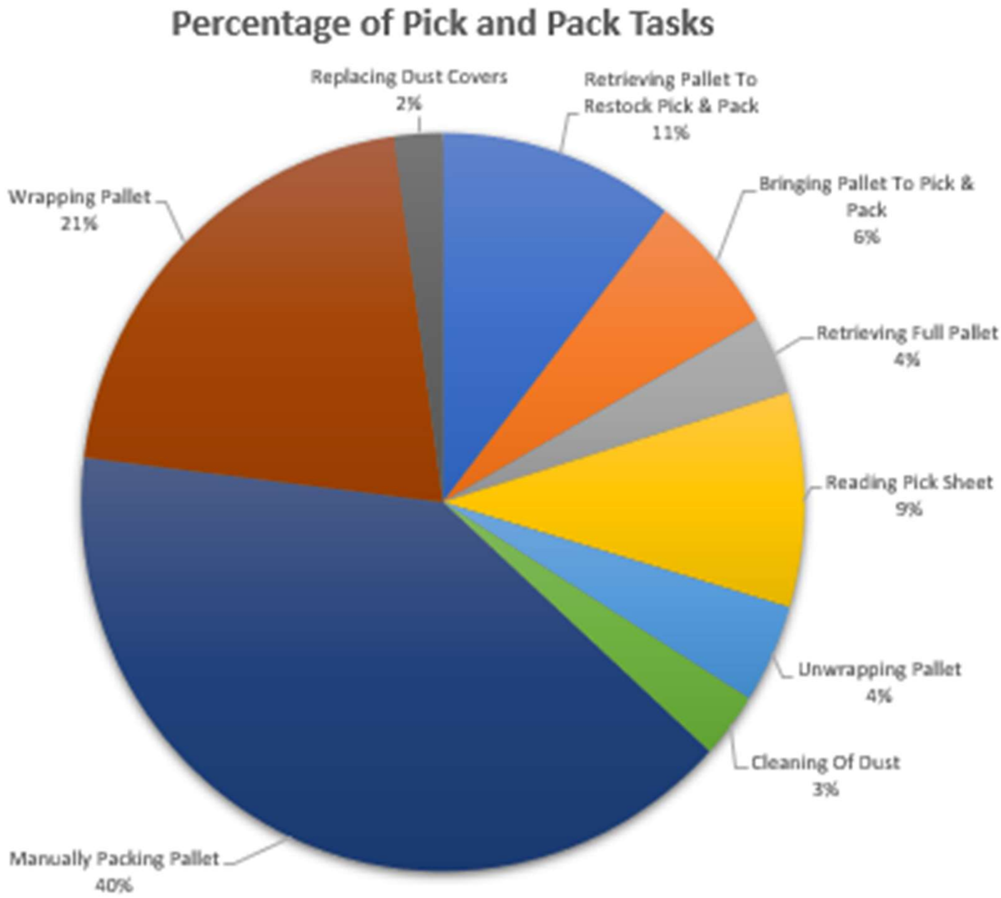


Figure 1.1: Ratio of Value and Non-Value Items in Pick &Pack Process

What peculiarly stood out during the film analysis, was that almost 4 minutes were spent retrieving pallets. This was done either when a fresh pallet was needed to build upon (a “base” pallet) or when a variety item ran out of stock in the Pick & Pack zone and needed to be replenished. At first sight, this seemed like a problem that could be fixed at low cost, and without the addition of new technology.

To begin fixing the problem, a map of the Pick & Pack zone was created. The map simply shows what SKU’s were being stored in the Pick & Pack area, and where they were. Next, some pick sheets that detailed Pick & Pack orders were given (a total of 59) and manually uploaded their information into excel. Once the data was uploaded, a pivot table was created to show which were the most popular items. With all this data, we could then add to our Pick & Pack map to create a visual that showed the Pick &Pack area items and their associated popularity. This map is shown below in Figure 1.2.

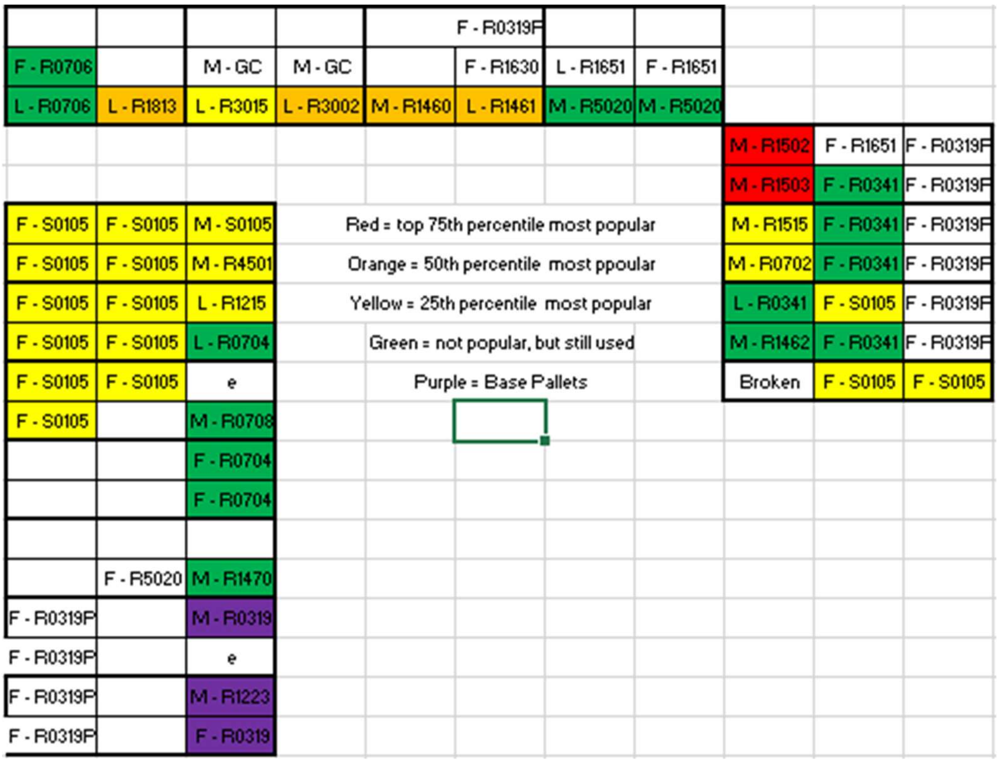


Figure 1.2: Map of Pick &Pack Area Before Proposed Solution

Some problems shown by this visual were that popular items are not kept with backups. Also, only 3 base pallets were kept on site, even though there is about 7 Pick & Packs per week. Additionally, there are several areas which are not highlighted in a color, indicating that they are not even being used in our 59 sample pick sheets. When recommending a proper Pick &Pack zone layout to Crowley in the future, we wanted to set our goals around providing space for backups for popular items, as well as providing base pallets near them so that an extra trip was not needed to retrieve base pallets. We also wanted to have a secondary emphasis on providing plenty of variable spots or overflow spots, whose SKUs could be left to Crowley's discretion. Using these principles, we generated the recommended Pick &Pack map below in Figure 1.3.

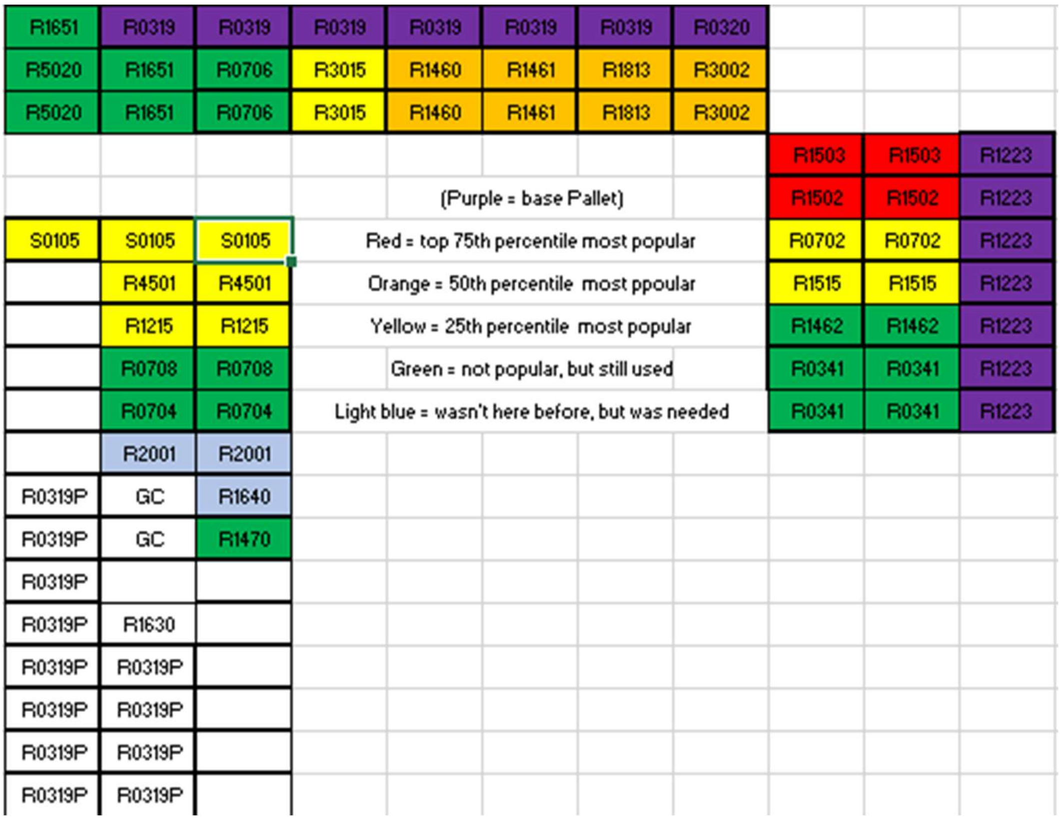


Figure 1.3: Map of Pick &Pack Area After Proposed Solution

This iteration of the Pick & Pack map consolidates all the most popular SKU's into a general area and keeps backups in the rack directly above them. If forklift operators replenish the Pick &Pack area to look like this map at the end of each week, then they will almost certainly have enough materials between the popular SKU's and their backups to be able to make it through the week without having to travel to get a new pallet mid-process. This recommended map also ensures that plenty of base pallets (highlighted in purple) are kept on hand, thus eliminating the time needed to travel to a different part of the warehouse to receive these. These changes will eliminate 3 minutes off from the Pick & Pack processing time - roughly 20% of the process time.

In addition to recommending reorganizing the Pick &Pack section, the team looked at the day to day processes of loading and unloading trucks. First, both processes were mapped out in Arena Simulation Software to demonstrate the flow of the process, as well as to simulate the time of the process. Shown in Figure 1.4 and Figure 1.5 are the load and unload processes respectively.

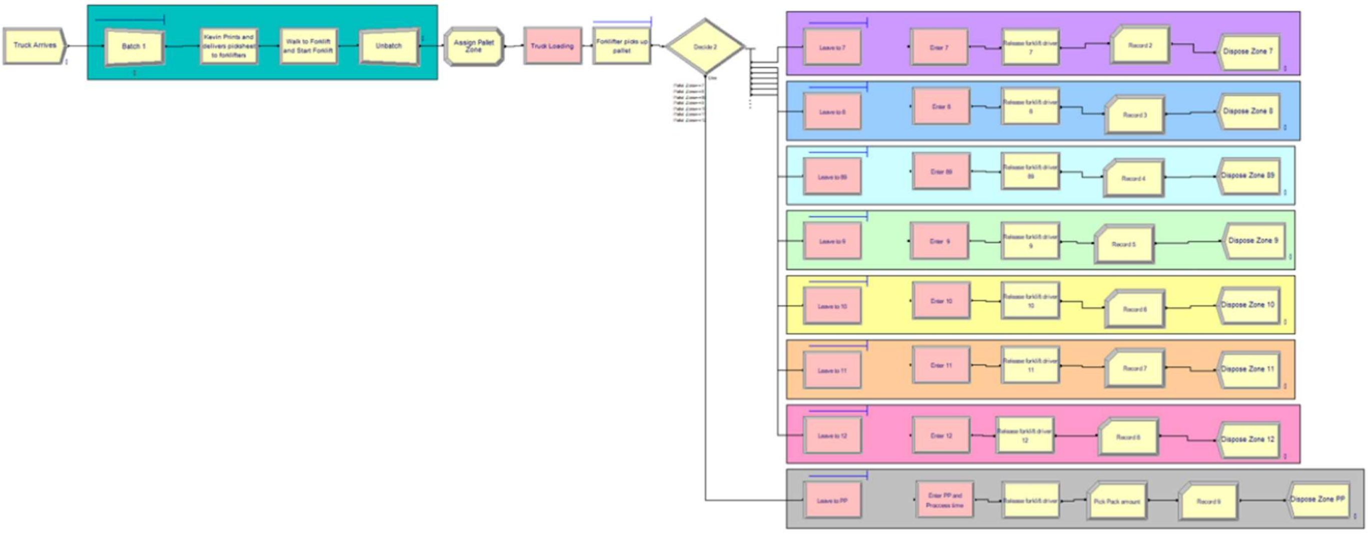


Figure 1.4: Arena Model of the loading process

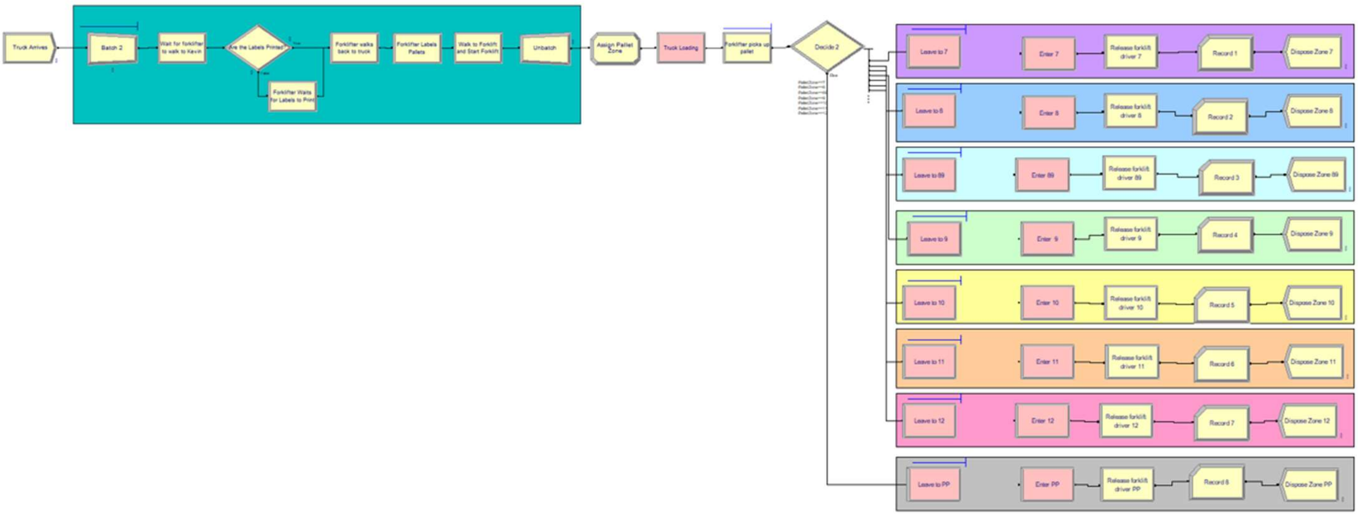


Figure 1.5: Arena Model of the loading process

The team noticed that the most waste in the process occurs when the forklift drivers are waiting around for pick sheets or labels either delivered by the logistics coordinator or obtained from the office. This walking or waiting time approximately is 2.2 minutes for a loading process and 4.4 minutes for an unloading process, which could save approximately 70 to 75 hours per year.

In order to minimize the non-value time of walking, the team looked for alternate solutions to reduce or eliminate this time. The team thought process was to implement visual management into the warehouse to help minimize the time of walking because “visual process management tools have been developed by lean practitioners as communication aids and are used to help drive operations and processes in real time” (Parry and Turner, 2006). The most cost-effective recommendation that the team came to a conclusion on was implementing a daily process tracking whiteboard. Figure 1.6 shows the example of the whiteboard to implement.

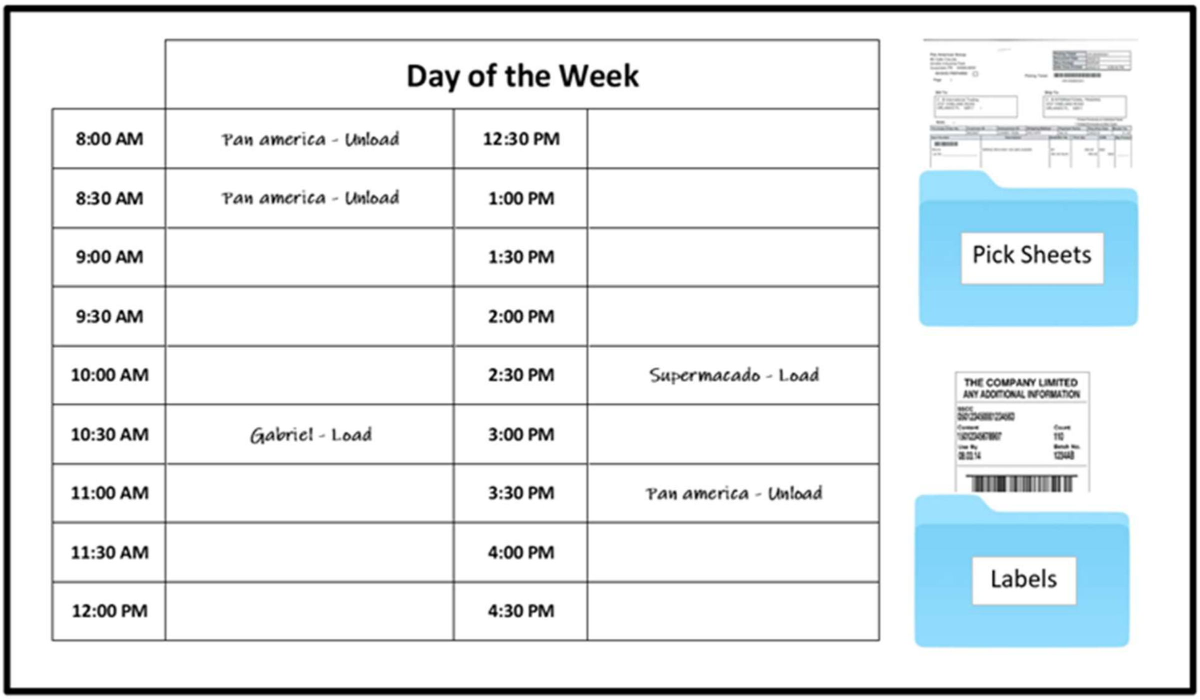


Figure 1.6: Example whiteboard for tracking daily operations

One half of the board will show the daily schedule of the loads and unloads throughout the day, while the other half of the board will contain folders for the pick sheets and labels needed throughout the day. This will reduce the time that it takes the forklift drivers to walk back and forth to the logistics office, or the time it takes for them to wait for the files to be delivered since the board would be implemented close to the truck bay. Forklift drivers can now quickly grab the sheets and move on to their next process. With an implementation of a whiteboard, Crowley Maritime will be able to save approximately $2,100 per year in terms of labor cost, as well as reduce the processing time.

Additionally, the team worked on creating more space in the Pan American Grain Warehouse to have more storage and hold more pallets. In order to complete this task, we used AutoCAD as a tool to design the racks of the warehouse. As seen in Figure 7, we were able to add 11 more rack units into the warehouse, creating room for 66 more pallets of rice to be held. These additional racks would be placed in free space area, i.e. end of rack rows that are already constructed in the warehouse and the top right corner of the warehouse that was not previously used. With more room to hold inventory, there is the new opportunity to bring in additional revenue to the Pan American Grain Warehouse. In adding these additional racks to the warehouse in the already available space, we were able to minimize the cost of implementation to only be for the cost of labor and implementing the racks, eliminating the cost of rearranging the racks and removing racks that are already in place.

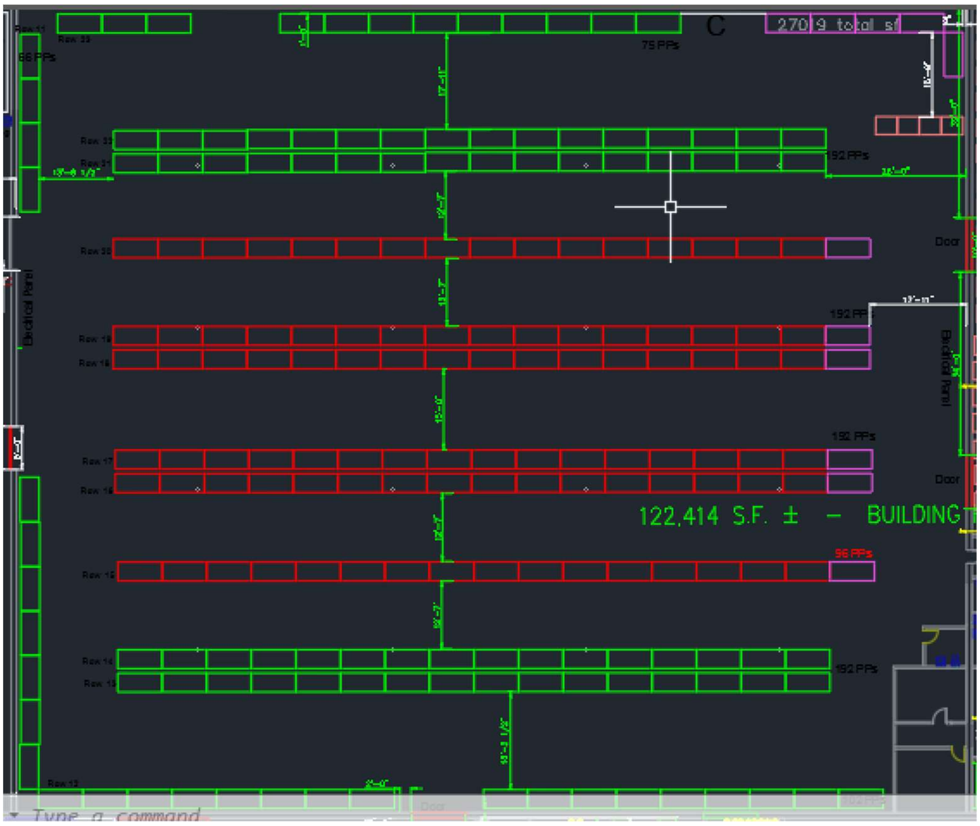


Figure 1.7: The additional racks highlighted in purple in the Pan American Grain Warehouse

Additional Factors

Rice has always had an impact on the way we eat food since the beginning of time. “Rice is a major staple among two-thirds of the world’s population.” (Batres-Marquez, 2005) Since rice is so important to global cuisine, it is imperative that this product arrives on time and in a prompt manner so that stores will always be stocked for their customers. With these recommendations to improve processes, it can be ensured that the goods are loaded and delivered on time.

In addition to rice distribution, warehouse has an environmental impact on society. One objective for this project is to reduce facility costs, specifically, by reducing lighting and air conditioning costs, causing the environmental effects to also be reduced. With our objectives to reduce the inefficiencies within the rice warehouse processes, the company will be able to bring more products in and out of the facility in a time effective manner. In this way, the warehouse will operate up to its maximum capacity without wasting utilities when the processes are at a standstill.

Conclusion

We have found many processes to improve upon within the rice warehouse. From inefficient Pick &Pack processes, to a high waiting and walking time to and from the warehouse to the administration offices, we have identified and provided solutions for various rice warehouse problems. The reduction in time we have created could lead to more trucks being able to load and unload products, ultimately increasing profits for the warehouse.

First and foremost, the Pick &Pack area could be improved with a reorganization of the area. Also, implementing a daily process tracking whiteboard would reduce the waiting time during the load and unload processes. Additionally, an addition of 11 racks, or 66 pallet spots, would help bring revenue to this warehouse, in turn, increasing overall profit. Finally, a standardization of the entire process would ensure that there is a reduction in variation and simplify loading and unloading.

With the proposed solutions, Crowley will be able to save the Pan American Grain Warehouse $2193.75 annually. However, the cost of implementation of the solutions would cost Crowley, up front, $1470. As mentioned, this is a one-time cost. However, this cost does not include the cost of purchasing new racks due to the consolidation of the warehouse in Miami. With this consolidation, the team is assuming Crowley will receive free racks from this warehouse. The proposed solutions have the potential annual revenue of $38,698.35

Overall, with improvements to these inefficient processes, the warehouse could achieve the objectives of reducing costs and increasing profits. As these recommendations are implemented, the processes will flow more smoothly, and the employees will be able to do their tasks effectively.

Chapter 2: Pool Point

Introduction

In this part of the project we are focusing in the logistics (packaging, storing and shipping out) goods from Bed Bath & Beyond and Foot Locker.

As shown in the following layout, the part of the warehouse where this process occurs is divided in two. The part on the left is the one originally designed for processing BB&B (already existing client) while the part on the right is brand new, thus empty, ready to process Foot Locker. In this second part of the project the scope is on improving the processes, layouts and general inefficiencies on the Bed Bath & Beyond part of the warehouse (left side) and replicate them in the new part of the facility for Crowley´s new client corresponding to FootLocker.

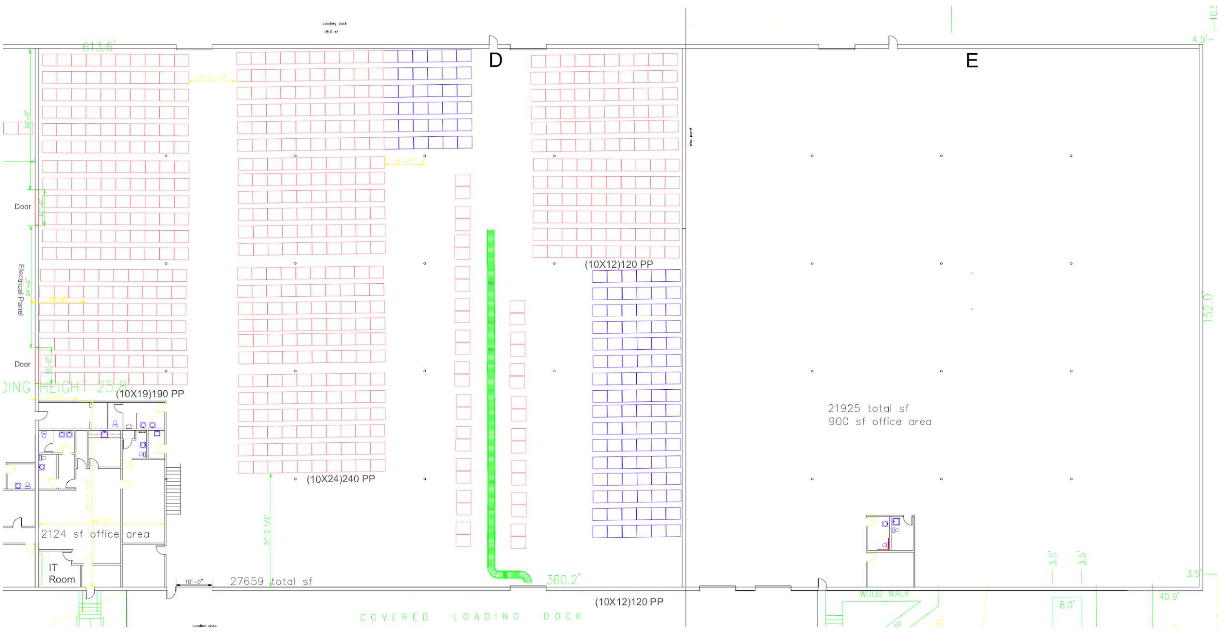


Figure 2.1: Layout of the Bed Bath & Beyond and FootLocker Warehouses

The activity starts at 7:00 a.m. At this time the trucks to unload for the day are usually already waiting outside. The labor force is made of 14 men, plus the office personnel and supervisors. In order to understand the process better, it has been separated in three main parts: inbound, organizing, and shipping out.

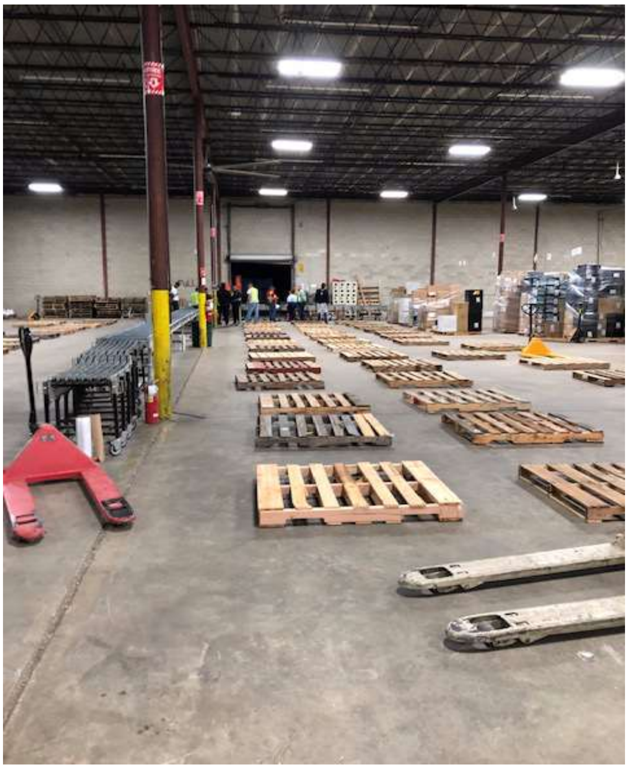


Figure 2.2. Pallets ready to build 7:00 a.m.

The inbound process

First, two men start unloading boxes from the truck onto a conveyor belt. Immediately, there is a person scanning the boxes and keeping a record of the damaged ones. After that, five people start "pulling" the boxes from the belt and throwing them to six different areas according to the box's destination. In the six different areas there is one person building the boxes into pallets. The pallets are built with boxes of a same store and then wrapped. The process of building also includes scanning every box before putting it into a pallet.

The main problems found in this process are: too many people working on it are inefficient because they are not following a standardized method (some workers will leave their task half done and start doing something different) and quality issues when pulling (throwing boxes can damage the good), among others.

In the following image we can see the Arena simulation we built to model the process as accurate as possible. Later on, in the assumptions section all the assumptions needed to build this model are explained.

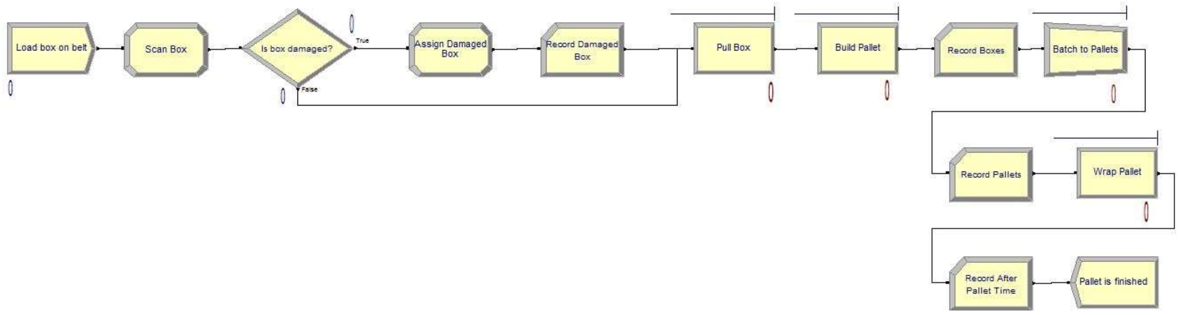


Figure 2.3: Arena Model of the inbound process

Organizing

After the pallet is wrapped, it is moved, either manually or using a forklift, to a specific part of the warehouse where more pallets for the same store are stored for shipping out. "Every pallet is supposed to stay in the warehouse for a maximum of 48 hours. (Cory Smith, 2019)" Every store has a fixed location along the walls in the warehouse.

Problems found in this part of the process: Lack of organization means that a forklift driver is needed just to organize pallets before shipping out and their travel distance is significantly large, if they were organized in the first place, maybe only one would be needed. Also, this lack of organization makes it seem like there is too much inventory, a better organization will allow us to hold more inventory. Finally, pallets stay more than 48 hours because stores set limits for shipping out while there is no limit for the inbound. In particular, contracts with the stores do not seem to reflect how this negatively impacts Crowley.

In the drawing below we find the actual layout of the warehouse. The inbound door is on the bottom right hand corner, where the conveyor belt starts, and the outbound door is in the bottom left hand corner of the drawing, where shipping out occurs. As mentioned before, we can see a lack of organization, unused space and inefficient storage (the stores are located numerically, not by route).

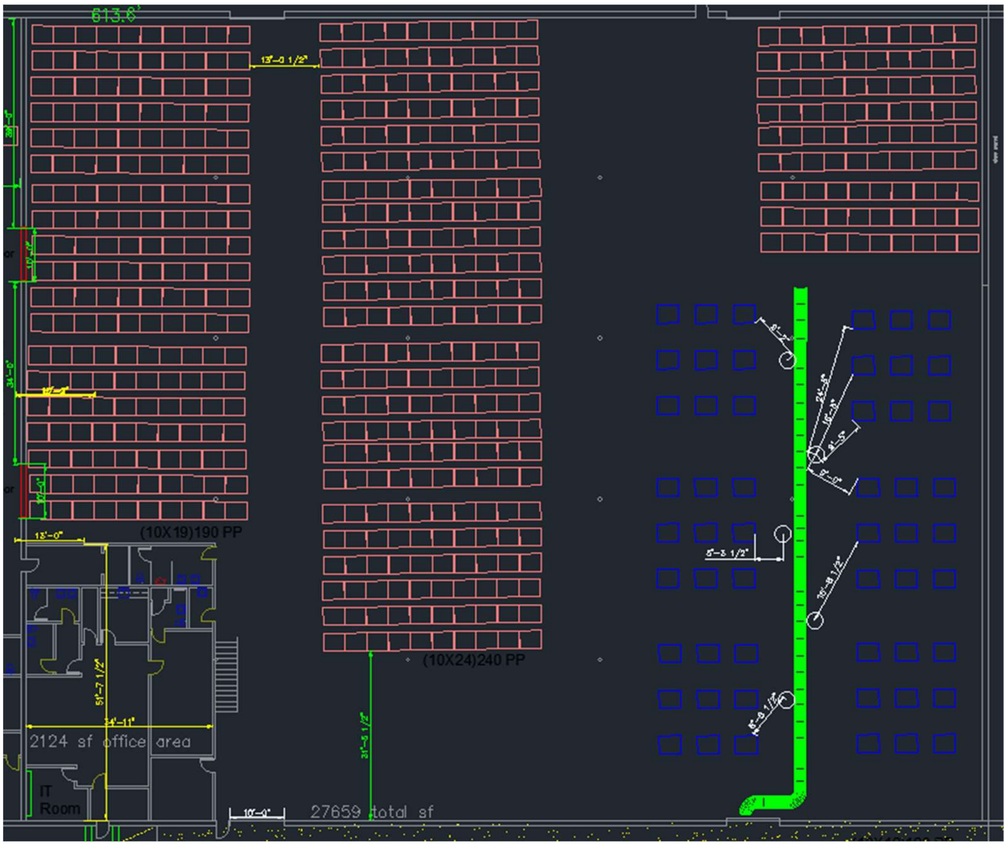


Figure 2.4: Actual Layout of the BB&B warehouse

Shipping Out

A person from the office does the manifest process, meaning that stickers are put on pallets to let the forklifts driver know which ones must be shipped out that day. This person follows a FIFO strategy to mark the pallets except when there are ones with perishable goods like coffee or high demanded goods like baby diapers, which will be sent out first. Two forklifts are in charge of loading the trucks. The first one organizes pallets and brings them closer to the door so the other driver can load it in the right into the truck.

<u>Problems found in this part of the process</u>: Manifesting takes too long. Specifically, the person in charge must look for the oldest date pallet and start marking them, but there is a box limit and a pallet limit set by every store. These two limits often conflict (may reach the box limit but not the pallet limit or vice versa), causing different issues to occur. For example, there may be pallets that cannot be sent out and were supposed to be shipped. Also, as mentioned before, one of the two forklifts is there just in order to organize the pallets.

The main objective for this chapter has been improving the inbound process and the organizing process (redesigning the layout).

Assumptions

Throughout a thorough examination of the Bed Bath & Beyond and Foot Locker warehouse, a fair amount of assumptions were made. These assumptions help the model focus on the processes that are running the most inefficiently. This also helps us distinguish our focus away from the efficient process, so we can focus on what is actually going wrong.

The inbound process for Bed Bath & Beyond begins once a truck arrives in the morning. The process includes 5 sub-processes: unloading, scanning, pulling, building, and then wrapping. Sometimes there is a different amount of temp labor workers doing the tasks each day. For the model to be able to work properly and efficiently, it must be assumed that the same number of workers is working on each process every day. This results in 2 unloaders, 1 scanner, 5 box pullers, and 6 builders/wrappers. Without this assumption the model would be inaccurate, therefore, not returning an optimal solution.

Furthermore, there is no standard procedure for the inbound process. Establishing a standard procedure "... can decrease ambiguity and guesswork, guarantee quality, boost productivity, and increase employee morale" (Brandall 2018). As stated above, there is supposed to be 2 unloaders, 1 scanner, 5 box pullers, and 6 builders/wrappers. The process begins with the unloading of the boxes onto the assembly line. Next, the boxes are scanned into the system and continue down the line. It is at this point in the process where things start to get unorthodox. 5 temp labor workers begin pulling the boxes off from the line and putting them in their designated store area. Some of these pullers will actually start building the pallets, leaving them half built. Then, the builders/wrappers will continue the pallets.

Through our examination, we have also noticed that the pallets will be half wrapped just to move them out of the way. For us to be able to model the process correctly, we must assume that each of the 5 sub-processes occur in that order and do not overlap. This assumption helps make the process as accurate as possible if there were a standard procedure with the processing times we found in our time studies.

The inbound and outbound processes are connected through palletizing from the end of the inbound process. Although they are connected, the processes do not directly depend on each other's processing times. Once a pallet is finished from the inbound process, it is then applied to the manifestation stage, which is started first thing the next day. Crowley ships these pallets out according to FIFO (First In First Out), yet the stores have until 3:30 to cancel an order. Since this process starts the day after the pallets are finished and they have to wait until 3:30 to actually ship them out anyways, we can assume that the processing times do not depend on each other.

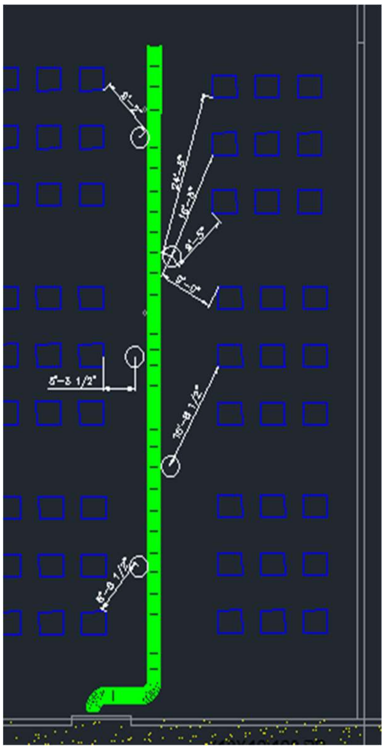
Proposed Solutions/Changes

After a full examination of the Bed Bath & Beyond pool point section of the warehouse, two key opportunities for improvement were clear. The first proposed solution involves improving the efficiency of the inbound process. Currently, cartons are unloaded off from an incoming container onto a conveyor belt. The cartons are then scanned, recorded if damaged, and flow down the belt. Cartons are pulled off the belt and placed next to empty/unfinished pallets that correspond to that carton's designated store. Employees build these pallets as incoming cartons build up, and then finally wrap the pallets when they are built to an appropriate height. In observing this process, we hypothesized that there were an unnecessary number of employees pulling cartons off from the belt. Furthermore, these "pullers" would often throw the cartons over to their designated locations without caution. In order to analyze this process more objectively, time studies were conducted of the sub-processes allowing the creation of an Arena model to represent the total inbound process.

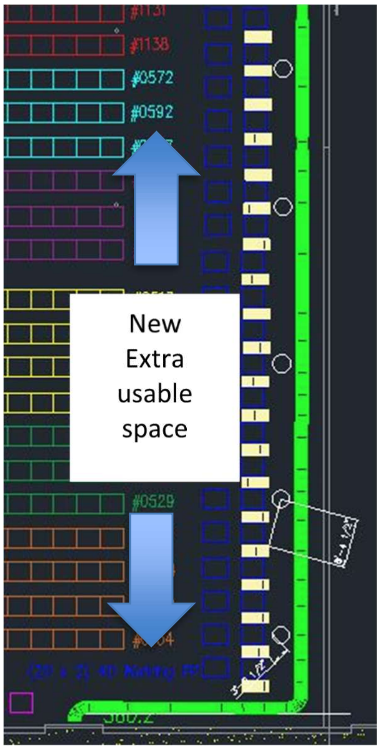
Through load-level analysis of the model, it was determined that—without sacrificing much time—a reduction of temp labor is possible. The cost savings associated with this reduction of labor is shown later in the cost-benefit analysis.

From the time study results, what calls the most attention is that the pulling sub-process time was curiously long and variable. In order to fix this, the implementation of gravity roller branches on the conveyor belt was proposed. With the addition of these branches, pullers can simply grab and place cartons immediately on their respective branch, as opposed to walking all the way the correct pallet. This also presents the "builder" with an orderly systematized queue of available cartons. Establishing a standard procedure for this subprocess will provide "further opportunities to streamline by eliminating unnecessary effort, movement of materials, and other waste" (Bartholomew 2008). The calculation shows that these branches would reduce the pulling time by five seconds, which reduces the overall process time by about 12 minutes. The cost savings associated with this reduction is shown in the cost-benefit analysis.

In the original layout, pallets formed groups against the walls, each group of pallets corresponded to a specific destination store and they were organized by store number. This was extremely inefficient since there were stores with an average low number of orders very close to the outbound door, while busier stores were positioned in the opposite corner of the warehouse resulting in a high time consuming task for the forklift drivers (had to drive all the way from side to side) to load them into the trucks through the outbound door. Therefore, second proposed solution involves re-designing the layout of the Bed Bath & Beyond warehouse. Four new facility designs were tested, all of them aim both to utilize more of the available space in the warehouse and to reduce the average travel distance of a pallet through the warehouse from inbound to outbound.



In order to utilize more of the available space, it was clear that the conveyor belt had to be pushed to the right wall of the warehouse, this would require a few extensions to make it long enough, but it results in a big new usable space available. The figure on the left shows the current position of the conveyor belt vs the figure on the right proposed position against the right wall and the addition of the roller branches previously explained.



All four designs share the same concept of organizing finished pallets according to their route. Stores of the same route are grouped together, and then these routes are organized according to their shipment frequency. The route that is shipped out the most is located closest to the outbound door, and so on. To calculate these frequencies, a year of past data was needed, the results are shown in the figure below:

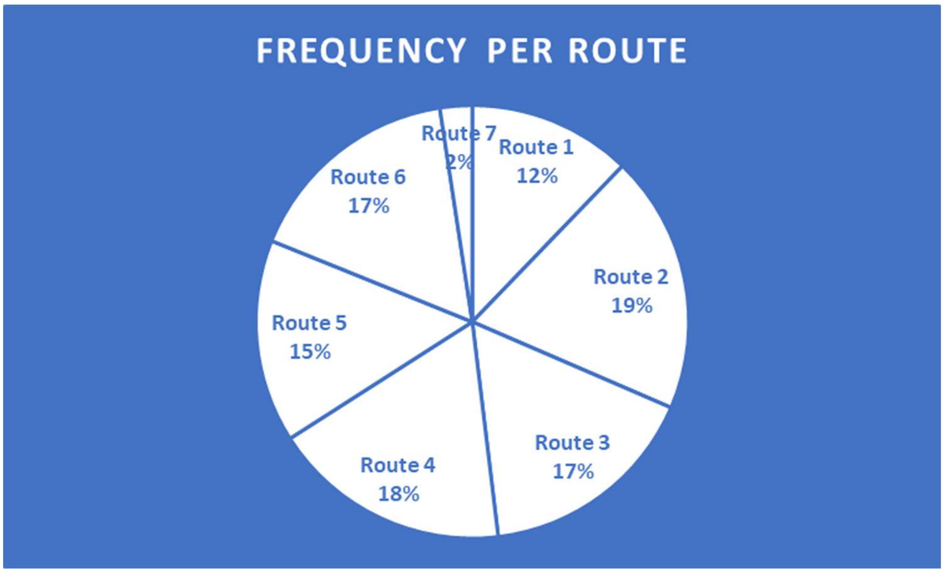


Figure 2.5: Shipping out Frequency per Route

Experts in warehouse management have "suggested that selecting appropriate storage assignment policies (i.e. random, dedicated or class-based) … is a possible solution to improve the efficiency [of the warehouse]" (Chan 2010). Figure 2.5 shows our column design, which organizes routes in vertical lanes, or "columns". In accordance with FIFO principles, the pallet that was wrapped most recently is placed in the back and flows downwards as more pallets are loaded into the lane.

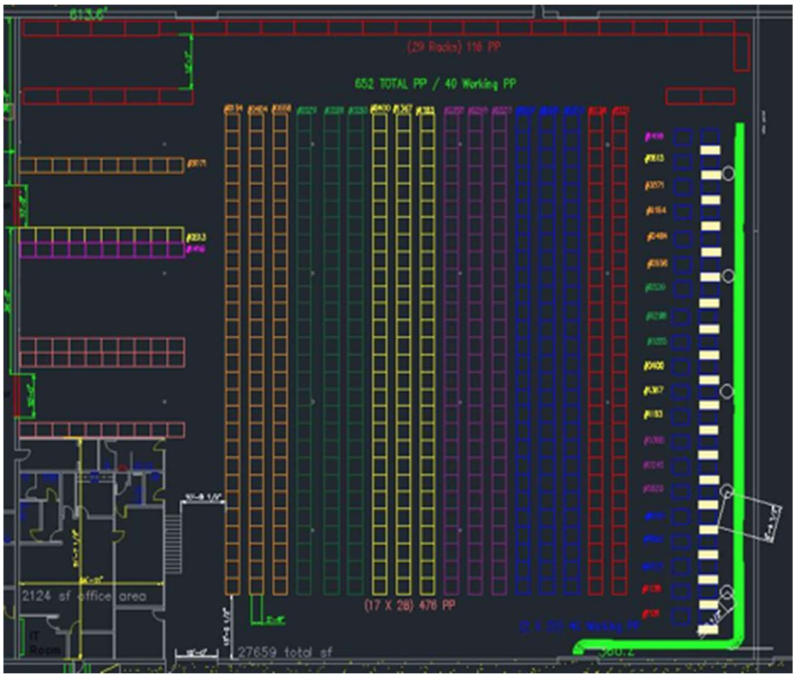


Figure 2.6: Column Design

Figure 2.7 shows our row design, which organizes the routes into horizontal lanes, or "rows", so that finished pallets can be immediately loaded in the right side of the lane, and flow leftwards. This design has a vertical travel lane for forklift drivers, allowing the driver to access pallets near the middle of each store row.

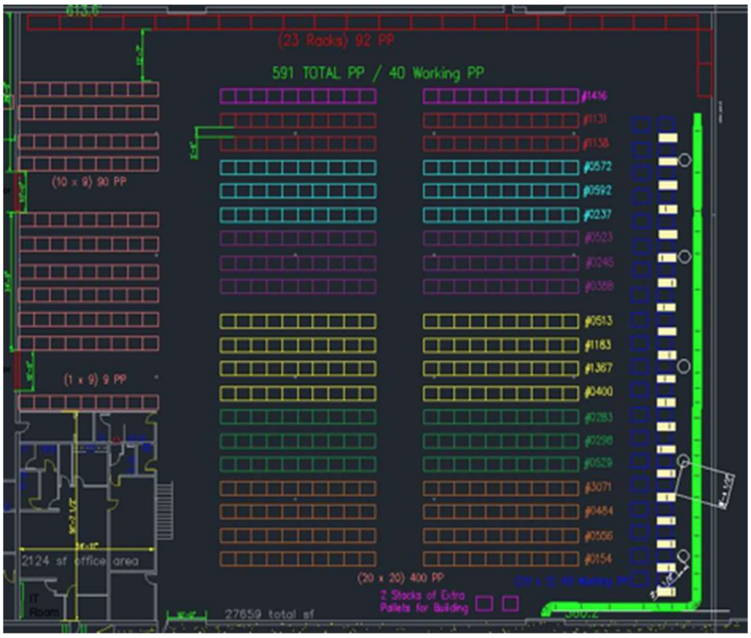


Figure 2.7: Row Design (vertical lane)

Figure 2.8 shows another version of our row design that implements a horizontal travel lane for forklift drivers, following the same pallet flow principles as the first row design.

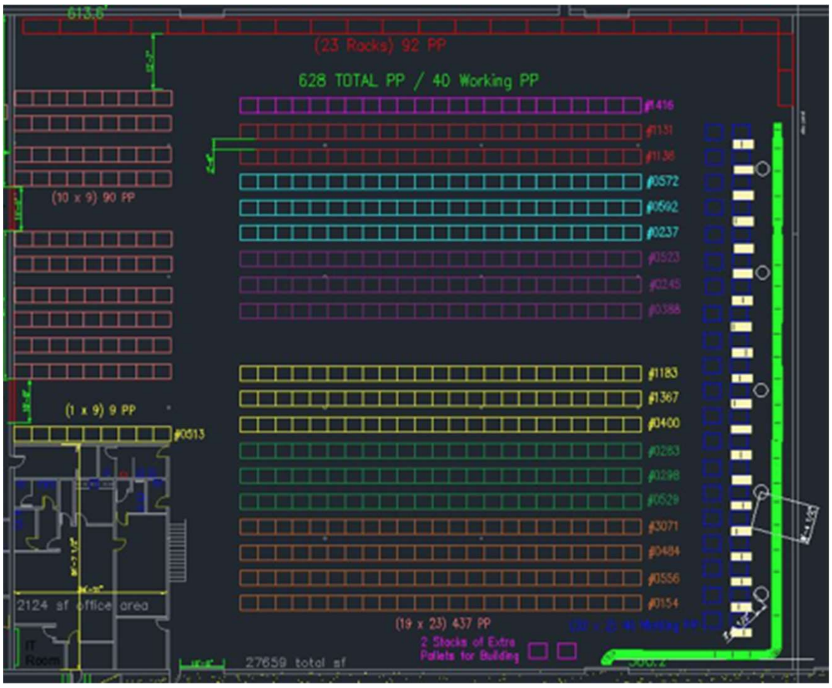


Figure 2.8: Row Design (horizontal lane)

Finally, figure 2.9. shows our carousel design, which follows a similar pallet flow concept as the row designs. This design allows for space for a carousel conveyor belt.

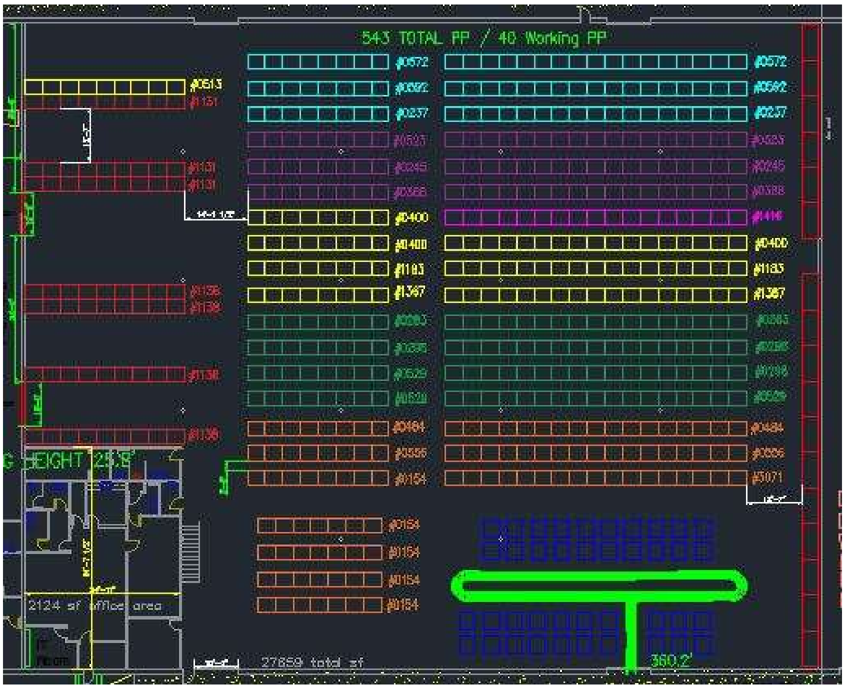


Figure 2.9: Carousel Design

Table 1 shows the capacity changes and average pallet travel distance reductions for each design compared to the original layout.

	Current Layout	Column Design	Row Design (w vertical lane)	Row Design (w horizontal lane)	Carousel Design
Capacity (Pallet Positions)	586	652	591	628	543
Average Pallet Travel Distance	398	375	221	223	352

Table 1: Capacity changes per design

The savings in distance travelled by the pallets automatically translates into time savings and other subjective benefits that come along with a more organized layout discussed later in our cost benefit analysis. In the same way, the capacity increase is useful because it allows the warehouse to take in more potential clients, nevertheless this would only be true if we were working at the maximum capacity level or less. The reality shows that, during peak season, the inventory levels reach over 2.5 times the actual maximum capacity of 586 pallets. In the short time, the possibilities to solve this are very limited since the clients can set by contract a pallet or carton maximum that can be sent by day.

This means, there is no limit on how many cartons Crowley takes in, but there is a tight limit on how many can be sent out, resulting on an overstocking of inventory during peak season. One of the proposed solutions was to charge clients a fee for the pallets that stayed over 48h, but, according to the legal department, this wouldn´t be a plausible solution for a while.

In our cost-benefit analysis, we break down the savings and potential revenue of each design versus the initial investment costs and recommend a design implementation.

Cost - Benefit Analysis

For the first part of the Cost - Benefit analysis an estimation of annual savings was obtained if we were to implement one of the four different designs proposed as solutions: Column Design, Row Design (with Horizontal and Vertical travel lane) and the Carousel Design. In the following table it is shown the process of calculating the savings for each design, eventually arriving to a total estimation of saving per year [$].

In order to arrive to this savings the average distance travelled by each pallet was first calculated, using AutoCAD we obtained a distance travelled (from the point where it is built to the outbound door, through their storing location) for each pallet from the 20 possible stores, then we averaged them according to the frequency of each pallet arriving to the warehouse (all the measurements are in feet with a 15% model allowance). With the average distance travelled per pallet and the forklift speed (~9.8 feet/s), we can easily get the average time to move the pallet.

Finally, comparing the different times to move pallets times the average pallets per day, month and year, we arrive to the total time saved in hours by forklift drivers resulting in $ savings using the data given by Crowley on salaries.

Forklift Time Savings	ACTUAL	Column Design	Row Design (Vertical Lane)	Row Design (Horizontal Lane)	Carousel Design	
Average total distance traveled (per pallet)	398.18	375.2	221.13	223.02	352.78	[feet]
Average time to move pallet	40	38	22	23	36	seconds]
Average time saved (per pallet)	-	2	18	18	5	[seconds]
Average time saved (per day)	-	4	28	28	7	[minutes]
Average time saved (per month)	-	1.28	9.86	9.76	2.53	[hours]
Average time saved (per year)	-	15.36	118.36	117.10	30.35	[hours]
Cost Savings (per year)	-	$ 377.69	$ 2,909.96	$ 2,878.89	$ 746.19	

Table 2. Estimation of total savings per year for each design

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Highlighted in green we can see the best two options: Both Row designs, Horizontal and Vertical lane, with an approximate total saving of $2,900.

In addition to this annual savings, we also estimated potential revenues derived from the capacity increase of our warehouse. In the following table we provided again the four different proposed designs with their respective available pallet position. The average revenue earned from Bed, Bath & Beyond, per pallet, per month is approximately $37, as calculated form the given data. Using the different capacity increases and the average revenue per pallet, we arrive to an estimation of potential revenues.

Capacity Savings	ACTUAL	Column Design	Row Design (Vertical Lane)	Row Design (Horizontal Lane)	Carousel Design
Available pallet positions	586	652	591	628	543
Pallet positions added	-	66	5	42	-43
Percent Increase	0%	11.3%	0.9%	7.2%	-7.3%
Potential Revenue Gained (per month)	-	$ 2,422.20	$ 183.50	$ 1,541.40	$ (1,578.10)
Potential Revenue Gained (per year)	-	$ 29,066.40	$ 2,202.00	$ 18,496.80	$ (18,937.20)

Table 3. Estimation of Potential revenue per year for each design.

Note that in this case, the biggest capacity increase is found in the Column design, with an additional 66 pallet position compared to the actual design. Also note that the Carousel design has 43 less available spaces, resulting in a potential loss.

The costs of implementing any of these four designs are included in the table below. This cost is the sum of the conveyor belt extensions (for the last design only) and the cost of the racks along the walls for extra capacity during peak season.

Table 4.

Costs For Designs	**ACTUAL**	**Column Design**	**Row Design (Vertical Lane)**	**Row Design (Horizontal Lane)**	**Carousel Design**
Racks	$ -	$ 10,121.00	$ 8,027.00	$ 8,027.00	$ 5,933.00
Carousel Extension	$ -	$ -	$ -	$ -	$ 5,332.00
Total	$ -	$ 10,121.00	$ 8,027.00	$ 8,027.00	$ 11,265.00

Estimation of Total costs of implementing each design

From this cost analysis we see that the two most affordable options are the ones highlighted in green, requiring a total investment of approximately $8,000.

Considering all the considerations mentioned (savings, potential revenues and costs) we conclude that the most profitable option is the Row Design (with Horizontal Lane)

- Savings → $2,900/year
- Investment → $8,027
- Potential Revenue → $18,497
- Years to recover the investment → 2.8

For the second part of this Cost - Benefit analysis we focused on the inbound process and its possibilities of improvement. As explained at the beginning of the Proposed Solutions section, we estimated that by adding gravity rolls as branches of the conveyor belt, we could reduce pulling time by five seconds per carton pulled. This allows us not only to reduce time, but to remove some temp labor. In the table below, an estimation of total annual savings is shown removing one, two or three temp laborers.

Inbound Process Savings	ACTUAL	With Gravity Roll Branches	With Gravity Roll Branches Minus 1 Temp Labor	With Gravity Roll Branches Minus 2 Temp Labor	With Gravity Roll Branches Minus 3 Temp Labor	
Process time	86.26	72.45	73.88	79.31	88.08	[minutes]
Time added	-	-	86.35	412.13	937.90	[seconds]
Worker-minutes (per process)	948.91	796.90	738.85	713.83	704.62	[minutes]
Worker-minutes (per day)	3795.63	3187.60	2955.38	2855.32	2818.47	[minutes]
Worker-hours (per month)	1328.47	1115.66	1034.38	999.36	986.46	[hours]
Worker-hours saved (per month)	-	212.81	294.08	329.11	342.00	[hours]
Cost Savings (per month)	-	$ 2,128.09	$ 2,940.85	$ 3,291.08	$ 3,420.04	
Cost Savings (per year)	-	$ 25,537.07	$ 35,290.19	$ 39,492.99	$ 41,040.54	

Table 5. Estimation of Total Savings for different inbound combinations.

All this data is obtained from our Arena simulation by changing the resources and the different process times. Although the data shows that taking out 3 temp labor will save more money than the option of taking out two, we decided to choose this last option (highlighted in green) as our preferred one for two main reasons: first is that taking out 3 people from the inbound process will affect the performance of the rest of the workers, it is a very physical job and performance is not included in our model; the second reason is that taking out two temp labors only differs by approximately $1,500 of savings a year, but we still manage to make it in less time that the actual process.

The costs of implementing the gravity rolls and the conveyor belt extension are shown in the following table.

Costs For Inbound	ACTUAL	With Gravity Roll Branches
Gravity Rolls	$ -	$ 11,534.40
Conveyor Belt Extension	$ -	$ 4,613.76
Total	$ -	$ 16,148.16

Table 6. Estimation of Total Costs of implementing gravity rolls.

Combining both estimations (total savings and total costs), our preferred solution for the inbound process will be: Add Gravity Roll Branches – Remove Two Temp Laborers.

- Savings → $39,493/year
- Investment → $16,148
- Years to recover the investment → 0.4

By combining both solutions (design and inbound process), we will obtain:

- Total Savings → $42,372/year
- Total Costs → $24,175
- Net savings of this combination after first year → $18,197
- Years to recover the Investment → 0.57

Additional Factors

In an examination of the environmental impacts of our proposed solutions, we take a closer look at the outbound side of things. One main objective for our project is to improve the manifest process. One component of our solution is to optimize the outbound pallets, so that the company can ship the optimal quantity of goods given the store constraints. By fully rounding out outbound trucks, we predict that over time, less shipments will be made on average. This leads to reduced carbon monoxide (CO) emissions.

Now, we want to factor in the inbound process. With our proposed solutions, we will reduce the time that forklift drivers are driving around the warehouse with our new layout of the warehouse. “If a forklift is running for a long time or left sitting idle, CO can build up and without working CO detectors can, without warning, create problems for workers and equipment” (Fairchild Equipment 2016). Our selected solution saves us around 118 hours per year of forklift travel time. This results in a large reduction of carbon monoxide emissions in the workplace and the environment as a whole.

In addition to the environmental impacts of our solutions, we also have positive impacts on society as well. Bed Bath & Beyond is one of the premiere retail stores for home goods. They have store locations in the United States, Puerto Rico, Canada, and Mexico. With our improvements, we can help Bed Bath & Beyond continue their mission "to be trusted by its customers as the expert for the home and heart-felt life events" ("Bed Bath & Beyond" 2018). This will ensure that their products are delivered on time and undamaged. As for Foot Locker, our improvements will help Crowley take in more boxes and efficiently distribute them. One of Foot Locker's core values is "Excellence. Strive to be the best in everything we do" ("About Us" 2018). With our proposed solutions we can help Foot Locker continue to honor this core value and become a better company.

Conclusion

With the scope of reducing overall warehouse costs, there were a multitude of potential improvements to be addressed. Thus, it was very important for our team to focus our attention on the specific areas of improvement that we felt would most greatly minimize the total warehouse cost. After an extensive observation and analysis of the facilities systems and how they interact, our team discovered much room for improvement. There were many issues at pool point that our team identified as potential bottlenecks to the system. Within inbound for Bed Bath & Beyond, we observed an inefficient allocation of temporary labor and a lack of standards. We also noticed potential for a layout redesign that could increase inventory storage capabilities. As a result, we decided to focus our project on two major solutions:

- Redesign the facility layout to:
    - Maximize inventory storage capability
    - Minimize the total distance travelled of all the pallets
- Model the inbound process to determine:
    - Optimal number of temporary workers to remove
    - effect of small changes on total process time

After four months of extensive data collection and analysis, modeling, and restructuring of the facility, the team discovered a set of suggestions that we feel will greatly reduce the annual warehouse cost. Firstly, we recommend implementing our "Row Design with Horizontal Travel Lane". Out of all our layout redesigns, this design most greatly minimized pallet travel distance while also maximizing storage capabilities. Additionally, we also recommend adding multiple gravity rolls alongside the conveyor belt. This greatly reduces "pulling time" by reducing the distance a temporary worker has to walk, while also improving quality by reducing the need to throw the boxes.

Lastly, by modeling the inbound process in Arena simulation software, we were able to determine an optimal number of temporary workers to remove from the process, while still maintaining an efficient speed. We discovered that if gravity rolls are implemented, we can remove two temporary workers from the process, and still maintain close to the process' original speed. This reduction in labor has a significant impact on annual costs.

Overall, all our improvements throughout the warehouse aim at the objective of reducing the facilities costs and increasing profits as a result. As a result of our recommendation, Crowley has the potential to save roughly $42k per year. We have great confidence that these goals can be achieved through the successful implementation of our suggestion:

- Implement the Row Design with Horizontal Travel Lane
- Add gravity rolls alongside the conveyor belt
- Remove two temp laborers

All these proposed solutions for the BB&B side of the warehouse are to be replicated in the Footlocker side. Idyllically, if Crowley manages to modify the contracts with the stores making the inventory levels drop, the BB&B side of the warehouse could take in both clients BB&B and FootLocker, leaving the empty side to take in a third potential client and rocket Crowley´s income.

Overall Conclusion

Overall, our improvements and proposed solutions should bring more profit to the Jacksonville 30th warehouse to help with the loss of money it is currently enduring. With the rice warehouse and Bed, Bath, and Beyond warehouse, there are foreseeable improvements in order to save to money and bring in profit. As a team, it was found that Crowley saved the entire warehouse $44,565.75 annually, through the proposed changes to Bed, Bath, and Beyond and Pan American Grain Warehouse. As well, the potential revenue Crowley can bring in through these changes is $57,195.35 annually. However, it will cost Crowley an upfront cost of $25,645.00 in a one-time cost. With the proposed changes, the team was able to achieve decreasing overall facility costs while increasing potential revenues, and standardizing facility processes.

On the 25th April 2019 the results of this project were given to some of Crowley´s stakeholders in their headquarters in Jacksonville, Florida. Shortly after, almost all of the proposed solutions exposed here were already being installed and put into practice.

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