Pharmaceutical Warehouse Product Flow Optimization

Hecyaliz Rubero, Leslie Ann Feliciano, Abneris Ayala and Jannette Pérez-Barbosa
Department of Engineering,
Universidad Ana G. Méndez,
Gurabo, Puerto Rico 00778, USA
Hrubero1@email.uagm.edu.com, lfeliciano80@email.uagm.edu, aayala155@email.uagm.edu
jperez222@uagm.edu

Abstract

The transportation and movement of waste results in extra locating time, materials, and people movement. The company selected produces 25 million tablets per day (9 billion annually). Their high demand results in higher inventory and product movement within manufacturing rooms and warehouses. The established objectives were to optimize the flow of warehouse production by at least 15% and increase operational efficiency also by at least 15%. After implementation, operational efficiency can increase by at least 35%, obtaining an investment return of 178%. Additionally, the objective to optimize the warehouse product flow by at least 15% after the implementations can be increased by at least 24%, obtaining a 3,990% return of investment. The implementations of creating a standard operating procedure, 5s + Visual Aids, train the personnel, maintenance of the forklift and layout analysis will take approximately 6 months to implement the recommended alternatives.

Keywords
Warehouse, Inventory Management, Cost Reduction, Continuous Improvement

1. Introduction
Due to the increase in demand for pharmaceutical products due to COVID-19 related to the Covid 19, the flow of materials has increased considerably. The requisitions of packaging components have been the one that has increased the most. It is necessary to find viable alternatives that help optimize the flow of materials and increase operational efficiency in the warehouse. Warehouse by improving and optimizing the layout of the materials so that the delivery of the components is more effective. This problem is significant they do not know how long it takes the operator to dispatch the packaging components to the packaging lines, and the operator must search in the five warehouses to see where the materials are located to start dispatching the components. The materials in the different warehouses are not segregated. There are mixed materials in the five warehouses within the plant. This makes it difficult to deliver materials when a requisition arrives. Operators must go to different warehouses to complete the delivery; several warehouses are far from the packing area where it is the area with the highest flow and delivery. This takes more time to complete the delivery than if the packaging materials were close to the area.

1.1 Objectives
The two objectives established were: optimize warehouse product flow by at least 15% and increase operational efficiency by at least 15%. The expected deliveries were optimized material flow to reduce costs and time, improve and standardize FIFO system and culture within warehouse, production rooms and shipping area. Inventory Management and for the current process analysis to provide process flow analysis and continuous improvement opportunities.

2. Literature Review
The literature review will focus on the methods of designing efficient warehouse layouts including workflow design, logistic network planning, order picking efficiency amongst others. Understanding how the facilities and layout

planning affects warehouses is critical for process improvement and future optimizations. Zakirah (2018) supports that service operation dedicated to offshore and onshore services observed that the warehouse system doesn't fit with the layout. The methods of modified systematic layout planning utilize activity relationship charts and activity relationship diagrams. Strategies in logistics planning with a focus on planning logistics networks, warehouse networks and transportation networks according with Gleissner (2013) means dealing with complex planning and decision problems. When storage assignment policies are used correctly, it is possible to employ the smallest amount of storage space to achieve the goal with the shortest total journey distance, which has a direct impact on order selection performance. According to Hsieh (2006), good routing planning can reduce total order picking costs while also achieving the goal of improving picking performance per unit time. As a result, this study investigates the effects of elements such as the amount and layout type of cross aisles in a warehouse system, storage assignment policy, picking route, average picking density inside an aisle, and order combination type on order picking system performance.

To perform sustainable improvements, tools such as activity relationship charts, fishbone and statistical analysis were applied to obtain optimum designs of a warehouses. Two publications that make ample use of statistical and process improvement tools are (Pérez-Barbosa, et all, 2021), where statistics and experimental design are used to optimize process time, and Cabrera (2021) that performs process improvement, including cycle time reduction, in a service facility. Both publications offer significant improvement with the application of DMAIC and lean tools.

3. Methods

The combination of several techniques both qualitative and quantitative, used to optimize warehouse product flow & increase operational efficiency. The methods consist of extracting the historical data, a time study and work sampling carried out a with a stopwatch to obtain the times it takes the operator to dispatch the packaging components to the packaging lines department from the five warehouses. A statistical analysis was performed to determine if there was a standardization between the time to deliver the packing components to the packaging lines department or if there is a variance in time. The tools & methods used were to validate if the data follows a normal distribution, ANOVA, I-MR & Moving range and capability sixpack.

For the root causes, the tools used were Fishbone, 5 Why's, Failure Mode Effects Analysis, activity Relationship chart, decision matrix and Re-order Point & Economic Order Quantity. Also, an economic impact (return of investment) (ROI) and payback were calculated to demonstrate the percentage of improvement across the warehouses to the packaging lines. As part of the project management, the implementation plan was performed utilizing Gantt Chart, visual Aids and Checklist for the completion of the proposed process optimization and standardization.

4. Data Collection

A stopwatch time study (Freivalds & Niebel, 2008) was carried out to obtain the times it takes the operator to dispatch the packaging components to the packaging lines department from each of the 5 warehouses in the plant. The sample size calculation shows that 45 observations were required, and 57 observations were collected. In this study, the goal was to eliminate non-value adding activities, defined by Wortman (2007) as those that the client doesn't want to pay for, does not transform the product, and are not made well the first time. There is an average of 16 hours for Waiting waste. The wastes with more opportunity are waiting & transportation since the warehouses are far away from the packing lines department, thus the operator requires more time to deliver the packing components to the lines. Observations that were collected with the Waste Walk tool are summarized in Table 1.

Waste	Observation
Overproduction	The warehouse had Redundant storage (Office Supplies) in areas closer to Packing Lines.
Waiting	Waiting for approvals, signs, searching in the warehouses for the packing components.
Transportation	The warehouses are far away from the packing lines department; the operator requires more time to deliver the packing components to the lines.
Inventory	Accumulation of unnecessary inventory near to the Packing lines.
Motion	Walking Between the five warehouses that don't add value to the customer.

Table 1: Summary of Waste Walk Observations

5. Results and Discussion

The variables are the distance between the warehouses (X) that affects the time to deliver the components to the packing lines (Y). Since the company has packing components in the five warehouses, a model Was recreated with the actual status using the historical data analysis. The analysis performed includes:

- Measuring the time to deliver the components between the warehouses.
- Measuring the frequency related to the order requested from the packing lines department.
- 5S Audits, layout analysis (Activity relationship charts)

5.1 Numerical Results

The next step is to compare the mean travel time from warehouses. One technique frequently used is ANOVA, which differentiates statistically the mean values. Pairwise comparisons are also used and serve to pinpoint specific data groups that are similar (Montgomery & Runger, 2010). Of the several existing methods, a Tukey Pairwise Comparison was performed in Minitab to confirm the variability in time of the warehouses to packing lines. It is concluded from the Tukey Comparison in Figure 1 that the warehouses 1, 2, and 4 are not significantly different between them, but ~~the~~ warehouses 5 and 3 are significantly different between each one.

Grouping Information Using the Tukey Method and 95% Confidence

Warehouse	N	Mean	Grouping		
Warehouse 5	11	286.9	A		
Warehouse 3	11	226.64		B	
warehouse 4	14	164.96			C
Warehouse 2	8	137.40			C
warehouse 1	13	133.57			C

Means that do not share a letter are significantly different.

Figure 1: Tukey Pairwise Comparisons from the different warehouses to packing lines

Statistical process control charts were used to determine special causes within warehouses (Montgomery, 2009). In this instance, IMR charts were used to analyze the trip-by-trip changes. From Figure 2, it can be observed that Warehouses 2 & 4 have observations out of the control limits in the Moving Range Chart. The Warehouse 2 observation 1 is 197.40 seconds (197.40 seconds = 3.29 min) & W4 observation 14 is 2.52 seconds (2.52 seconds = 4.20 min). These observations are out of control because the associate stopped the process to search for information (sign a paper from the Packing line department and search in the "Picking List" where the material is in the warehouses).

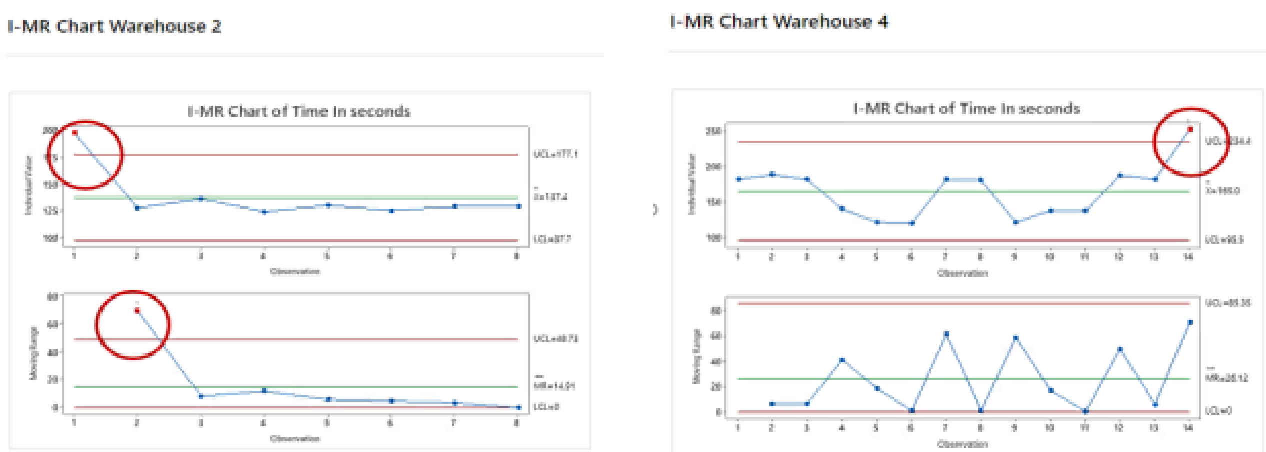

Figure 2: I-MR Chart Warehouse #2 & Warehouse #3.

The information was obtained from the "Picking Lists", the orders requested from the packing lines department. Warehouses 1 (906 Frequency) & 3 (793 Frequency) were the most visited in the last 4 months as seen in Table 2. The result for this analysis is Warehouse 3 has a frequency of 793 times and is the warehouse farthest away from the packing department. The other Warehouse that can improve is Warehouse 4: it has less frequency than warehouse 2, which is closer to the packing lines department. Also, another result with this analysis is warehouse 5 which doesn't have packing components materials. The Low distance score for the actual Layout is 3,258, as seen in Table 2. The information utilized was the frequency vs distance between the warehouses to the packing line department.

Warehouse	Bottle 1	Bottle 2	Bottle 3	Bottle 4	Total
1 (194 ft 8 in)	228	263	176	239	906
2(327 ft 8 in)	31	13	0	4	48
3 (440 ft 7 in)	279	357	99	58	793
4(426ft 4 in)	232	93	17	17	359
5(426 ft 4 in)	0	0	0	0	0
Total	770	726	292	318	

Table 2: Frequency June-July – August – September 2021 & the distance from the packing lines (3,258 LDS)

Department	Rect Distances	Charge	LDS
Warehouse-1	1	906	906
Warehouse-2	1	48	48
Warehouse-3	2	793	1586
Warehouse-4	2	359	718

Table 3: Low Distance Score for the actual Layout.

5.2 Graphical Results

The historical data analysis showed that the main identified problems were:

1. There are same components in different warehouses without segregation – Analyzing the frequency. The four types of bottles are located mixed in the warehouses, resulting in a Low distance score of 3,258.
2. There are packaging components away from the packaging area – There are packing components in ~~the~~ warehouses 3 and 4 resulting in being 440 ft and 426 ft away from the packaging department by shipment vs ~~the~~ warehouse 1, where the distance is 194 ft from the packaging line department.

To better understand and identify the problems a root cause analysis was performed. In Figure 3 you can identify the following potential root causes: mixed material, poor identification, distance between the warehouses to packing line department, Lack of standard procedure and the transportation of the materials. Also, in Figure 4 are the potential root causes for the components being in different warehouses without segregation: Office supplies near to the packaging area, The layout being poorly detailed and mixed stacking materials.

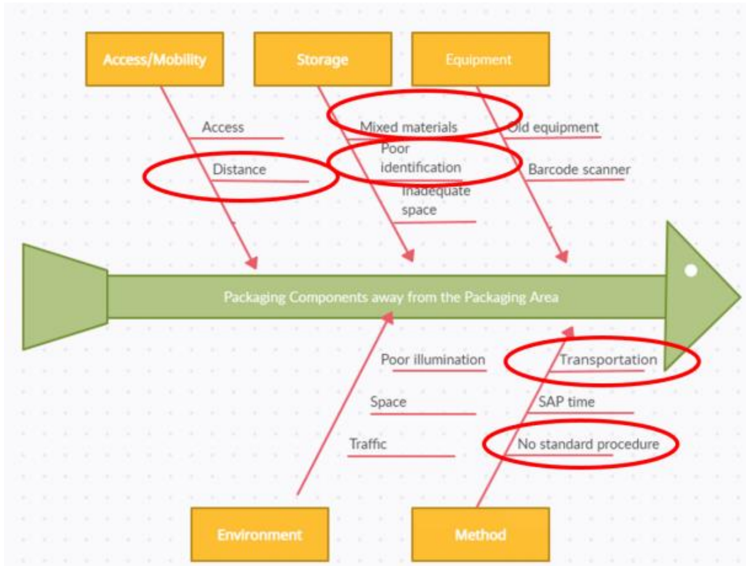

Figure 3: Fishbone - There are packaging components away from the packaging area.

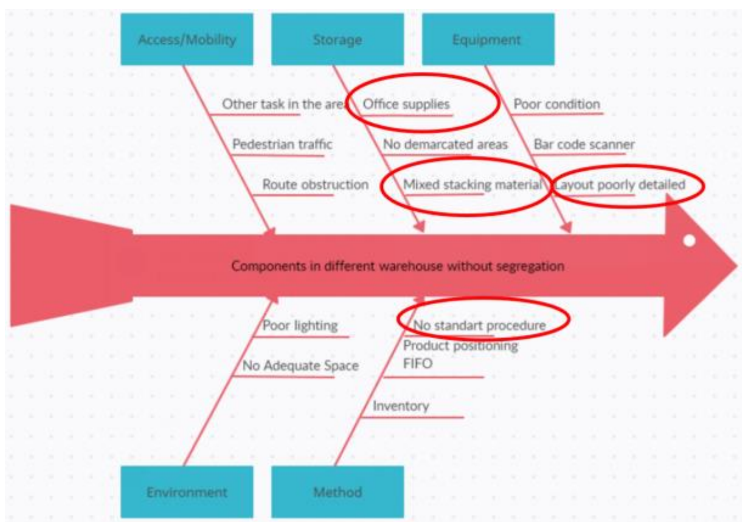

Figure 4: Fishbone – components with no segregation

5.3 Proposed Improvements

For problem #1, the 3 main alternatives provided are: create a standard operating procedure, perform a 5s + Visual Aids in the warehouses on a monthly basis and provide training to the personnel. If the company implements all ~~the~~ 3 alternatives, they can obtain a 58% of improvement. The cost to create a standard operating procedure is approximately $3.6K, for the 5s + Visual Aids $600, training the personnel $1.2K, and implementing all the alternatives is approximately $5.4K. These statements can be found on Table 4. From problem #2, the two main alternatives recommended were: maintenance frequency of the Forklifts and layout design. If the company implements ~~all~~ the 2 alternatives, they can obtain a 64% ~~of~~ improvement. The cost to maintain is $3.5Kin a monthly basis and the layout design is $3.6K. If the company implements the 2 main alternatives, the cost is approximately $7.1K.

Alternative	Cost	Implementation Time	Advantages	Disadvantages	% Objective Improvement
Create Standard Operating Procedure	$3.6K	3 weeks	Reduce Waste of transportation	SAP permits to put all components in the 5 warehouses.	19%
5S + Visual Aids in the Warehouses	$600	1 Week	Standardize Sustaining the Warehouse & Visual Aid to identify resources	5s inaccurate measurements, label design memorization, and insecurity of it being correct due to automatization.”	19%
Train personnel	$1.2K	2 Weeks	Personnel will follow the new method (Sort, set in order, shine, standardize, and sustain the warehouses)	Waste of space and excessive or unnecessary supply	20%
All of the above	$5.4K	6 Weeks	Implement all the alternatives	Resources (Personnel & time) not available.	58%

Table 4: Alternatives for Problem #1: components in different warehouses without segregation.

Alternative	Cost	Implementation Time	Advantages	Disadvantages	% Objective Improvement
Maintenance frequency (Forklifts)	$3.5K	3 Months	Increase safety and reduce stopping operations	Increased cost and personnel for the maintenance.	24%
Layout Design	$3.6K	3 weeks	Product transportation is reduced & increase efficiency	Requires design, time, personnel & extra costs.	40%
All of the above	$7.1K	6 months	Reduce time, transportation & re-work	Resources (Personnel & time) not available.	64%

Table 5: Alternatives for Problem #2: Packing Components away from the packing area

5.4 Validation

Alternatives were selected by the client according to the benefits presented, as seen in Table 6.

Problem(s)	Alternative selected	Payback in Year 1	Return of Investment (%)
1	A4	$3,240	178%
2	A3	$138,100	3,990%

Table 6: Selected alternatives for each of the main problems

For problem 1, all the alternatives mentioned are selected (Realization of checklist 5s monthly, develop a standard operating procedure, train the personnel). Table 7 shows return of investment for the 5s + Visual Aids is 257%. The return of investment to create a standard operating procedure is 67%, if the company implements this alternative separately, they will see revenue in year 2. The ROI (Return of investment) to train the personnel is 400%. Finally, implementing all above alternatives the return of investment is 178 %. The second problem also selected all the alternatives presented: Maintenance (Forklifts and Layout design). In Table 8 you can see return of investment for the Maintenance is 329%, and for the Layout design it's 3740%. The ROI (Return of investment) for implementing all of them is 3990%.

Alternatives	ROI
5s (A1)	257%
Standard Operating Procedure (A2)	67%
Train Personnel (A3)	400%
All Above (A4)	178%

Table 7: Return of investment and Payback in Year 1 for problem #1.

Alternatives	ROI
Maintenance (Forklifts) (A1)	329%
Layout Design (A2)	3740%
All Above (A3)	3990%

Table 8: Return of investment and Payback in Year 1 for problem #2.

To make a new layout, the following things are taken into consideration: optimum space needs to be allocated to the packing materials, proper safety measure for the operators, compliance with the standards and regulation by the pharmaceutical (ergonomic, materials, protection, sustainability). The method to be presented in Figure 5 comes out of Permatasari, 2020. This is used for the following. We followed these steps: performed an activity relationship chart, draw the actual layout with the distance in feet and perform a Low Distance Score analysis for the actual layout and proposed layout (Figure 6 Actual Layout and Table #3) (Figure 7 Proposed layout and Table #9).

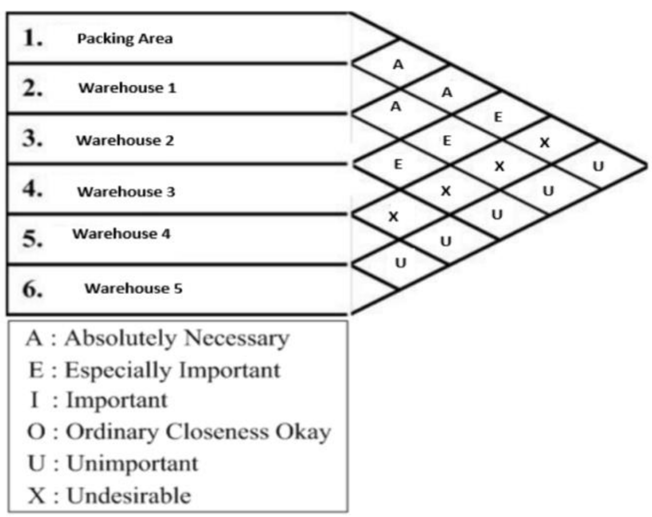

Figure 5: Activity relationship chart

The activity relationship chart in figure 6 represents the departments of packing area and warehouse 1 to 5. Defining by Necessary, Especially Important, Important, Ordinary Closeness, Unimportant & Undesirable. Warehouses 3 & 4 obtained an Unimportant score and warehouse 5 obtained Undesirable. Also, packing area, warehouse 1 and, 2 obtained Absolutely Necessary.

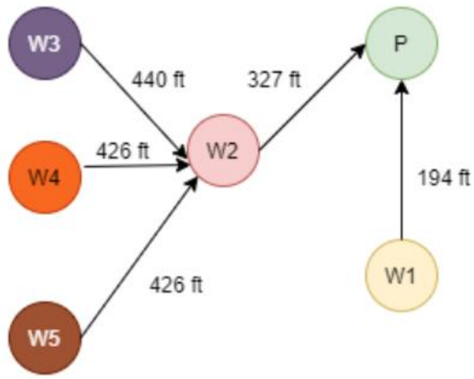

Figure 6: Actual Layout -product flow

The operator delivers the packing components from Warehouse 1 to Warehouse 5. The Low distance score for the actual Layout is 3,258. This is the base to compare with the model proposed.

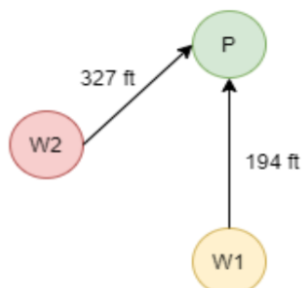

Figure 7: Proposed Layout

The model proposed consist of reducing the material flow to Warehouse 1 & 2. With this model the low distance score decreases to 2,106, comparing with the actual material flow 3,258, for an improvement of 35%. The proposed layout consists of the operator should looking for the packaging components in Warehouse 1 and 2. The operator doesn't have to search for the materials in warehouse 3, 4 & 5 with this model. This study meets the second objective: the optimization of warehouse product/production flow by at least 15%. If the packaging components are in Warehouses 1 and 2, there will be a possible improvement of 35% when compared to the actual layout. Comparing with the first layout, now the operator should look for the packing components only in Warehouse 1 & 2. The largest percentage of waste is in overproduction, transportation, waiting, inventory, and motion. By improving transportation and motion, the percentage of waste can be reduced from 62% to 38%; since all the packing components (4 types of Bottles) are in the same area, identified properly and near to the packing area department. Following the evaluation of: Sorting, setting in order, shining, Standardizing of the Warehouses, a new process is proposed in Figure 8.

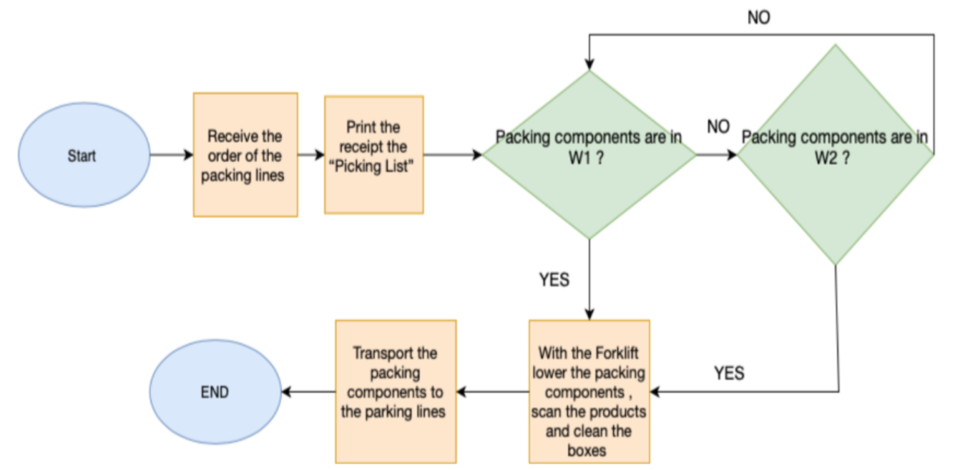

Figure 8: Flowchart Proposed

The company will implement all the alternatives presented in this project as shown on the timeline in Table 9. The layout design will take 6 months, since they accommodate all the packing components in Warehouses 1 & 2.

Implementation Plan							
Team	Activities	Jan	Feb	Mar	Apr	May	Jun
Administration	Create Standard Operating Procedure	3 weeks					
Administration	5s + Visual Aids in the Warehouses	1 Week					
Administration	Train Personnel	2 Weeks					
Technician	Maintenance Frequency (Forklifts)	3 Months					
Operators	Layout Design	6 months					

Table 9: Implementation Plan

6. Conclusion

This paper demonstrates the process that using continuous improvement tools in the pharmaceutical Industry can help to identify defects in the warehouse operations related to waste in transportation, overproduction,waiting, inventory management and motion. Since they don't stop, operations don't notice the no add values in the operations. The objectives of Increase operational efficiency at least 15% and Optimized warehouse product flow 15% were achieved the Table 10 demonstrates the summary of the project achievements.

Objetives	Baseline	Achieved	Differences	Objective Accomplished?
Increase operational efficiency at least 15%	15%	35 %	20%	Yes
Optimized warehouse product flow 15%	15%	24%	9%	Yes

Table 10: Summary of project achievements

Acknowledgements

We would like to thank our professor Jannette Pérez for her support, and for presenting this opportunity for us to continuously improve ourselves. When we work in a team, we can develop big changes for our community. Her guidance has been key in our professional careers. Also, we want to thank you the pharmaceutical company for the opportunity, and their guidance during the process.

References

Bintang Bagaskara, K., Gozali, L., Widodo, L., & Jusuf Daywin, F. (2020). Comparison study of facility planning and layouts studies. *IOP Conference Series. Materials Science and Engineering, 852*(1), 12105. https://doi.org/10.1088/1757-899X/852/1/012105

Cabrera, J., Rivera, D., Tapia, D., & Pérez-Barbosa, J., (2021). Improvement of Receiving and Handoff Service Times at a Car Dealership. Proceedings. First Central American and Caribbean International Conference on Industrial Engineering and Operations Management Conference

Freivalds, A., & Niebel, B.W. (2008). Niebel's Methods, Standards, and Work Design.

Hsieh, L., & Tsai, L. (2006). The optimum design of a warehouse system on order picking efficiency. *International Journal of Advanced Manufacturing Technology, 28*(5), 626-637. https://doi.org/10.1007/s00170-004-2404-0

Montgomery, D. C. (2009). Introduction to statistical quality control. John Wiley & Sons, Inc.

Montgomery, D. C., & Runger, G. C. (2010). Applied statistics and probability for engineers. John Wiley & Sons.

Permatasari, A. A., Pramandha, F. N., Karima, M. I., & Santoso, E. (2020). Re-layout facility to minimize defects and production cost in PT. sendanis jaya makmur. IOP Conference Series. Earth and Environmental Science, 426(1), 12166. https://doi.org/10.1088/1755-1315/426/1/012166

Pérez-Barbosa, J., Rivera, D., Rodríguez, R. E., & Rosa, R. G. (2021). Optimization of parachute flying time and selection of best model. IIE Annual Conference. Proceedings, 453-458.

Wortman, B., & Quality Council of Indiana. (2007). Lean six sigma primer. West Terre Haute, Ind: Quality Council of Indiana.

Zakirah, T., Emeraldi, R., Handi, O. M., Danil, D., & Kasih, T. P. (2018). Warehouse layout and workflow designing at PT. PMS using systematic layout planning method *IOP Conference Series. Earth and Environmental Science, 195*(1), 12026. https://doi.org/10.1088/1755-1315/195/1/012026`

Biographies

Abneris Ayala Pedraza has bachelor's degree in Industrial Engineering from Ana G. Méndez University, Puerto Rico **and is currently** completing a master's degree in Engineering Management from Ana G. Méndez University. Currently holds LSS White Belt, LSS Yellow Belt, Project Management Essentials, and Protecting Human Research Participant certifications. Her engineering research experiences include competing in U.S. Department of Energy: Marine Energy Blue Economy winning 3rd place, Honeywell: UAV Navigation Challenge wining 1st place and performed additional investigations in chemistry and engineering areas. Has participated in engineering internships and coops experiences in pharmaceutical and medical devices industries. Has professional experience working as an Industrial Engineer performing and leading lean six sigma cost reduction projects. The main areas of interest are validation, project management and continuous improvement.

Leslie Ann Feliciano has a bachelor's degree in Chemistry from the University of Puerto Rico, Mayagüez and a bachelor's degree in Industrial Engineering from ~~the~~ Ana G. Méndez University, Puerto Rico and is currently completing a master's degree in Engineering Management from Ana G Mendez University. Currently holds LSS Green Belt certification, White Belt and Biotechnology certification. Professional experience as a Computer System Validation Specialist, Manufacturing Specialist and Quality Engineer consultant for several pharmaceuticals and medical device industries. Performed equipment validations, system and process validations in Puerto Rico and United States. The main areas of interest are project management, automation area, process improvement, and validations areas.

Hecyaliz Rubero Colón has a bachelor's degree in Industrial ~~and~~ Engineering from ~~the~~ Ana G. Méndez University, Puerto Rico and is currently completing a master's degree in Engineering Management from Ana G. Méndez University. Currently holds LSS White Belt, Yellow Belt & Project Management Essential certifications. She is a dynamic scholar and professional whose abilities shine in a competitive, innovative, and creative environments. The main areas of interest are Root Cause Analysis, Business Decisions, Optimization & Standardization. She was recognized with the with the Honor Student Scholarship at UAGM, Gurabo. In 2021, she was the Webmaster of the Institute of Industrial and System Engineers Taínos Chapter #698. Her previous engineering experience includes roles as an Engineer Assistant, Information System Consultant & Tier 1 Security Information Analyst. She has worked in companies of Technology, Pharmaceutical Industry and Capital Improvement Programs.

Jannette Pérez Barbosa, PE is an assistant professor in the Industrial and Management Engineering program at Ana G. Méndez University, Puerto Rico. She has bachelor's and master's degrees in Industrial Engineering from the University of Puerto Rico, Mayagüez, and is currently completing a Ph.D. in Systems Engineering from Colorado State University (CSU). As the Senior Design Project (Capstone) instructor, her students' projects have been recognized for their excellence in engineering competitions in Puerto Rico. In 2021, a group of her students participated for the first time in the IISE Design Project Competition. She is a licensed engineer and the coordinator of the FE and PE exam reviews for Puerto Rico's engineering association (CIAPR). Her research interests include decision-making methods, engineering education, and process improvement. She was recognized as UAGM's Distinguished Engineering Professor in 2018 and IISE's Southeast Region Outstanding Faculty Advisor in 2021. She is also 2020 CIAPR's Distinguished Industrial Engineer. Her previous engineering experience includes roles as a Technical Service Specialist, Statistician, and Industrial Engineering team leader at Pfizer, where she received several site and corporate awards. Additionally, she has served as a trainer and consultant for several manufacturing and service companies on the island.