

# **Ecomspaces: Warehouse Workflow Optimization**



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### **Abstract:**

The following report provides consultation and analysis for Ecomspaces, a bootstrapped parcel forwarding and fulfillment company based in Atlanta, GA. Implementing Industrial and Systems Engineering concepts and knowledge gained, most notably six sigma tools and the DMAIC process, our key focus was to better utilize the facility floor space to improve productivity, optimize the workflow by standardizing safety and maintenance procedures, and create benchmarks for the current state of the operation for continuous improvement purposes. The overall goal of this project was to facilitate the overall growth and sustainability of Ecomspaces business operation, while accommodating for their fast-growing customer demand.

## Executive Summary

Ecomspaces specializes in fulfillment services for e-commerce businesses, providing as a full-service provider for storage, shipping, and rental office space solutions. RelayShopUSA focuses on parcel forwarding services to both domestic and French international customers. The two services operate under the same roof and utilize near-identical resources. For the sake of simplicity, both services will be referenced throughout this document as *Ecomspaces*.

Ecomspaces has been experiencing difficulty in accepting and handling a greater volume of clients due to infrastructure-related problems within their warehouse. Management is seeking the development of both scalable and sustainable systems to cut costs and achieve long-term growth for their operation.

This report summarizes the strategies that have been proposed and implemented by the Optimized Brain E-spaces team to benefit the overall warehouse operation through (1) the implementation of layout changes to optimize workflow and to regain floor space throughout the facility, (2) the standardization of the safety, housekeeping, and maintenance of the warehouse, (3) the development of accessible and robust key performance indicators and standard operating procedures necessary for process improvement.

These goals have been accomplished through the collection and statistical analysis of time and motion study data, alongside raw historical data obtained from reports generated by Ecomspaces warehouse management systems. Several tools and methodologies have been utilized in this scenario which include (1) project management tools such as project charter, work breakdown structure, Gantt chart, financial planning/budgeting, and economic analysis, (2) Six Sigma tools such as pareto charts, process flowchart, critical to quality, key process indicators, cause and effect diagram, and the DMAIC process, and (3) traditional industrial and systems engineering tools such as time and motion studies, spaghetti diagram, and system modeling/simulation.

Our team's design proposal is based on the evaluation of both current-state and possible future-states of the warehouse through computer modeling with ARENA simulation. This information was supplemented with on-site visits to conduct interviews for management and employees, completed audits for OSHA requirements pertaining to warehouse safety and maintenance, and foundational understanding of the work-processes within the operation to develop baseline productivity levels and standard times for each station.

Regarding our team's three suggested facility layout changes, we recommend the implementation of our proposed solution A, involving the consolidation of oversized/palletized inventory to be placed adjacent to the wall between the receiving and loading docks, and to add a fourth shipping in the dock 2 area (not being utilized previously). This optimal solution was identified through TOPSIS, with a detailed analysis provided in Appendix L.

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# Chapter 1: Project Background

## 1.1 Introduction

Ecomspaces was founded after the successful Relay Shop USA (RSU) business. RSU offers fast, reliable, and efficient package, mail and freight forwarding to over 220 countries. Many products are either less expensive or can only be found in the United States, but sellers and websites do not always ship directly to international addresses. RSU allows its customers overseas to be able to (1) shop websites like eBay, Amazon and Walmart and other small businesses, (2) have their purchases shipped to the warehouse, and (3) have their items aggregated into one order and shipped internationally to the customer, while offering services such as condensed packaging and additional protection.

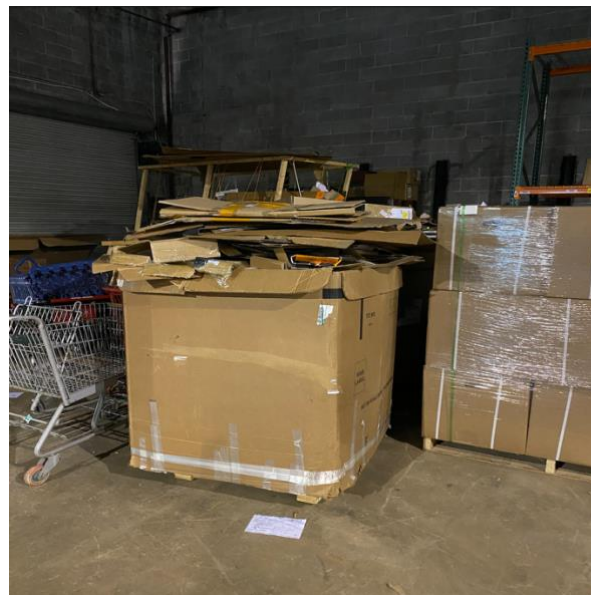
Ecomspaces is a bootstrapped parcel forwarding and fulfillment organization providing e-commerce entrepreneurs with comprehensive services, facilities, support, and the community needed to efficiently operate and expand their online businesses. Over 175,000 users are currently being provided storage facilities along with shipment services attached with fees.

## 1.2 Initial Findings and Project Focus

The focus of this project will be to apply lean six sigma concepts and methodologies to the 19,553 ft<sup>2</sup> facility, with the overall goal of developing sustainable and scalable systems for future operations by regaining floor space and developing performance indicators. The current warehouse conditions indicate that Ecomspaces is incapable of accommodating for a higher volume of clients and shipments due to a lack of standardization and organization within the facility, along with excess waste and debris found throughout the warehouse.



*Figure 1: Excess Clutter in Aisle D*



*Figure 2: Waste Blocking Dock 2*

Figure 1 showcases the excess clutter and current condition of aisle D located in the middle of the warehouse. This aisle was originally intended to store additional shelves for inventory as the business continues to grow. Currently, the aisle holds overstock facility materials such as large boxes, palletized inventory, and waste, which accounts for 883.32 ft<sup>2</sup> of the total 11309.16 ft<sup>2</sup> available. This aisle has no organizational structure and is unsafe for any warehouse facility personnel to walk through.

Figure 2 depicts the current condition of dock 2 located in the back corner of the warehouse, with debris blocking access to the dock door. This space is currently occupied by 486 ft<sup>2</sup> of waste, serving no purpose to the operations of the warehouse. Additionally, the dock 2 door is defective due to inactivity and lighting in this corner of the facility is dim.

### 1.3 Project Background

Ecomspaces continues to grow its business and plans to expand on the number of orders shipped daily to their customers for both the order fulfillment and parcel forwarding services they provide. It has been established and alluded by the owner of Ecomspaces that the warehouse layout needs to be optimized to provide a solid foundation to allow for scalability. We plan to accomplish this by improving the facility organizational layout to optimize space utilization which will allow for improvement of worker productivity and promote a safer work environment.

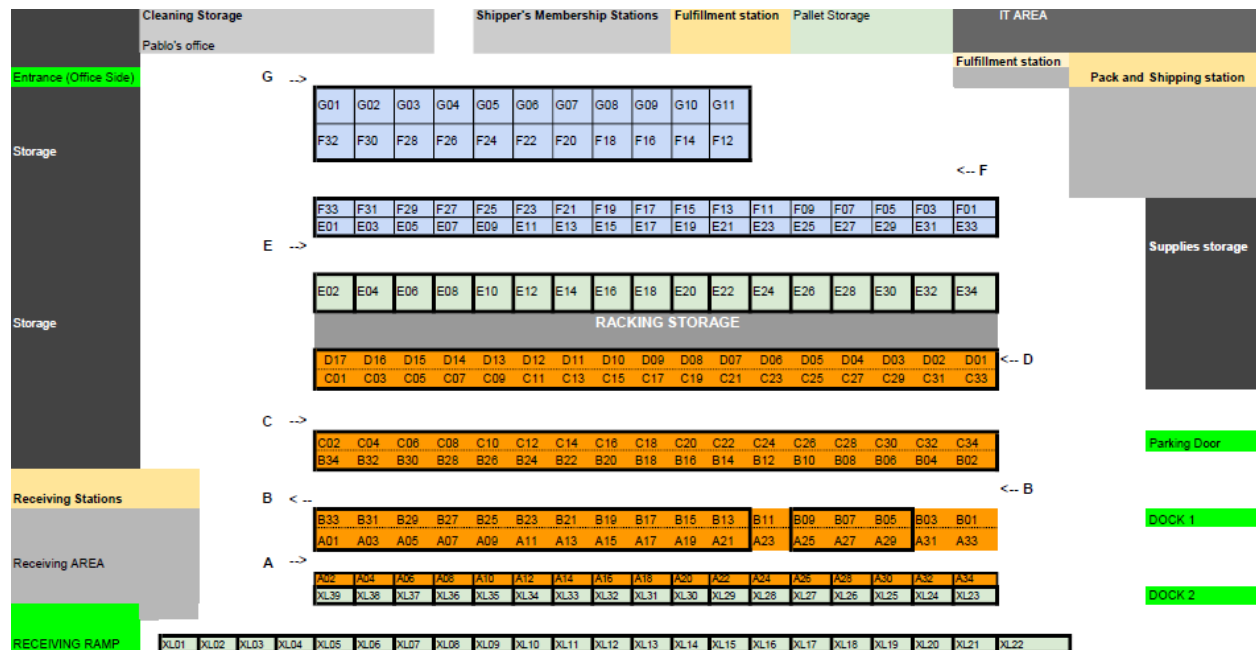


Figure 3: Ecomspaces Current Layout

To understand the scope of the problem, root causes analysis was conducted to find the main issues causing the overall inefficiency in the warehouse. Initially, the owner provided a map of their warehouse layout to showcase the current arrangement of their workstations and rack storage. However, after conducting an investigation within the warehouse, the figure above does

not provide a clear visualization and clarity about the situation in the warehouse. The current situation in the warehouse includes a lot of excess clutter and disorganized items on the floor. Specifically, the dock 2 area is currently blocked by personal items from employees, and the area between aisle C and D is not being properly utilized. In addition, there are two non-operational vending machines consuming space in sections C31 and C33.

Hence, there are many improvements that can be made to improve the overall organization, space utilization, and worker productivity for Ecomspaces.

#### ***1.4 Objective***

The project objective will be to improve the organization's facility layout, utilizing the warehouse space optimally. Our team aims to (1) reduce 3% of the junk/wasted space within the facility, resulting in 16% of overall improvement in the workflow of the warehouse by April 28, 2021, (2) maintain and prevent accidents and human errors from occurring by conducting safety and maintenance audits regularly, and (3) enhance the overall productivity by enforcing appropriate SOPs to standardize processes for each workstation. The development of SOPs will not only assist the workers in understanding the appropriate procedures, but also serves to reduce human errors that could reduce lagging time. This project also incorporates and examines the quality aspects to the solution to ensure all stakeholders and shareholders have the best experience during the process.

#### ***1.5 Justifications***

After speaking with Maire Rosa, the CEO of Ecomspaces, we determined that this project is justified because current warehouse operations cannot accommodate the inflow of additional customers and clients. The interviews we conducted with all the employees also strengthen the evidence for the need to improve the overall efficiency of the warehouse. From interview results, we found several main problems are the causes of inefficiency within the warehouse, including miscommunication between systems, misplaced packages, inconsistent material location, incorrect orders in fulfillment, and disorganized items on the floor. Therefore, we aim to propose and implement facility layout improvements to promote space utilization in the warehouse, enact the safety and maintenance checklists, and detailed process procedures that will help Ecomspaces achieve their end goal of ensuring both a sustainable and scalable operation for years to come while maintaining their quality of service.

#### ***1.6 Problem Statement***

Ecomspaces business depends heavily on order fulfillment, inventory storage, and delivering. Without proper facility planning and standard operating procedures for warehouse maintenance and safety, it will be problematic for Ecomspaces to accommodate orders that continue to grow, resulting in failure to fulfill customer orders and leading to customer dissatisfaction. Thus, the project will analyze the overall order fulfillment operation within the company to improve process efficiency and reduce human errors by utilizing root cause analysis and the DMAIC model.

## **Chapter 2: Literature Review**

This section covers a detailed review of scholarly articles and technical documents to describe and analyze existing methods for traditional warehouse operations, facility layout, along with OSHA requirements, worker safety, and ergonomics. The purpose of this section is to provide sufficient background and justification to works referenced later in this document, especially regarding warehouse processes and facility maintenance.

### ***2.1 Overview of Distribution Centers (DC)***

Warehouses allow businesses to respond quickly to variations in demand [1]. Due to the popularization of new management philosophies such as JIT and lean manufacturing, warehouses are continually seeking improvements regarding inventory control for the purpose of attaining faster response times and the capability of handling an ever-increasing variety of products [2]. From a business perspective, the purpose of a warehouse or DC is to aggregate products in order to reduce costs that are transportation-related and to provide service to customers [1]. Through a distribution center, the packages delivered are bulkier but come in fewer shipments rather than smaller packages but with many shipments, resulting in cost savings.

There are several different types of distribution centers. Notably, a fulfillment or e-commerce distribution center is one that regularly handles small orders that are processed immediately after purchase confirmation [1]. Other warehousing types include retail distribution centers and service parts distribution centers. As mentioned in [3], warehouses can be observed from three different perspectives: their processes, resources, and organization, each with varying requirements that must be fulfilled. As a result, active coordination between businesses, stakeholders, and customers are critical during the facility planning process.

### ***2.2 Warehouse Design***

Since warehouses commonly involve large investment sums and costs for operations, proper planning and continuous improvement steps are highly sought after. The warehouse design and operational framework are shown in figure 4 [4] which provides a robust framework for the design and operation of warehouse facilities.



Design and operation problems		Decisions	
Warehouse design	Overall structure	<ul style="list-style-type: none"> <li>• Material flow</li> <li>• Department identification</li> <li>• Relative location of departments</li> </ul>	
	Sizing and dimensioning	<ul style="list-style-type: none"> <li>• Size of warehouse</li> <li>• Size and dimension of department</li> </ul>	
	Department layout	<ul style="list-style-type: none"> <li>• Pallet block-stacking pattern (for pallet storage)</li> <li>• Aisle orientation</li> <li>• Number, length, and width of aisles</li> <li>• Door locations</li> </ul>	
	Equipment selection	<ul style="list-style-type: none"> <li>• Level of automation</li> <li>• Storage equipment selection</li> <li>• Material handling equipment selection (order picking, sorting)</li> </ul>	
	Operation strategy	<ul style="list-style-type: none"> <li>• Storage strategy selection (e.g. random vs. dedicated)</li> <li>• Order picking method selection</li> </ul>	
Warehouse operation	Receiving and shipping		<ul style="list-style-type: none"> <li>• Truck-dock assignment</li> <li>• Order-truck assignment</li> <li>• Truck dispatch schedule</li> </ul>
	Storage	SKU-department assignment	<ul style="list-style-type: none"> <li>• Assignment of items to different warehouse departments</li> <li>• Space allocation</li> </ul>
		Zoning	<ul style="list-style-type: none"> <li>• Assignment of SKUs to zones</li> <li>• Assignment of pickers to zones</li> </ul>
		Storage location assignment	<ul style="list-style-type: none"> <li>• Storage location assignment</li> <li>• Specification of storage classes (for class-based storage)</li> </ul>
	Order picking	Batching	<ul style="list-style-type: none"> <li>• Batch size</li> <li>• Order-batch assignment</li> </ul>
		Routing and sequencing	<ul style="list-style-type: none"> <li>• Routing and sequencing of order picking tours</li> <li>• Dwell point selection (for AS/RS)</li> </ul>
		Sorting	<ul style="list-style-type: none"> <li>• Order-lane assignment</li> </ul>

Figure 4: Warehouse Design and Operational Framework [4]

A common method of evaluating a warehouse is through the comparison of current and future states [5]. Process improvements generally revolve around eliminating unnecessary material handling steps, reducing excess travel time, and minimizing the total duration spent during manual search. Design criteria for warehouses generally consist of maximizing throughput, minimizing operational costs, and maximizing storage capability [5]. As discussed in [6], zoning within a warehouse can be applied to divide up sections based on product classifications determined by the analyst. Another option for class-based storage is mentioned in [7], where the inventory is classified and stored in a location based on the most-picked product type.

### 2.3 Warehouse Operations

Warehouses serve as a bridge between producers and their customers [4]. A specific type of warehouse, known as a distribution warehouse, is one where inventory from a variety of suppliers is collected and delivered to customers [4]. For this type of facility, the following activities are summarized in [9] with their key processes enumerated below:

1. Receiving involves the process of discharging products from a transport carrier, recording the inventory, and inspecting the product to identify any mistakes in quality.
2. Put-away involves the transfer of newly registered products to their respective storage locations within the warehouse.

3. Order picking involves the process of retrieving the necessary products from storage to satisfy a customer order.
4. Shipping is the process of aggregating, packaging, labeling, and sending out completed customer orders consisting of one or more inventory items.

Of these four processes, picking is known to be the most labor-intensive operation in warehouses with manual systems and can be very costly to automate [9]. Such considerations for picking include routing problems, batch sizing, organization of inventory (such as bins, stacking, shelving, palletizing, etc.), as well as material handling.

#### ***2.4 OSHA, Safety, and Ergonomics***

The cleanliness of a facility is directly related to its performance. During times of emergency, it is important for workers to be able to easily identify and access emergency equipment such as first aid kits and fire extinguishers. Fire safety equipment must also be properly maintained to provide safety for both people and property in the warehouse [8]. Warehouse fires can result in material loss and disruption of the warehouse management processes [8].

Workers within a warehouse must be able to visually identify possible hazards and dangers such as wet floors, misplaced equipment, and protruding inventory. As told in [10], poor lighting in a facility can stem from insufficient lighting, glare, variable contrast, light distribution, and flicker. Poor lighting also facilitates employee fatigue, thereby directly influencing worker fatigue and strain [6]. Proper lighting is crucial for processes which involve manual search such as order picking, a common bottleneck to many warehouse operations [9]. Considering the cost of implementation for lighting fixtures, the initial price is only 3% of the total cost of lighting given use [11].

#### ***2.5 Work Measurement in Warehouse***

Warehouse workers are essential and responsible in ensuring all items are shipped to customers on-time and all packages need to be packed according to customer requests. It is crucial to provide excellent customer service to not only satisfy customers, but also exceed their expectations. Thus, work measurement needs to be conducted to review workers' performance in meeting customers' needs to identify ways to enhance overall warehouse productivity [12].

Benefits of conducting work measurement and implementing ways to ameliorate overall warehouse productivity include:

- Increased revenue, cost savings, and cost avoidance
- Increased process productivity
- Simplified processes and workflow steps
- Promoted company reputation
- Enhanced ability to serve more customers
- Attracted more clients to utilize company's services
- Honed communications between internal and external customers
- Improved in thriving the business

Furthermore, KPI (Key Performance Indicator) and economic analysis needs to be built and performed to identify the current warehouse and business circumstances. This indicator also helps in the evaluation process in comparing how successful the proposed solutions are to the current situation by considering different metrics, such as time, cost, quality, and productivity [13]. Observations and interviews are needed to be performed to retrieve accurate data in defining KPI, identifying root-cause, and verifying proposed solutions whether it is feasible to implement [14]. The best graded and most used KPIs are shown in figure 5 [15] which illustrates 13 important KPIs used by multi-channel retailers for measuring eFulfillment service performance. The data retrieved by sending an online questionnaire to 100 supply chain or marketing managers of French and Chinese multi-channel retail companies.

KPI	Name	Grade mean	Grade SD	Use	Criteria
1	Total investment of the warehouse	6.55	1.69	78.60	Fulfillment infrastructure cost (100.0%)
22	Order fill rate	8.46	1.66	92.90	Fulfillment infrastructure cost (75.0%)
2	Inventory cycle time	6.75	1.54	92.90	Stock and inventory efficiency (100.0%)
4	Safety stock volume	5.92	1.51	85.70	Stock and inventory efficiency (81.3%)
5	Rate of obsolete inventory	6.73	1.35	85.70	Stock and inventory efficiency (81.3%)
6	Order to delivery time	7.15	1.77	85.70	Stock and inventory efficiency (81.3%)
23	Stock-out rate	8.42	1.56	85.70	Stock and inventory efficiency (68.8%)
14	Shipping accuracy	8.15	1.34	92.90	Picking and order efficiency (50.0%)
21	Percentage of on-time deliveries	7.90	1.66	78.60	Picking and order efficiency (62.5%)
28	Invoice accuracy	8.08	1.78	85.70	Picking and order efficiency (87.5%)
15	Cost per shipment	6.43	1.90	100.00	Delivery cost efficiency (68.8%)
16	Percentage of shipment arrived in good condition	7.15	1.77	92.90	Condition (68.8%)
27	Number of damage claims	6.82	1.78	78.60	Return (68.8%)

Figure 5: The 13 Best Graded and Most Used KPIs by the 15 Multi-Channel Retailers by Criteria [15]

Once proper work measurements have been conducted and the root cause has been resolved, increased operating speed and time as well as better space utilization will occur.

## 2.6 Warehouse Maintenance

Maintenance for warehouses is important to improve safety and productivity, reduce cost and waste, and ensure continuous business and service operation. Warehouse maintenance costs are cheaper than the cost of fines, damage items, or compensation for any accidents that may occur in the warehouse. Therefore, the owner needs to collaborate with the team to construct and implement a strategy to reduce overall business costs [16]. One of the strategies is to assure the warehouse is fully ergonomic to prevent any injuries or accidents from occurring. As stated in [17], picking from a titled and smaller container for boxes is more ergonomic than picking from a horizontal and bigger container. In addition, conducting audits to review the current warehouse situation is important to determine and identify which areas need improvement.

## ***2.7 Gaining Competitive Advantage through Ergonomic Improvements***

Ergonomics plays a critical role in understanding the physical capabilities of workers and translating those into requirements related to those workers' assigned tasks, tools and equipment as well as the procedures they have to follow within their day-to-day work environment. The main objective of the ergonomics design approach is to optimize the effectiveness and productivity of work systems while assuring the safety, health, and well-being of the workers [18]. It has been proven that investment in ergonomic improvements in the workplace can result in a return on investment ranging from 3:1 to 15:1 [19]. Hence, implementation of ergonomic systems in a warehouse facility is a way to gain a competitive advantage.

## ***2.8 Order Picking Operations***

Order picking is the most critical function in distribution operations. It is at the center of the flow of products from suppliers to customers. Warehouse professionals identify order picking as the highest-priority activity in the warehouse for productivity improvements [20]. Therefore, one of the very important factors that must be considered during storage area planning is the order picking process [21]. During the picking process, warehouse employees perform the following actions: travel to, from, and between pick locations, extract items from storage locations, reach and bend to access pick locations, document picking transactions, sort items into orders, pack items, and search for pick locations. To optimize order picking, warehouses should aim to eliminate the time to perform each action.

## ***2.9 Visual Management***

Visual management helps to communicate divisions in the workspace at a glance. A key factor that ensures a business is successful and able to grow is to empower employees at all levels. When visual management is applied in the workplace, it empowers workers at all levels to take accountability and make effective decisions. This management system improves organizational performance by connecting and aligning the use of sight to convey goals, core values, standards, and workplace culture [22]. Based on a study completed at a 3PL (third party logistics) provider in South Africa researcher Alexander Swart found in a study that continuous improvement and visual management there is a gap of true understanding of these lean warehouse principles [23]. Items such as visual reminders in work areas goes a long way to ensuring that a standard of cleanliness is met throughout the warehouse, leading to a reduction in errors, less waste, easier workflow processes, and improved safety.

## Chapter 3: Project Management

### *3.1 Requirements and Specifications*

The three primary goals of the project are to (1) to propose facility layout changes to optimize overall workflow and to regain floor space throughout the facility, (2) standardize the safety, housekeeping, and maintenance of the warehouse, and (3) develop accessible and robust key performance indicators and standard operating procedures necessary for process improvement. Requirements include analyzing current space utilization, as well as the evaluation of existing warehouse safety with audits, the work-processes within the operation to generate standard times, and to develop baseline productivity levels across each station. By conducting a series of time studies, analyzing raw data from their warehouse management systems, and coordinating with key personnel at Ecomspaces, we aim to provide multiple feasible solutions that are cost-effective and easy to implement to improve the overall warehouse utilization and workflow of their operation.

In an effort to obtain accurate data recording, we requested permission to record observations throughout Ecomspaces facility and operation at any given time, as well as administrator access to their software utilized for raw data collection and analysis.

### *3.2 System Overview*

Figure 6 below depicts Ecomspaces warehouse workflow processes. This flowchart shows the processes starting from carriers dropping off packages at the front receiving station or at the dock area. Then, the receiver will put all packages on the portable racks to be processed. The processes include opening the package, verifying items if they are eligible to be shipped, printing labels, and repackaging. Afterward, verified items will be stored on the rack based on the label numbers by the put away worker. Next, the shipper will pick items based on the order received from clients and verify the items by scanning the barcode to ensure the shipper retrieves the right items to be shipped. Lastly, the shipper will wrap the packages based on the customers' request, such as bubble wrap, double wall, and condense as much as possible, and then items are ready to be shipped.

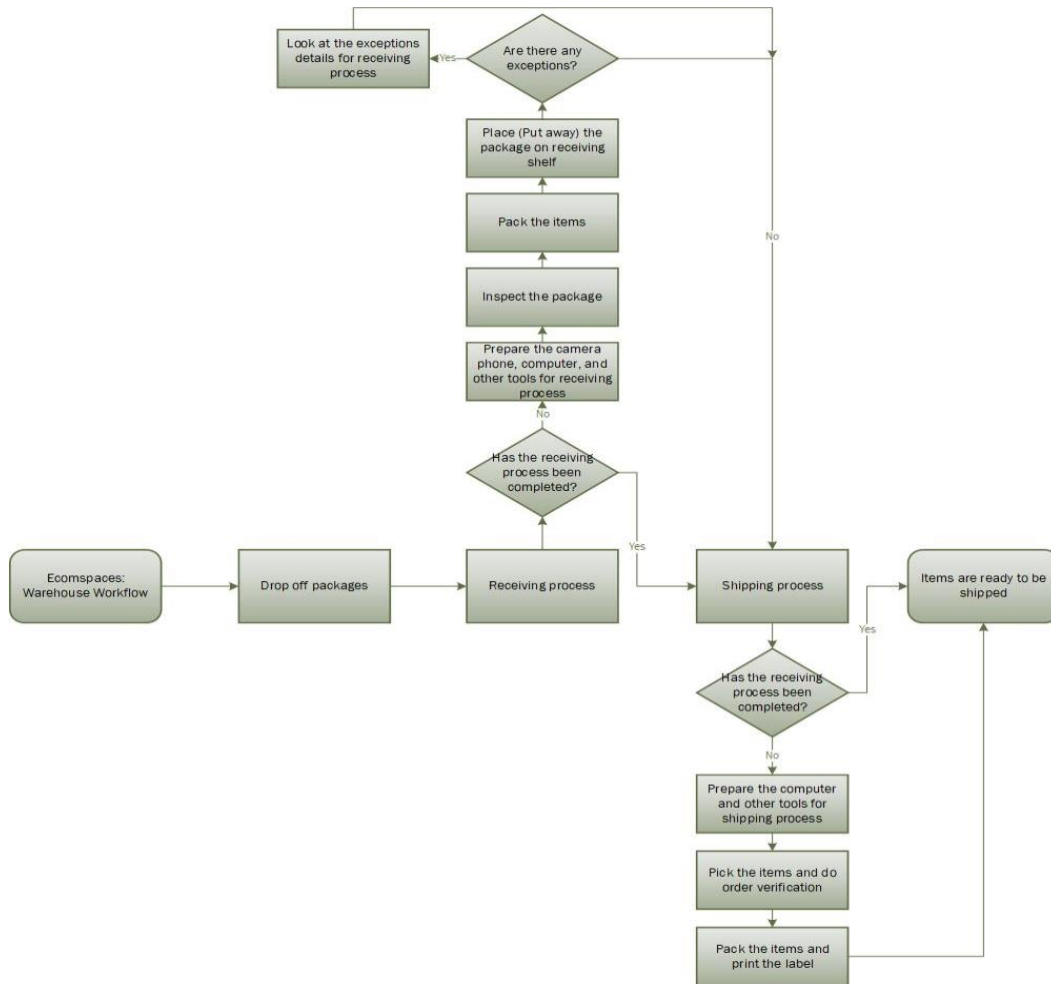


Figure 6: Ecomspaces Warehouse Workflow Processes

### 3.3 Project Charter and Work Breakdown Structure

This section provides an overview for The Optimized Brain project structure in both project charter and work breakdown structure (WBS). A project charter is a short document that gives a snapshot of our project in its entirety. This consists of the project statement, goal and objectives, project scope, requirements, timeline, and potential risks to our project. The project charter serves as a guide to our team throughout the project as it develops. Our project charter is below in Table 1.

<b>Table 1: Project Charter</b>			
<b>Project Name</b>	<i>Lean Six Sigma Warehouse Optimization</i>		
<b>Team Name</b>	<i>The Optimized Brain E-Spaces</i>	<b>Date</b>	<i>23-Jan-21</i>
<b>Sponsor</b>	<i>Ecomspaces</i>	<b>Team Leader</b>	<i>Gustavo Andrade</i>
<b>Problem Statement</b>	Ecomspaces' business is experiencing steady growth. Due to their current organizational structure, however, the facility is having problems with space utilization. The project will create a proposed layout by utilizing root cause analysis and the DMAIC model to better optimize the workspace.		
<b>Goal and Objective</b>	Implement new layout recommendations to increase warehouse space utilization by 16% creating a foundation that can allow for new space as the company continues to grow.		
<b>Scope</b>	<b>In</b>	Layout organization, warehouse maintenance and safety, and SOPs	
	<b>Out</b>	Human resources, service tiers, membership initiative, Wifi services	
<b>Requirements</b>	Reduce and remove items that are resulting in lower space utilization in the warehouse by using the DMAIC process and various root cause analysis tools.		
<b>Timeline</b>	<b>Phase</b>	<b>Planned Complete Date</b>	<b>Actual</b>
	Design proposal	26-Jan-21	26-Jan-21
	Planning	28-Jan-21	22-Feb-21
	Execution	20-Mar-21	20-Mar-21
	Control	7-Apr-21	7-Apr-21
Wrap up	23-Apr-21	23-Apr-21	
<b>Potential Risks</b>	<ol style="list-style-type: none"> <li>1. Team may not meet current deadlines due to adding unplanned specifications in the future.</li> <li>2. Process understanding and learning curve of company processes.</li> <li>3. Any potential employee turnovers.</li> </ol>		

The WBS allows us to break down the project into smaller deliverable components. These smaller components create manageable sections to organize the team throughout the project by providing phases that can be achieved. Our WBS can be seen below in Figure 7.

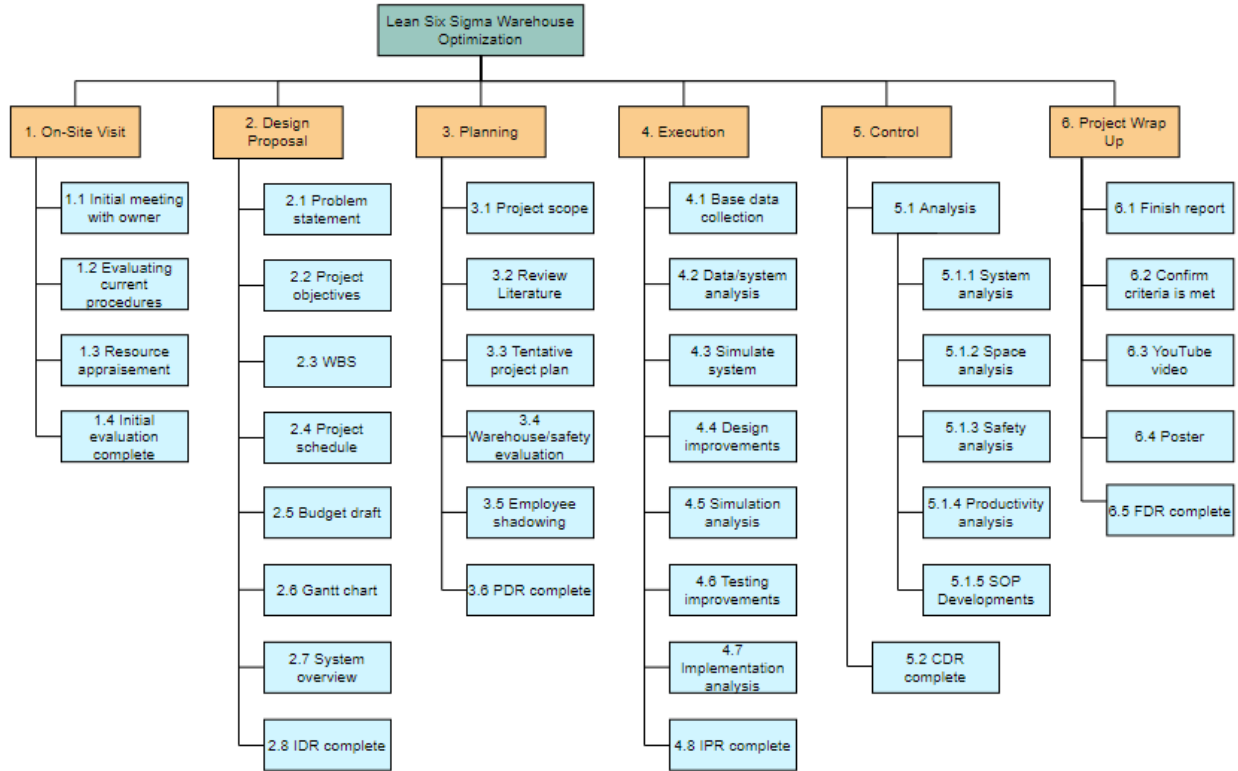


Figure 7: Work Breakdown Structure

### 3.4 Gantt Chart/Schedule

The Gantt chart and schedule section provides a tool in assisting our team in the planning and scheduling of our project in its entirety. A Gantt chart uses a bar chart to illustrate the project schedule signifying start and finish dates which helps in visualizing the duration of each task. The figure below breaks down the first three phases of our project and their respective tasks. The full Gantt chart can be found in [Appendix X](#).

✓	★	5	▲ 5 Control	14 days	Fri 3/19/21	Wed 4/7/21	
✓	★	5.1	▲ 5.1 Analysis	13 days	Fri 3/19/21	Tue 4/6/21	
✓	★	5.1.1	5.1.1 System analysis	3 days	Fri 3/19/21	Tue 3/23/21	Melanie Cardenas
✓	★	5.1.2	5.1.2 Labor analysis	2 days	Mon 3/22/21	Tue 3/23/21	Gustavo Andrade
✓	★	5.1.3	5.1.3 Safety analysis	2 days	Tue 3/23/21	Wed 3/24/21	Nicolai Sison
✓	★	5.1.4	5.1.4 Productivity analysis	4 days	Fri 3/26/21	Wed 3/31/21	Gustavo Andrade
✓	★	5.1.5	5.1.5 Cost analysis	3 days	Mon 3/29/21	Wed 3/31/21	Edwin Lim
✓	★	5.2	5.2 Milestone: CDR Complete	0 days	Tue 3/30/21	Tue 3/30/21	
✓	★	6	▲ 6 Project Wrap up	18 days	Wed 3/31/21	Fri 4/23/21	
✓	★	6.1	6.1 Finish report	5 days	Wed 3/31/21	Tue 4/6/21	Edwin Lim,Gustavo Andrade,Mela
✓	★	6.2	6.2 Confirm criteria is met	2 days	Wed 4/7/21	Thu 4/8/21	Edwin Lim
✓	★	6.3	6.3 Youtube video	3 days	Thu 4/8/21	Mon 4/12/21	Nicolai Sison,Edwin Lim
✓	★	6.4	6.4 Poster creation	2 days	Tue 4/13/21	Wed 4/14/21	Melanie Cardenas
✓	★	6.5	6.5 Milestone: FDR Complete	0 days	Fri 4/23/21	Fri 4/23/21	

Figure 8: Gantt Chart



### 3.5 Responsibilities

The team's responsibility is to implement a plan that will increase the space utilization of Ecomspaces' warehouse and provide the necessary infrastructure to support long-term growth and optimize the workflow process of picking orders. Using tools of the DMAIC process and analyzing the results, we will be able to provide solutions to achieve lasting efforts.

### 3.6 Financial Plan/Budget

As shown on Table 2 below, a budget has been created to estimate the total cost for each task throughout the lifetime of the project. The budget estimates are based on each consultant's experience and Ecomspaces overall needs. It will take approximately 246 hours and cost \$6,150 to complete the project. The estimated work hours by task are subject to change as the companies needs may vary.

Table 2: Total Budget

<b>Budget</b>						
<b>Ecomspaces Warehouse Workflow Optimization</b>						
Gustavo Andrade, Melanie Cardenas, Edwin Lim, Nicolai Sison						
<b>Manpower Requirements</b>						
<b>Task</b>	<b>Estimated work hours by task</b>				<b>Totals by Task</b>	
	<b>Gustavo</b>	<b>Melanie</b>	<b>Edwin</b>	<b>Nicolai</b>	<b>hrs</b>	<b>\$</b>
Initial Project meeting (01/18/21)	1	1	1	1	4	100
Virtual Consultation (01/20/21)	1	1	1	1	4	100
On Site Consultation (01/21/21)	8	4	8	8	28	700
Initial Design Review (01/23/21)	2	2	2	2	8	200
Develop Project Schedule (01/23/21)		3			3	75
IDR Powerpoint (01/25/21)	1	1	1	1	4	100
Time Study (01/28/21)	5	3		5	13	325
Analysis of Time Study (01/30/21)	4			2	6	150
Survey Employees (02/10/21)	3		3	3	9	225
Warehouse Measurements (02/15/21)	2	3	2	3	10	250
Facility Layout (02/20/21)	2	5	2		9	225
Key Performance Indicators (02/20/21)				3	3	75
Preliminary Design Review (02/24/21)	4	4	4	4	16	400
Design Improvement Models (02/04/21)	2	6	5	2	15	375
Safety & OSHA Audits (02/20/21)	1		3	3	7	175
Create Arena Model (02/14/21)		4	5		9	225
Economic Analysis (03/02/21)			6		6	150
Configuration Analysis (03/03/21)	1			3	4	100
Literature Review (03/05/21)	3	3	3	5	14	350
Design Implementation Meeting (03/08/21)	2	2	2	2	8	200
In Progress Review (03/24/21)	2	3	3	2	10	250
Design for Safety (03/28/21)		3	2		5	125
Present Implementation Findings (03/09/21)	2		2	2	6	150
Eliminate Warehouse Waste (03/20/21)	3	3	3	3	12	300
Critical Design Review (04/14/21)	2	3	3	1	9	225
Time Study with Implementation (04/16/21)	4				4	100
Detailed Design (04/18/21)	2	2	1	3	8	200
Final Design Review (04/28/21)	3	3	3	3	12	300
<b>Total hours</b>	<b>60</b>	<b>59</b>	<b>65</b>	<b>62</b>	<b>246</b>	
<b>Rate \$/hr</b>	<b>25</b>	<b>25</b>	<b>25</b>	<b>25</b>		
<b>Dollars</b>	<b>\$1,500</b>	<b>\$1,475</b>	<b>\$1,625</b>	<b>\$1,550</b>		<b>\$6,150</b>

### 3.7 Economic Analysis

Economic Analysis involves formulating, estimating, and evaluating the expected economic outcomes of alternatives designed to accomplish a defined purpose [4]. Through statistical analysis, we can further simplify the economic evaluation of possible alternatives at Ecomspaces. Annual expenses, annual income, and net income (before tax) were examined thoroughly and considered throughout the course of the project.

Table 3: Annual Expenses 2014-2019

Annual Expense 2014-2019						
Description	2014 Cost	2015 Cost	2016 Cost	2017 Cost	2018 Cost	2019 Cost
Utilities	\$0.00	\$1,250.00	\$3,720.00	\$14,081.79	\$16,596.03	\$16,551.23
Professional dues and subscriptions	\$1,239.00	\$11,138.00	\$11,040.00	\$12,859.37	\$37,104.73	\$11,972.01
Supplies	\$8,338.00	\$16,540.00	\$21,373.00	\$10,697.78	\$30,706.47	\$132,674.56
Rent	\$0.00	\$14,043.00	\$47,100.00	\$98,900.00	\$97,644.00	\$100,573.32
Telephone	\$0.00	\$0.00	\$0.00	\$2,061.84	\$2,400.00	\$1,260.00
Payroll	\$0.00	\$1,807.00	\$48,030.00	\$64,984.63	\$57,592.30	\$88,104.18
Insurance	\$0.00	\$0.00	\$0.00	\$2,298.00	\$2,964.00	\$4,050.00
Postage	\$138,010.00	\$182,611.00	\$179,077.00	\$221,658.00	\$263,763.16	\$258,009.12
Interests	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$7,523.87
Bank Fees	\$6,886.00	\$15,809.00	\$15,362.00	\$17,426.10	\$23,387.20	\$23,548.05
Advertising	\$0.00	\$55.00	\$234.78	\$399.30	\$1,979.39	\$7,398.27
<b>Total</b>	<b>\$154,473.00</b>	<b>\$243,253.00</b>	<b>\$325,936.78</b>	<b>\$445,366.81</b>	<b>\$534,137.28</b>	<b>\$651,664.61</b>
<b>% Increase</b>	<b>0.00%</b>	<b>57.47%</b>	<b>33.99%</b>	<b>36.64%</b>	<b>19.93%</b>	<b>22.00%</b>

Table 3 above depicts the annual expenses at Ecomspaces from 2014 to 2019. Professional dues, subscriptions, postage, and bank fees were the first cost incurred on the company when it first began operations. Utilities, rent, telephone, payroll, insurance, interest, and advertising were incurred in later years as the business continued to grow. From Table 3, it is evident that the three most expensive costs are supplies, rent, and postage. In addition, increases in rent costs are generally unavoidable, due to the growth of property values over time. In summary, the percent increase from 2014 to 2015 is 57.45%, from 2015 to 2016 is 33.99%, 2016 to 2017 is 36.64%, 2017 to 2018 is 19.93%, 2018 to 2019 is 22.00%. The full annual expense chart for each category from 2014-2019 can be found in [Appendix E](#).

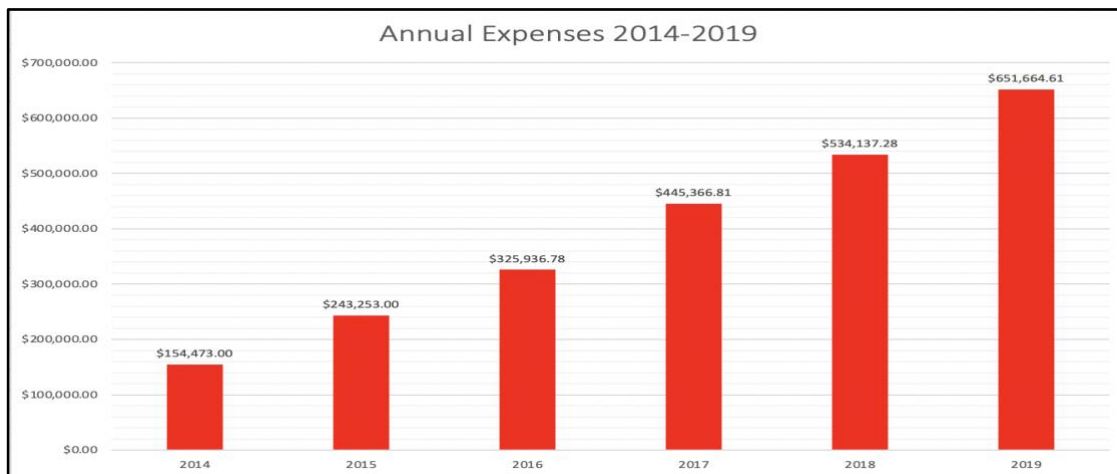


Figure 9: Annual Expenses Chart 2014-2019

This figure 9 above depicts an increasing trend for expenses from 2014 to 2019. This chart visualizes each expense data per year in US dollars. The expenses for 2014 is \$154,473.00, for 2015 is \$243,253.00, for 2016 is \$325,936.78, for 2017 is \$445,366.81, for 2018 is \$534,137.28, and for 2019 is \$651,664.61.

Table 4: Annual Income 2014-2019

Annual Income 2014-2019						
Description	2014	2015	2016	2017	2018	2019
	Amount	Amount	Amount	Amount	Amount	Amount
<b>Income 1099-K</b>	No Breakdown Provided	No Breakdown Provided	No Breakdown Provided			
Stripe	\$0.00	\$0.00	\$0.00	\$38,641.43	\$32,641.43	\$29,456.87
Square	\$0.00	\$0.00	\$0.00	\$97,801.30	\$149,803.25	\$130,697.64
Paypal	\$0.00	\$0.00	\$0.00	\$285,782.96	\$400,118.58	\$407,059.70
Peerspace	\$0.00	\$0.00	\$0.00	\$0.00	\$2,589.10	\$35,198.15
Rent Offices	\$0.00	\$0.00	\$0.00	\$24,450.00	\$38,800.00	\$44,550.00
Croissant	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$120.00
LiquidSpace	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$23,456.79
<b>Total</b>	<b>\$165,193.00</b>	<b>\$265,376.00</b>	<b>\$340,622.00</b>	<b>\$446,675.69</b>	<b>\$623,952.36</b>	<b>\$670,539.15</b>
<b>% Increase</b>	<b>0.00%</b>	<b>60.65%</b>	<b>28.35%</b>	<b>31.14%</b>	<b>39.69%</b>	<b>7.47%</b>

Table 4 above depicts the annual income for Ecompsaces from 2014 to 2019. The major sources of income include: Stripe, Square, Paypal, Peerspace, Rent Offices, Croissant, and LiquidSpace. There is no breakdown provided from 2014 to 2016. In 2019, the company’s main source of income came from Paypal as it accounted for 60% of the total annual income at Ecompsaces. The percent increase from 2014 to 2015 is 60.65%, from 2015 to 2016 is 28.35%, 2016 to 2017 is 31.14%, 2017 to 2018 is 39.69%, 2018 to 2019 is 7.47%.

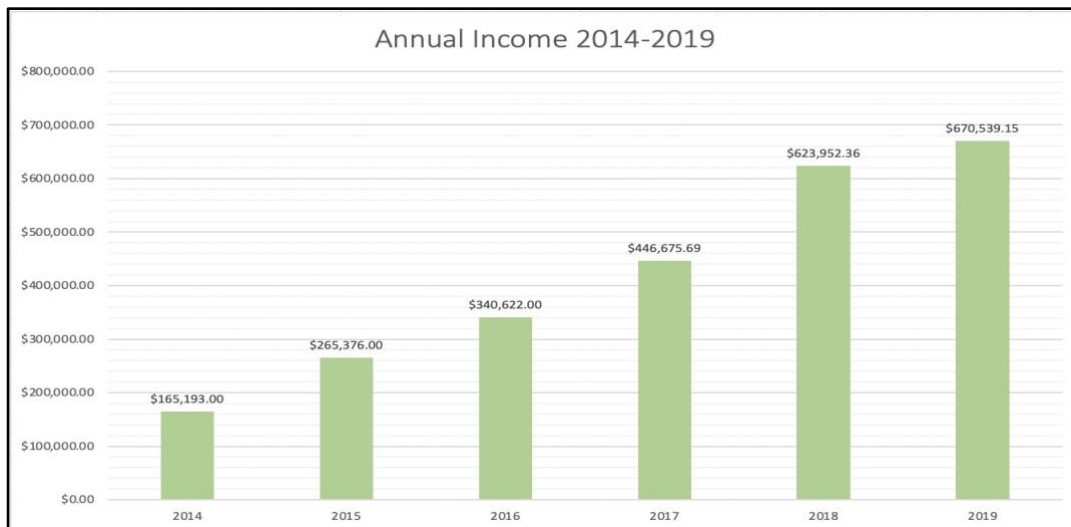


Figure 10: Annual Income Chart 2014-2019

This figure 10 depicts an increasing trend for income from 2014 to 2019. This chart visualizes each income data per year in US dollars. The income for 2014 is \$165,193.00, for 2015 is \$265,376.00, for 2016 is \$340,622.00, for 2017 is \$446,675.69, for 2018 is \$623,952.36, and for 2019 is \$670,539.15.

Table 5: Net Income (Before Tax) Overview 2014-2019

Net Income (Before Tax)			
Year	Description	Amount	% Increase
2014	Net Income	\$10,720.00	
2015	Net Income	\$22,123.00	106.37
2016	Net Income	\$14,685.22	-33.62
2017	Net Income	\$1,308.88	-91.09
2018	Net Income	\$89,815.08	6761.98
2019	Net Income	\$18,874.54	-78.99
<b>Total</b>		<b>\$138,652.18</b>	

Table 5 above depicts the net income (before tax) for Ecomspaces. In accounting, net income is equal to annual income subtracted by annual expenses. The remainder of the earnings is considered as net income. From Figure 11 below, 2017 was an indigent year for the company as it only profited \$1,308.88 dollars. Contrarily, the most profitable year for the company was 2018.

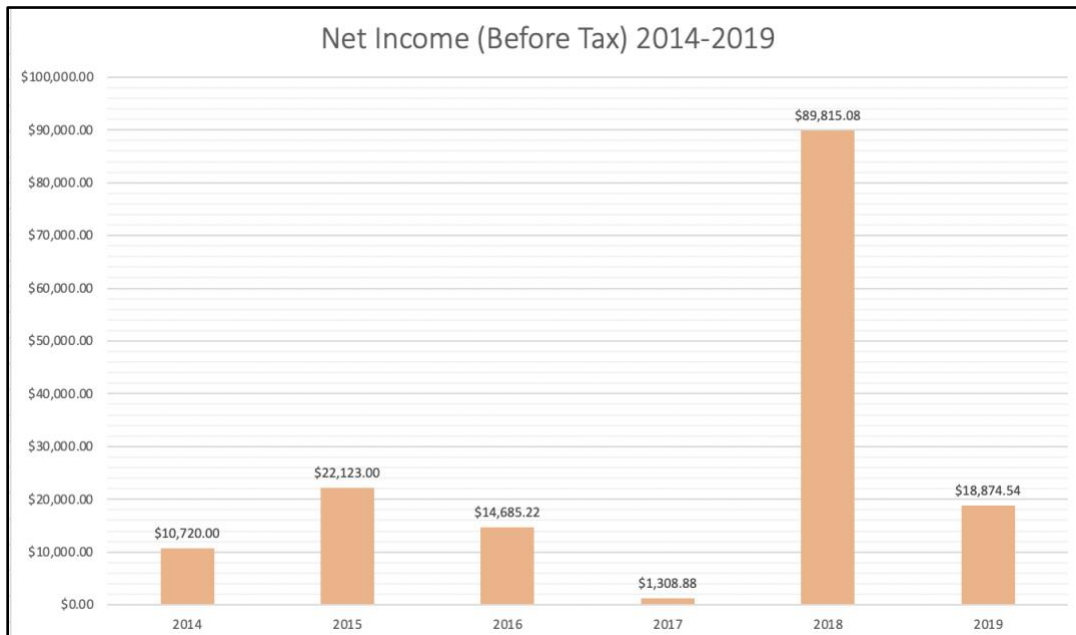


Figure 11: Net Income (Before Tax) Chart 2014-2019

Figure 11 above shows fluctuations in Ecomspaces net income from 2014 to 2019. The net income for 2014 is \$10,720.00, for 2015 is \$22,123.00, for 2016 is \$14,685.00, for 2017 is \$1,308.88, for 2018 is \$89,815.08, and for 2019 is \$18,874.54.

### ***3.8 Resources Utilized***

The materials that were utilized for data collection and process simulation were cameras, time-study charts, and personal protective equipment (PPE). Furthermore, we used key-card access to the warehouse during hours of operation.

The following is list of resources we utilized:

1. Software:
  - a. Arena Simulation Software
  - b. Adobe Illustrator
  - c. MS Office (Word, PowerPoint, Excel, Outlook, Visio, Project)
  - d. Python (data analysis)
  - e. Minitab
  - f. Collaborate Ultra
  - g. Google Drive
  - h. iMovie/Sony Vegas Pro 17
  - i. ProCreate
2. Hardware:
  - a. Lux Meter
  - b. Video Camera
  - c. Smartphone/Tablet
  - d. Laser Tape Measure

### ***3.9 Resources Available***

The resources we had available include the information provided by Maire Rosa and Nicolas Troplent, facility access and observation to the warehouse, employee schedules, client information, and administrator access to their warehouse management systems (WMS). Additionally, we were able to interact with their employees to learn and understand their work-processes.

The following is list of softwares that utilize at Ecomspaces:

1. Shipstation → order management
2. Halsystem → inventory management, only for Relay Shop USA (RSU)
3. Groovepacker → inventory management, for order fulfillment & Relay Shop USA (RSU)
4. Ring → notifies employees when items are delivered to the warehouse

## **Chapter 4: Proposed Solutions**

### ***4.1 Regain Floor Space***

Upon entering the facility, our team immediately noticed an abundance of space not being properly utilized in key locations throughout the warehouse. The removal of debris, excess pallets, cardboard boxes, and previously used packaging is an opportunity to regain unused floor space. Regaining floor space within the warehouse can lead to (1) the development of additional workstations for future employees and scalability, (2) more vertical storage racks for greater inventory capacity, and (3) an overall cleaner look for the facility.

### ***4.2 Floor Identifiers***

Another solution would be to have floor identifiers to highlight walkways in the aisles, divide up designated workspaces, and allocate sections of the warehouse for equipment storage. Floor identifiers would allow aisles to be clearly marked so that regular cleaning can take place in that area and prevent the obstruction of movement. When equipment is designated to certain locations, it helps to streamline pathing during the picking process by reducing time spent looking in the warehouse for the order items.

### ***4.3 Warehouse Safety***

After our first set of on-site visits, we noticed that the excess clutter within the warehouse did not create the ideal environment for employee safety. The additional debris and cardboard boxes could lead to employee injury during the completion of daily processes and could also be potential fire hazards. By creating a warehouse safety standard to establish a clean workspace we can safeguard employees from harm in the future, and also reduce the risk for any unforeseen expenses following any possible OSHA fines.

#### ***4.3.1 Emergency Exit***

Within the warehouse, we recognized a scarcity of emergency exit signs. The warehouse has one exit door located near dock 1 and dock 2 but it is not designated with any signage that indicates an emergency exit. There is inadequate signage pointing to the door's location in nearby areas. If a crisis or disaster were to occur within the facility, new employees or those located furthest from the exit door would have trouble locating it. Furthermore, if there was a designated emergency exit, employees could regularly maintain the path to this door, and have the surrounding area be free from any obstructions that could hinder anyone during an emergency.

#### ***4.3.2 Warehouse Lighting***

Subsequently, our team observed that the lighting in various locations of the warehouse was inconsistent. The variability of lighting could lead to errors, the improper stacking of products, and an increase in employee fatigue from eye strain during the put away and picking processes. Having consistent lighting for the warehouse would help increase productivity by decreasing manual search errors, reducing eye strain for employee

fatigue, and creating a safer working environment since potential hazards can be made visible.

#### ***4.4 Standard Operating Procedure for Warehouse Maintenance***

Our final solution of creating SOPs for maintenance of the warehouse would help guarantee the upkeep of a cleaner and safer workplace. By providing Ecomspaces with audits forms to easily utilize, we can help reduce the risk of injury to employees, ensure that items used daily in the facility are maintained, and lessen any potential fire risks in the future. This will also help in finding any specific areas or equipment that need immediate attention.

#### ***4.5 Advantages and Disadvantages of Solutions***

Taking an overview of each of these solutions, it is clear that there are specific advantages and disadvantages to each. These proposed solutions are compared in Table 6 below:

<b><i>Table 6: Advantages and Disadvantages of Proposed Solutions</i></b>		
<b>Solution</b>	<b>Advantage</b>	<b>Disadvantage</b>
4.1: Regain Floor Space	This would provide more space to reorganize the warehouse leading to an increase of space utilization, remove obstructions hindering workflows resulting in more efficient work process times, and opens potential space for additional workstations which contribute to the bottom line.	We estimate it would take between 40-60 working hours to complete a thorough cleaning of the warehouse, costing \$480-720 in labor cost. We also estimate it would take 40-50 working hours to reorganize the space costing \$480-600 totalling \$960-1320.
4.2: Floor Identifiers	Designated spots where equipment can reliability be found for work processes, and clear boundaries to ensure proper cleaning is taking place.	The warehouse would need an estimated 1500 ft of lean floor type costing \$143 per 100 ft for a total of \$2,145.
4.3: Warehouse Safety	Ensures the company is complying with warehouse safety standards, decreases the chances of being fined for violations with OSHA, and creates an environment that	To complete fire inspections on site by employees would be 1-2 hours a month costing \$12-24 per month. Regular cleaning of the warehouse could be assigned at the end

	makes audits easy to carry out.	of shifts for 30min-1 hour for each station and 1 to 2 personnel to remove waste throughout the warehouse costing a total of \$36-75 per day.
4.3.1: Emergency Exit	The exit can be quickly found during a crisis or emergency especially for anyone who might be new to the facility and ensure that the exit is easily accessible during all operating hours.	Monthly fire drills at 1-2 hours each month possibly reducing output on that day. To install an emergency exit on the warehouse door can range from \$300-\$4100.
4.3.2: Warehouse Lighting	Consistent lighting would reduce employee errors, work fatigue, higher productivity from less time spent doing manual searches, and increase overall safety in the warehouse.	Increased energy consumption, as well as the additional costs for installing new light and replacing light bulbs that are not working.
4.4: SOPs for Warehouse Maintenance	A cleaner and safer warehouse is regularly maintained, ensures hardware and equipment are functioning properly, and helps prevent any injury or crises in the future. Potential to continue increasing space utilization.	Will consume employee time to carry out audits and might require a temporary worker while implementing to keep up with order demand.



## Chapter 5: Six Sigma/Continuous Improvement

### 5.1 Define

The Define stage is the first step of the DMAIC process, which details the primary focus, scope, and direction of the overall project goals, while identifying both internal and external deliverables for the customer.

#### 5.1.1 Stakeholder Analysis

Stakeholders represent the individuals and entities who are either actively involved in a project, or whose interests may be affected after implementation of our proposed design. The diagram in Figure 12 showcases an analysis done on our stakeholders contributing to our project for Ecomspaces, which consist of (1) facility staff, (2) the facility and logistics managers, and (3) senior management, where *Impact Level* describes the roles and effects undertaken by a given stakeholder after implementation, *Influence* the shows degree of authority of a given stakeholder, and *Interest* describes who is most affected by the project proposal.

Stakeholders	Impact Level	Influence	Interest	Action	Goals, motivations, and interests	Win/Win strategies
Facility staff	Impacts	Low	High	Show Consideration	Need to continue day to day operations with out any impact to the service they provide to the customers.	Show attention to with regular updates and provide a way for them to express any concerns.
Facility & Logistic Manager	Affected	High	Low	Meet Requirements	Contribute needed information regarding the system and the process design and testing throughout project	Involvement in testing phase to ensure project follows correct procedures
Senior Management	Decision Authority	High	High	Key Player	The successful delivery of the project within the duration of semester with a reasonable budget.	Approves of key decisions and stages of the project

Figure 12: Stakeholder Analysis

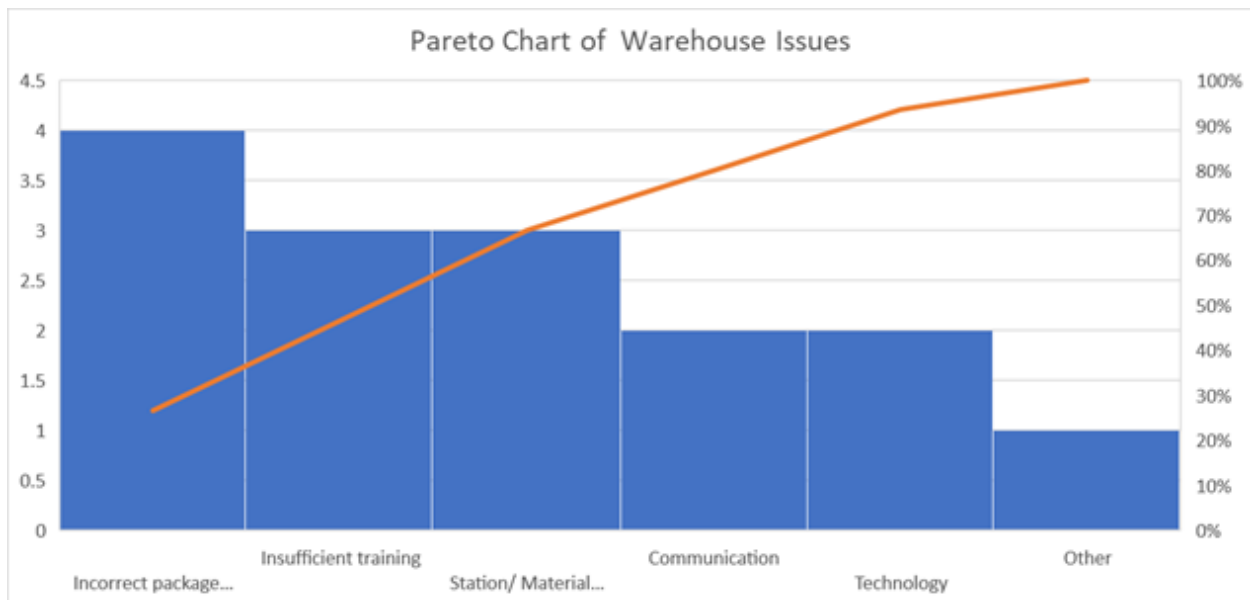
From our analysis, we find that senior management serves as the key stakeholder in establishing our project requirements and ensuring that our deliverables are justified and oriented to yielding appropriate results for all parties involved.

#### 5.1.2 Employee Survey

During our on-site visits to Ecomspaces, we conducted surveys to determine the most often occurring issues in the operation, as well as employee satisfaction and suggestions. See the frequency table and pareto chart in Table 7 and Figure 13 as shown below.

<i>Table 7: Frequency Table of Employee Survey Results</i>	
Incorrect package handling	4
Insufficient Training	3
Station/Material Location	3
Communication	2
Technology	2
Other	1

From our aggregated results, the most frequent problem stems from incorrect package handling, with a total of four votes. In the second most frequent problem surveyed, employees were concerned with insufficient training as well as station and material location. Problems with both communication and technology were observed with two votes each.



*Figure 13: Pareto Chart of Employee Survey Responses*

Results from both the pareto chart and frequency table above suggest that the majority of complaints from Ecomspaces employees stem from topics which broadly revolve around mistake-proofing and process improvement, SOP development and revision, and facility layout optimization.

### 5.1.3 Critical to Quality (CTQ)

Performance and target measurements are important factors to consider for the calculation and evaluation of process improvement. A CTQ tree provides a graphic for internal quality parameters that are based on the voice of the customer. While considering the CTQ diagram, it is important to note that RSU and Ecomspaces have entirely different client bases. RSU customers order packages to be sent directly to them, while Ecomspaces offers storage and fulfillment services for businesses to send products to their customers.

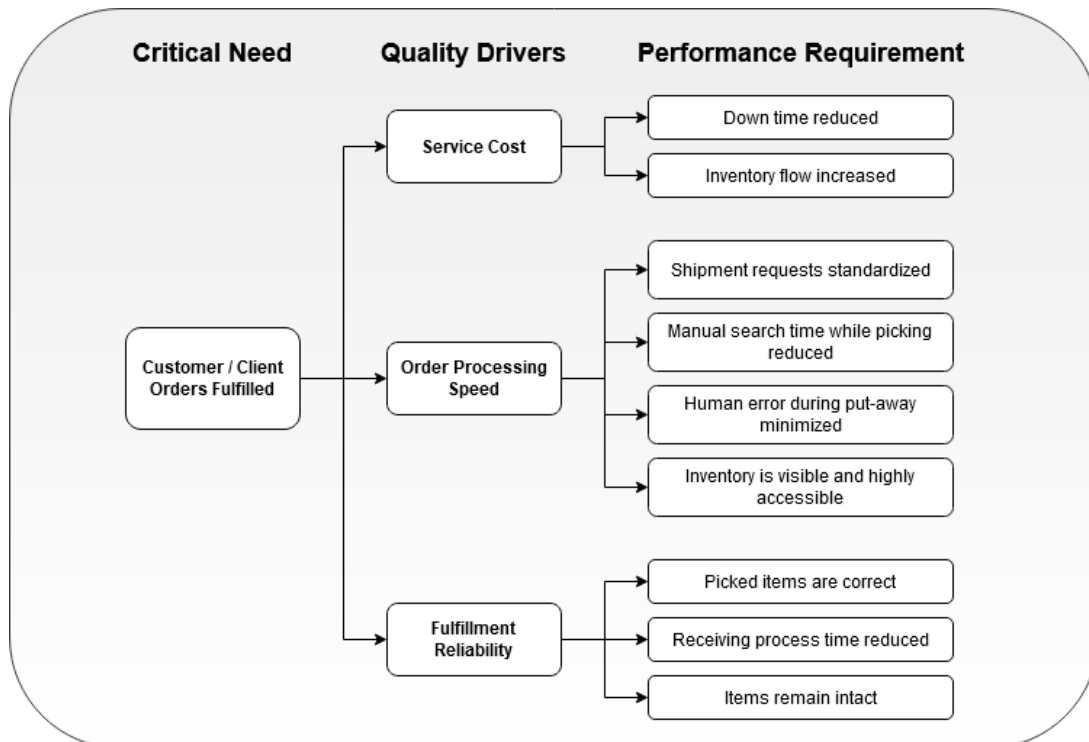


Figure 14: Generalized Critical to Quality (CTQ) Diagram

Figure 14 above depicts a generalized CTQ diagram for Ecomspaces' warehouse operation, with *Critical Need* representing the baseline requirement for the customer, *Quality Drivers* describing the traits and characteristics that most influence the decision of the customer purchasing the specified product or service, and *Performance Requirement* detailing the changes that must be implemented to attain desirable results and appeal to the customers themselves.

### 5.1.4 Key Performance Indicators (KPIs)

Key performance indicators (KPIs) are used to quantify and evaluate the processes necessary for completing a given task or operation for a business. Table in [Appendix F](#) showcases the KPIs identified for Ecomspaces, along with a data collection source and description for each indicator. The majority of sources stem from either (1) on-site



The above figure 15 depicts the current layout at Ecomspaces we created utilizing ProCreate. There are many improvements that can be made to improve the overall efficiency and effectiveness workflow such as moving unnecessary items from one place to other places. By collecting this, we further can analyze the current space utilization for each area. The green color presents the workstation (receiving, order fulfillment workstation, and shipping workstation). The red color presents areas that are not utilized properly due to improper organization and plan. We immediately noticed opportunities to redistribute the items from the black area to place them in the other racks to optimize space utilization. The aisle between row C and D also needs to be cleaned to promote safer and cleaner workspace as well as overall organization in the warehouse. By implementing a proper layout and having a designated location for every equipment, it will intensify the efficacy of the warehouse.

### ***5.2.3 Develop Safety Audits***

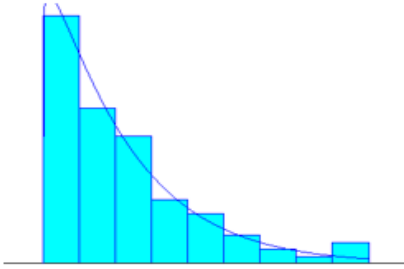
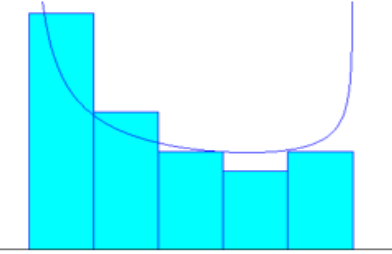
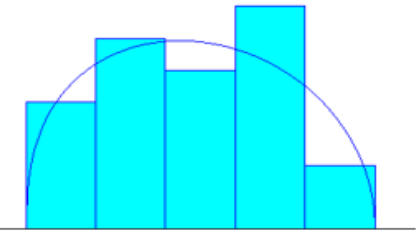
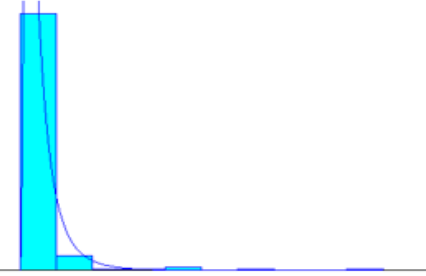
In an effort to promote safer and cleaner workplace, audit checklists need to be developed so that workers understand how to implement good standards at the warehouse to enhance the overall efficiency and effectiveness of facility layout as well as workers productivity. There are four audits/checklist we created for Ecomspaces to utilize:

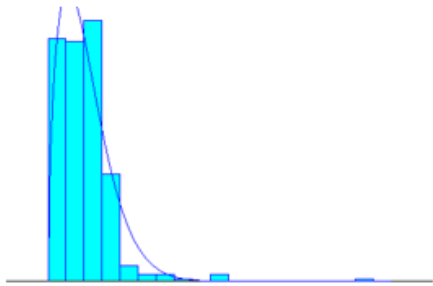
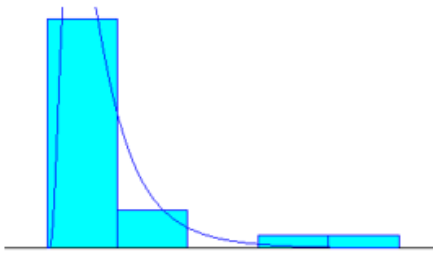
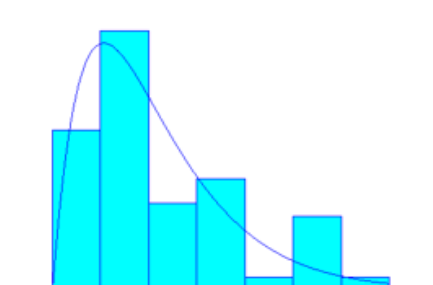
1. OSHA warehouse safety checklist consists of questionnaires for audits to measure whether the warehouse follows the standards of good best practice. The OSHA warehouse safety checklist can be seen in [Appendix H](#)
2. Maintenance housekeeping audit consists of questionnaires for audits to measure whether the warehouse has been properly maintained in the timely manner. The maintenance housekeeping audit can be seen in [Appendix I](#)
3. Fire safety checklist consists of questionnaires for audits to measure whether the warehouse is operating with functioning fire safety tools. The fire safety checklist can be seen in [Appendix J](#)
4. Warehouse lighting audit consists of questionnaires for audits to measure whether each area in the warehouse uses the appropriate lighting. Proper lighting is important to improve workers productivity. The Warehouse Lighting Audit can be seen in [Appendix K](#)

### ***5.2.4 Initial Input Analyzer Info***

In this third stage of the DMAIC model, measure, we used the input analyzer in Arena. Input Analyzer is one of the features that allow users to find all the distributions from the data collections to generate expressions for the process module in Arena. Table 8 below are screenshots of each distribution for each process. We used each expression in the simulation model to gather and obtain the correct outputs that reflect the current workflow at Ecomspaces. As shown below, all of them have p value  $> 0.05$  which means that failing to reject the null hypothesis and the better fit data than other probability distributions. In addition, all of the square errors are smaller than one that means they are the better fit than other probability distributions and should be used in the simulation model.

Table 8: Input Analyzer Results

	Histogram	Distribution Summary	Data Summary
Arrival Packages- Front Door		<p>Expression: <math>1 + \text{WEIB}(78, 1.06)</math>                      Square Error: 0.001675</p> <p>Chi Square Test                      Number of intervals = 4                      Degrees of freedom = 1                      Test Statistic = 0.612                      Corresponding p-value = 0.455</p> <p>Kolmogorov-Smirnov Test                      Test Statistic = 0.0689                      Corresponding p-value &gt; 0.15</p>	<p>Number of Data Points = 101                      Min Data Value = 1.2                      Max Data Value = 313                      Sample Mean = 77.2                      Sample Std Dev = 69.9</p>
Arrival Packages- Dock		<p>Distribution: Beta                      Expression: <math>6 + 324 * \text{BETA}(0.587, 0.801)</math>                      Square Error: 0.003490</p> <p>Chi Square Test                      Number of intervals = 4                      Degrees of freedom = 1                      Test Statistic = 0.616                      Corresponding p-value = 0.454</p> <p>Kolmogorov-Smirnov Test                      Test Statistic = 0.0963                      Corresponding p-value &gt; 0.15</p>	<p>Number of Data Points = 33                      Min Data Value = 6.98                      Max Data Value = 330                      Sample Mean = 131                      Sample Std Dev = 102</p>
Receiving		<p>Distribution: Beta                      Expression: <math>2 + 3.68 * \text{BETA}(1.39, 1.5)</math>                      Square Error: 0.009472</p> <p>Chi Square Test                      Number of intervals = 3                      Degrees of freedom = 0                      Test Statistic = 0.856                      Corresponding p-value &lt; 0.005</p> <p>Kolmogorov-Smirnov Test                      Test Statistic = 0.118                      Corresponding p-value &gt; 0.15</p>	<p>Number of Data Points = 24                      Min Data Value = 2.13                      Max Data Value = 5.35                      Sample Mean = 3.8                      Sample Std Dev = 0.9925</p>
Putaway Process		<p>Distribution: Lognormal                      Expression: <math>\text{LOGN}(0.444, 0.431)</math>                      Square Error: 0.004384</p> <p>Chi Square Test                      Number of intervals = 2                      Degrees of freedom = -1                      Test Statistic = 11.5                      Corresponding p-value &lt; 0.005</p> <p>Kolmogorov-Smirnov Test                      Test Statistic = 0.0717                      Corresponding p-value = 0.0848</p>	<p>Number of Data Points = 307                      Min Data Value = 0.08                      Max Data Value = 7.9                      Sample Mean = 0.513                      Sample Std Dev = 0.893</p>

Order Received		<p>Distribution: Weibull  Expression: WEIB(0.0468, 1.5)  Square Error: 0.009347</p> <p>Chi Square Test  Number of intervals = 6  Degrees of freedom = 3  Test Statistic = 29.1  Corresponding p-value &lt; 0.005</p> <p>Kolmogorov-Smirnov Test  Test Statistic = 0.0638  Corresponding p-value = 0.0794</p>	<p>Number of Data Points = 397  Min Data Value = 0.00556  Max Data Value = 0.354  Sample Mean = 0.0419  Sample Std Dev = 0.0315</p>
Picking Process		<p>Distribution: Lognormal  Expression: LOGN(1.11, 0.876)  Square Error: 0.010334</p> <p>Chi Square Test  Number of intervals = 2  Degrees of freedom = -1  Test Statistic = 1.22  Corresponding p-value &lt; 0.005</p> <p>Kolmogorov-Smirnov Test  Test Statistic = 0.16  Corresponding p-value &gt; 0.15</p>	<p>Number of Data Points = 23  Min Data Value = 0.38  Max Data Value = 6.55  Sample Mean = 1.22  Sample Std Dev = 1.43</p>
Shipping Process		<p>Distribution: Erlang  Expression: 1 + ERLA(7.3, 2)  Square Error: 0.019416</p> <p>Chi Square Test  Number of intervals = 5  Degrees of freedom = 2  Test Statistic = 4.22  Corresponding p-value = 0.131</p> <p>Kolmogorov-Smirnov Test  Test Statistic = 0.0825  Corresponding p-value &gt; 0.15</p>	<p>Number of Data Points = 58  Min Data Value = 1.82  Max Data Value = 48  Sample Mean = 15.6  Sample Std Dev = 11.1</p>



## 5.2.5 Arena Model

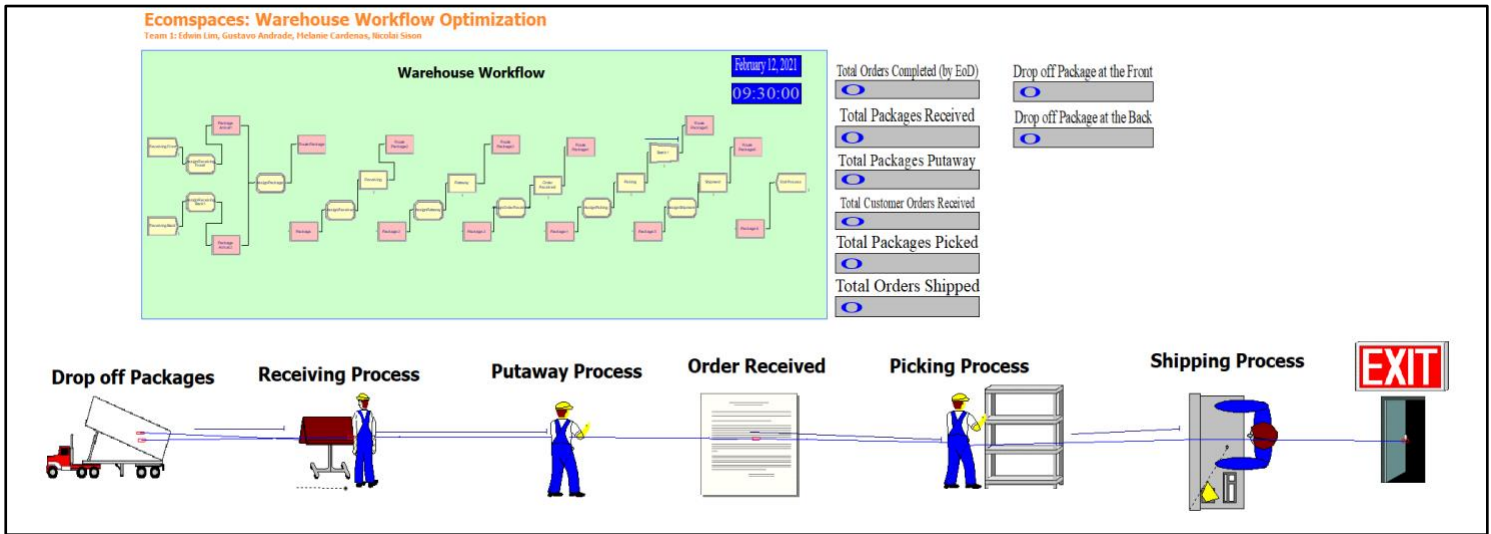


Figure 16: Ecomspaces Arena Model

This above figure 16 depicts the current Ecomspaces warehouse workflow model in Arena simulation software. This model includes the animation to display the activity that is being simulated. The warehouse workflow includes the arrival packages (drop off packages), receiving process, putaway process, order received, picking process, shipping process, and items are ready to be shipped. This model also includes the variables to present the outputs for each process.

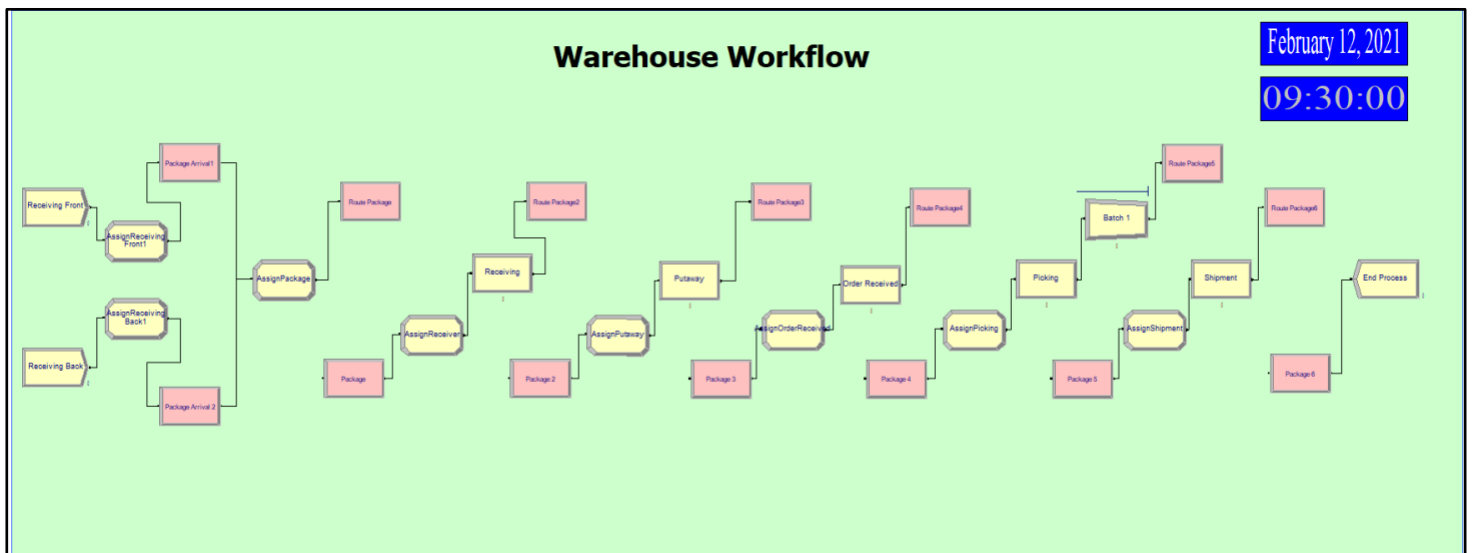


Figure 17: Ecomspaces Arena Model Modules



This above figure 17 depicts the process for the simulation model. The yellow color is for the process module and light red color is for the animation module. This simulation also includes the date and time to present the running time to the audience when the simulation executes.

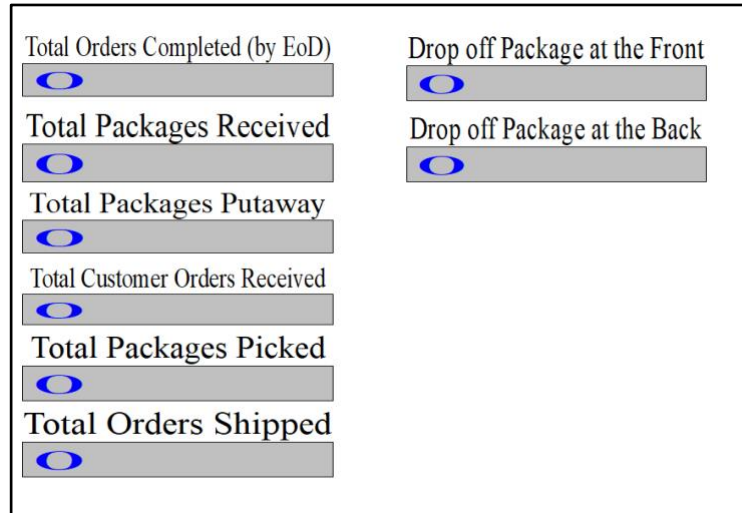


Figure 18: Ecomspaces Arena Model Variables

This above figure 18 depicts the variable outputs after the simulation runs. The total orders completed can be found using expression Number Out. The total packages received, putaway, picked, and shipped can be found using the assign module and expression Count. The total customer orders received can be found by using Count and divide by two to account for batch size of 2.

### 5.3 Analyze

The Analyze stage of DMAIC focuses on why defects, errors, or excessive variation occur. Our group identified a potential variable that we believe causes inefficiency of the workflow throughout the warehouse. We hypothesized that the source of all their problems come from the waste and disorganization scattered throughout the warehouse. To test our hypothesis, we will collect data from the current layout condition of the warehouse operations, analyze the data from warehouse management systems and time studies, and use tools such as cause-and-effect diagrams, pareto charts, interview analysis, and Arena to reach a reasonable and statistically supportable conclusion. Table 9 lists the different tools we plan to utilize and provides a description of how we plan to apply them.

<b>Table 9: List of Tools to Analyze Data</b>	
<b>Tools</b>	<b>Application</b>
Cause-and-effect diagram	Brainstorm amongst our group to identify and understand the root cause, or true source of a problem.
Arena Simulation Model	Simulate the current process using our collected data and adjust entities to find alternative solutions.
Time and Motion Study	Record data based on employee movements to determine which activities are the most time consuming and eliminating non-value added movements.
Key Performance Indicator (KPI)	Create a quantifiable measure that can be used to gauge the company's performance and efficiency.
Warehouse Audits	Assessing and monitoring daily warehouse operations to eliminate potential hazards and comply with OSHA and fire safety standards.
Spaghetti Diagram	Observe the flow of employees throughout the warehouse to expose any recurring patterns and expedite the process flow.
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	A technique used to find the best alternative solution by considering implementation cost, employee safety, efficiency, and productivity.
Cost Analysis	A tool for comparing implementation cost to determine the best cost-effective solution to a project before implementation.

**5.3.1 Cause and Effect**

The most useful tool for identifying the causes of problems is a cause-and-effect diagram, also known as a fishbone or Ishikawa diagram. A cause-and-effect diagram is simply a graphical representation of an outline that presents a chain of causes and effects [7]. This tool was utilized to brainstorm ideas and identify the most likely causes of a problem so that further data collection and analysis can be carried out. Five major factors were

considered to find the inefficiencies at Ecomspaces: environment, equipment, people, management, materials, and process. Figure 19 below depicts the cause-and-effect diagram that was created by the Optimized Brain E-spaces. At the end of the horizontal line is the problem that must be addressed. Each branch points to the main stem, representing a possible cause of the inefficient workflow within the warehouse at Ecomspaces. After brainstorming several possible ideas, it became evident that the major issue with the inefficiency of Ecomspaces was due to the excessive waste and clutter spread throughout the warehouse.

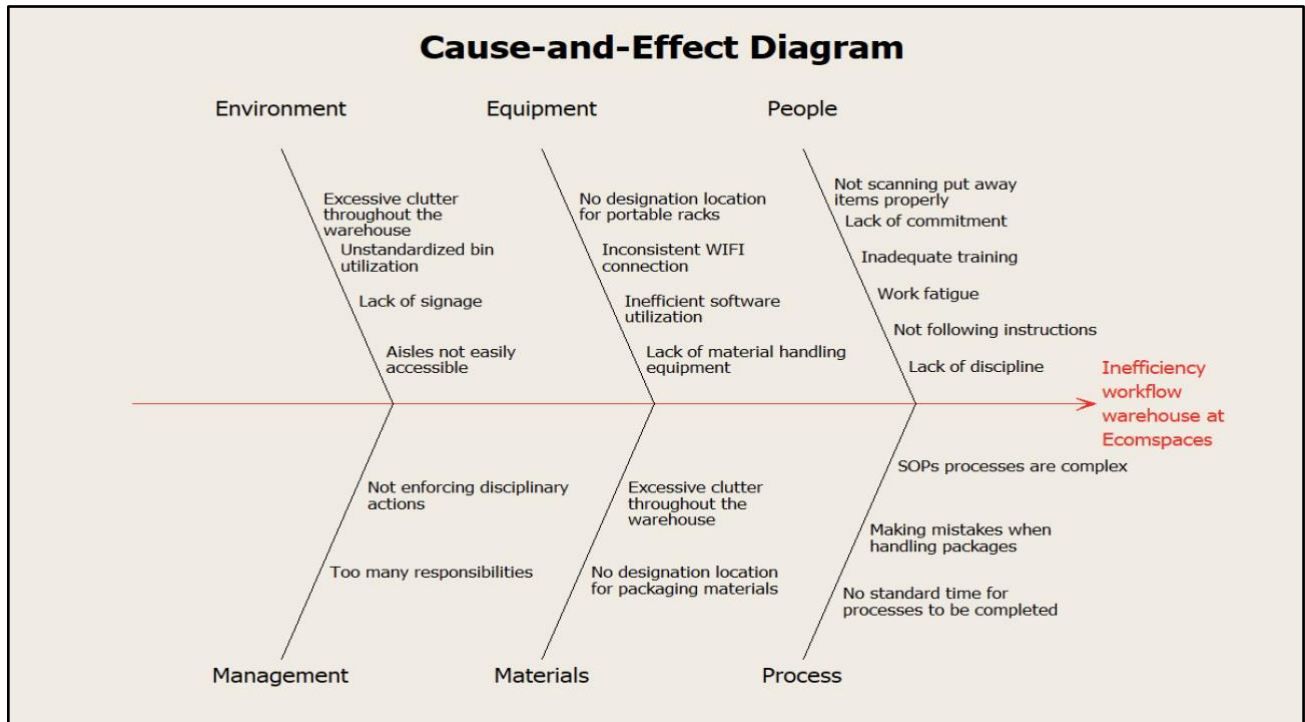


Figure 19: Cause-and-Effect Diagram of Ecomspaces Inefficiencies

### 5.3.2 Arena Simulation Model and Process Analyzer

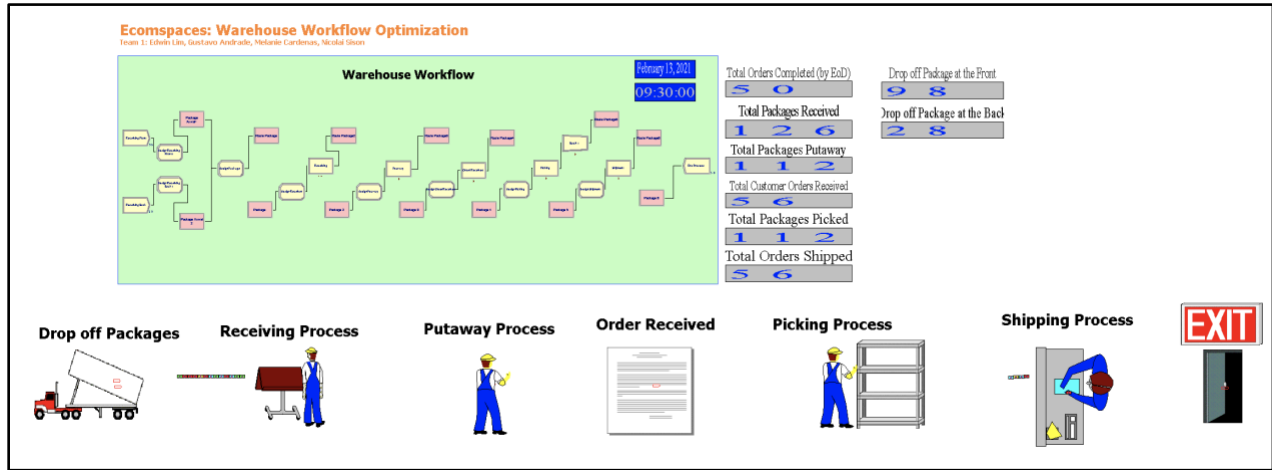


Figure 20: Ecomspaces Arena Model After Running

This above figure 20 depicts the output after the simulation is running and displays how the animation runs through the simulation. To reflect the accuracy of number resources, we use the same number resources in the actual current warehouse at Ecomspaces. There are 1 receiver, 1 putaway worker, 1 picker, 2 shippers, 2 receiving stations, 1 putaway station, 1 picking station, and 2 shipping stations. As a result of the simulation process, there are 50 total orders completed in a day, 126 total packages received by receiver, 112 total packages retrieved by putaway workers, 56 total customers orders received, 112 total packages retrieved by picker, 56 total orders are ready to be shipped. This simulation runs in a day for 8 hours to reflect the actual hours.

S	Scenario Properties			Controls									Response
	Name	Program File	Reps	receiver	putaway worker	Picker	shipper	Receiving Station	Putaway Station	Picking Station	Shipping Station	System.NumberOut	
1	Baseline	3 : Senior Pr	1	1	1	1	2	2	1	1	2	50.000	
2	Add 1R	3 : Senior Project - Ani	1	2	1	1	2	2	1	1	2	52.000	
3	Add 2R, 2PR, 1P, 1RS, 2PUS, 1PIS	3 : Senior Project - Ani	1	3	3	2	2	3	3	2	2	49.000	
4	Add 1S, 1SS	3 : Senior Project - Ani	1	1	1	1	3	2	1	1	3	56.000	
5	Add 9R, 9PW, 9P, 8S, 8RS, 9PUS, 9PIS, 8SS	3 : Senior Project - Ani	1	10	10	10	10	10	10	10	10	70.000	
6	Add 11R, 11PW, 11P, 10S, 10RS, 11 PUS, 11PIS, 10SS	3 : Senior Project - Ani	1	12	12	12	12	12	12	12	12	56.000	
7	Add 10R, 10PW, 10P, 9S, 9RS, 10PUS, 10PIS, 9SS	3 : Senior Project - Ani	1	11	11	11	11	11	11	11	11	70.000	
8	Add 11R, 10PW, 10P, 9S, 10RS, 10PUS, 10PIS, 9SS	3 : Senior Project - Ani	1	12	11	11	11	12	11	11	11	56.000	
9	Add 19R, 2PW, 2P, 1S, 18RS, 2PUS, 2PIS, 1SS	3 : Senior Project - Ani	1	20	3	3	3	20	3	3	3	67.000	
10	Add 11R, 2PW, 2P, 1S, 10RS, 2PUS, 2PIS, 1SS	3 : Senior Project - Ani	1	12	3	3	3	12	3	3	3	72.000	
11	Add 12R, 2PW, 2P, 1S, 11RS, 2PUS, 2PIS, 1SS	3 : Senior Pr	1	13	3	3	3	13	3	3	3	67.000	
12	Add 10R, 2PW, 2P, 1S, 9RS, 2PUS, 2PIS, 1SS	3 : Senior Pr	1	11	3	3	3	11	3	3	3	70.000	
13	Add 11R, 2PW, 1P, 1S, 10RS, 2PUS, 1PIS, 1SS	3 : Senior Project -	1	12	3	2	3	12	3	2	3	70.000	
14	Add 11R, 2PW, 2P, 10RS, 2PUS, 2PIS	3 : Senior Project -	1	12	3	3	2	12	3	3	2	71.000	
15	Add 11R, 1PW, 2P, 1S, 10RS, 1PUS, 2PIS, 1SS	3 : Senior Project - Ani	1	12	2	3	3	12	2	3	3	56.000	
16	Add 11R, 3PW, 2P, 1S, 10RS, 3PUS, 2PIS, 1SS	3 : Senior Project - Ani	1	12	4	3	3	12	4	3	3	72.000	
17	Add 11R, 19PW, 2P, 1S, 10RS, 19PUS, 2PIS, 1SS	3 : Senior Project - Ani	1	12	20	3	3	12	20	3	3	72.000	
18	Add 11R, 2PW, 3P, 1S, 10RS, 2PUS, 3PIS, 1SS	3 : Senior Pr	1	12	3	4	3	12	3	4	3	56.000	
19	Add 11R, 2PW, 5P, 1S, 10RS, 2PUS, 5PIS, 1SS	3 : Senior Pr	1	12	3	6	3	12	3	6	3	67.000	
20	Add 11R, 2PW, 6P, 1S, 10RS, 2PUS, 6PIS, 1SS	3 : Senior Pr	1	12	3	7	3	12	3	7	3	56.000	
21	Add 59R, 14PW, 14P, 13S, 58RS, 14PUS, 14PIS, 13SS	3 : Senior Pr	1	60	15	15	15	60	15	15	15	68.000	
22	Add 47R, 11PW, 11P, 10S, 46RS, 11PUS, 11PIS, 10SS	3 : Senior Pr	1	48	12	12	12	48	12	12	12	68.000	
23	Add 39R, 9PW, 9P, 8S, 38RS, 9PUS, 9PIS, 8SS	3 : Senior Pr	1	40	10	10	10	40	10	10	10	68.000	
24	Add 19R, 4PW, 4P, 18S, 18RS, 4PUS, 4PIS, 3SS	3 : Senior Pr	1	20	5	5	20	20	5	5	5	68.000	
25	Add 15R, 3PW, 3P, 2S, 14RS, 3PUS, 3PIS, 2SS	3 : Senior Pr	1	16	4	4	4	16	4	4	4	69.000	
26	Add 7R, 1PW, 1P, 6RS, 1PUS, 1PIS	3 : Senior Pr	1	8	2	2	2	8	2	2	2	70.000	
27	Add 7R, 1PW, 6RS, 1PUS	3 : Senior Pr	1	8	2	1	2	8	2	1	2	70.000	

28	Add 6R, 1PW, 5RS, 1PUS	3 : Senior Pr	1	7	2	1	2	7	2	1	2	65.000
29	Add 7R, 1PW, 6RS, 1PUS & Reduce 1S, 1SS	3 : Senior Pr	1	8	2	1	1	8	2	1	1	50.000
30	Add 7R, 6RS	3 : Senior Pr	1	8	1	1	2	8	1	1	2	56.000
31	Add 3R, 2RS & Reduce 1S, 1SS	3 : Senior Project - Ani	1	4	1	1	1	4	1	1	1	46.000
32	Add 10R, 10PW, 10P, 13S, 9RS, 10PUS, 10PIS, 13SS	3 : Senior Project - Ani	1	11	11	11	15	11	11	11	15	70.000
33	Add 11R, 12PW, 11P, 10S, 10RS, 12PUS, 11PIS, 10SS	3 : Senior Project - Ani	1	12	13	12	12	12	13	12	12	56.000
34	Add 11R, 29PW, 11P, 10S, 10RS, 29PUS, 11PIS, 10SS	3 : Senior Project - Ani	1	12	30	12	12	12	30	12	12	56.000
35	Add 29R, 29PW, 11P, 10S, 28RS, 29PUS, 11PIS, 10SS	3 : Senior Project - Ani	1	30	30	12	12	30	30	12	12	68.000
36	Add 19R, 19PW, 12P, 13S, 18RS, 19PUS, 12PIS, 13SS	3 : Senior Project - Ani	1	20	20	13	15	20	20	13	15	68.000
37	Add 19R, 19PW, 17P, 13S, 18RS, 19PUS, 17PIS, 13SS	3 : Senior Project - Ani	1	20	20	18	15	20	20	18	15	68.000
38	Add 19R, 19PW, 12P, 18S, 18RS, 19PUS, 12PIS, 18SS	3 : Senior Project - Ani	1	20	20	13	20	20	20	13	20	68.000
39	Add 24R, 24PW, 24P, 23S, 23RS, 24PUS, 24PIS, 23SS	3 : Senior Project - Ani	1	25	25	25	25	25	25	25	25	68.000
40	Add 98R, 98PW, 98P, 97S, 97RS, 98PUS, 98PIS, 97SS	3 : Senior Project - Ani	1	99	99	99	99	99	99	99	99	68.000

Figure 21: 40 Scenarios in Process Analyzer ARENA

This above figure 21 represents 40 scenarios we generated in the Process Analyzer ARENA to identify the optimal solution from the model we built. The first scenario is the baseline or the current resources at Ecomspaces that includes 1 receiver, 1 putaway worker, 1 picker, 1 shipper, 2 receiving stations, 1 putaway station, 1 picking station, and 2 shipment stations. For descriptions, “R” represents receiver, “PR” represents putaway worker, “P” represents picker, “RS” represents receiving station, “PUS” represents putaway station, “PIS” represents picking station, “SS” represents shipping station. Our goal is to find a way to improve the existing output of 50 we found from running the simulation model in ARENA by utilizing minimal resources as little as possible. After we generated multiple scenarios, we found that they needed to hire more receivers to balance it out with the order received rate otherwise it would become a bottleneck for other processes.

From the 40 scenarios, we found that the best way to generate highest output at this rate is by increasing number of receivers to 12, put-away workers to 3, pickers to 3, shippers to 3, receiving stations to 12, put away stations to 3, picking stations to 3, and shipping stations to 3 (scenario 10). Other alternatives are scenarios 12 and 14, producing outputs of 70 and 71, respectively. Although these alternatives do not produce as much as scenario 10 does, they use less resources, which means more savings. Scenario 12 utilizes 11 receivers, 3 put-away workers, 3 pickers, 3 shippers, 11 receiving stations, 3 putaway stations, 3 picking stations, and 3 shipping stations. Scenario 14 utilizes 12 receivers, 3 put-away workers, 3 pickers, 2 shippers, 12 receiving stations, 3 putaway stations, 3 picking stations, and 2 shipping stations. However, Ecomspaces is currently limited by space, so they can take advantage of these scenarios for future use. The most realistic solution for Ecomspaces from comparing these 40 scenarios is to implement scenario 2 by hiring a receiver to increase the output from 50 to 52. Due to the variety of items, it is difficult to predict how much profit will be generated after deducting labor costs.

### 5.3.3 Time and Motion Studies

Ecomspaces practices a manual picking procedure where employees must (1) print the orders that need to be gathered or picked, (2) walk to each aisle in the warehouse to search for items, (3) pick the items, then (4) prepare the order to be shipped. This process is crucial because if an item is incorrectly picked and shipped to the wrong customer, Ecomspaces pays for both the cost of shipping and the replacement of the item for the customer. This process is time-consuming and the rate at which mistakes are made vary between every employee, influenced by factors such as experience level. Figure 22 below depicts a time and motion study that was conducted for the picking process at Ecomspaces. This study was conducted two times for three employees for a total of six-time studies. The purpose of this time study was to create a standard time to pick orders. Examination of each individual movement was timed throughout the process. According to [21], the picking process is the most time-consuming process for any warehouse facility. Hence, further analysis for this procedure was conducted.

<b>The Optimized Brain-E Spaces Ecomspaces</b>				1 to 4 = Each Individual Time		8 = Rating Factor (90% = .90, 100% = 1.00, 110% = 1.10)					
				5 = Total of all Times		9 = Base Time (7 multiplied by 8)					
				6 = Number of Time Values		10 = Frequency (1 = every cycle, 1/10 = once per 10 cycles)					
				7 = Average (5 divided by 6)		11 = Normal Time (9 multiplied by 10)					
Element Description	1 Time	2 Time	3 Time	4 Time	5 Total	6 No.	7 Avg.	8 Rate	9 Base	10 Freq.	11 Norm.
Rolling Shelf to aisle	0:00:25				0:00:25	1	0:00:25	0.95	0:00:24	1	0:00:24
Picking Item	0:00:17	0:00:14	0:00:13	0:00:12	0:25:43	27	0:00:57	0.9	0:00:51	4/1	0:03:26
	0:00:42	0:00:26	0:04:41	0:05:12							
	0:00:53	0:00:18	0:00:09	0:00:19							
	0:00:30	0:00:14	0:00:40	0:00:18							
	0:00:15	0:00:09	0:04:16	0:00:20							
	0:01:21	0:00:46	0:01:32	0:00:14							
	0:01:03	0:00:17	0:00:12								
Placing/ rearranging items on rack	0:17:54				0:17:54	1	0:17:54	0.9	0:16:07	1/4	0:04:02
<b>Operation: Picking process</b>			<b>Foreign Element Explanations:</b>					Total Normal Time = 0:07:51			
<b>Picking process employee: Chance</b>			Rolling shelf used to place picked items while gather more items					25%P,F,and D = 0:01:58			
<b>Equipment: Manual Operation</b>			Picking items are the packages that customers requested					Total Standard Time = 0:09:49			
<b>Date: February 2, 2021</b>			Placing/ rearranging items on rack is the time spent rearranging					(0:07:51 + 0:01:58)			
<b>Elapsed Time: 0:43:37</b>			picked orders on racks to make more room for more packages					Standard Time to Pick Orders			

Figure 22: Time and Motion Study of Picking process at Ecomspaces

### 5.3.4 Completed KPI and Standard Times

The table in [Appendix P](#) showcases the completed KPI for Ecomspaces using data collected from the sources mentioned in [Appendix F](#). The current state of a given performance indicator is provided, alongside a numerical target that our design proposal seeks to address. While a leading indicator presents us with information that may lead to future success, a lagging indicator tells us of both current and historical performance rates.



The values for cycle time and productivity levels are based on the mean observed times (also known as cycle times) for each station. Using the cycle time values collected from the time study data, we are able to generate standard times for all of the major work-processes within the business-operation at Ecomspaces, see Figure 23 below. The formulas used for the calculation of standard times are as follows:

<i>Number of Observations, n</i>	$Cycle\ Time, T_C = \frac{\sum T_{obs}}{n}$
<i>Performance Rating Factor, F<sub>P</sub></i>	$Normal\ Time, T_N = T_C \times F_P$
<i>Allowance Factor, F<sub>A</sub></i>	$Standard\ Time, T_S = \frac{T_N}{(1-F_A)}$

Figure 23: Formulas for Work Measurement

It is important to note that both the performance rating factor F<sub>P</sub> and the allowance factor F<sub>A</sub> are subjective values made by the analyst, where F<sub>P</sub> is based on an estimate for a particular worker’s performance at the time of recording, and F<sub>A</sub> is an approximation for an allowance factor to account for a worker’s personal fatigue and any unavoidable delays. Generally, a lower performance rating factor indicates a worker whose production output is faster than average (e.g., an experienced worker), whereas a higher performance rating factor indicates someone whose output is slower than average (e.g., a new hire). Figure 24 below depicts the calculated standard times for the receiving, put-away, picking, and shipping processes at Ecomspaces by employee.

Ecomspaces - Standard Times for Work Processes					
Work Element	Employee Name	Mean Observed Time	Performance Rating Factor	Normal Time (minutes)	Standard Time (minutes)
Receiving	Diamond	3.46	1.15	3.98	4.68
Put-Away	Chaunce	0.59	1.10	0.65	0.76
Picking	Valentine	1.44	0.85	1.22	1.44
Shipping	Ali	15.6	0.90	14.04	16.52
	Valentine	17.4	0.85	14.79	17.40
<b>Total Time (minutes):</b>	<b>N/A</b>	<b>21.99</b>	<b>N/A</b>	<b>20.27</b>	<b>23.84</b>
<b>Allowance Factor:</b>	<b>0.15</b>				

Figure 24: Standard Times at Ecomspaces

### 5.3.5 Completed Audits

#### 5.3.5.1 OSHA/Fire Safety

The initial assessment of the warehouse showed there are several areas for improvement as it pertains to safety, and workplace standards. From our completed audits for both fire and OSHA safety show the warehouse workspace is failing to meet certain requirements of the title 29 Code of Federal Regulations (CFR) 1910. The 29 CFR 1910 provides a collection of regulations that ensure

safety in day-to-day workplace operations. For the warehouse, there were roughly six sections that appeared to be potential violations.

Most of the violations were centered around the excess clutter present in the warehouse, such as extra boxes and debris on the floor of the main walkways throughout the warehouse. Section 1910.22(a) and 1910.22(d) focus heavily on ensuring that passageways and walking-working surfaces are kept clean, orderly, and inspected on a regular basis. A simple solution to prevent any fines associated with an unexpected OSHA visit would be to implement regular cleaning of the warehouse focusing on workspaces that are used regularly and all aisles that are used during any work process.

Another area where the warehouse seems to be at potential risk of OSHA violations relates to fire safety standards. Sections 1910.37 to 1910.39 relate to having proper emergency exit routes, emergency action plans, and fire prevention plans. This would include ensuring that there are fire prevention and housekeeping-like processes to control the amalgamation of flammable waste, exit routes for emergencies are free of obstructions which includes pathing to the exit and area near the door, as well as proper signage to indicate the exit location. The maximum fee per violation can be up to \$13,653 per fine resulting in a large, unexpected cost to the company. We aim for Ecomspaces to build a foundation for continued growth and that means maintaining their facility and prevent any unexpected cost that could result from OSHA violations. Having regular evaluation of these issues can result in a cleaner, better organized, and safer warehouse. Additionally, we have assessed that these issues be corrected with monthly maintenance for fire safety, and weekly or daily evaluation of cleanliness of the warehouse with proper utilization of our audit checklist lists that can be integrated with SOP developments.

The original documentation for our OSHA and fire safety audits can be found in [Appendix Q](#) and [Appendix R](#), respectively.

#### **5.3.5.2 *Lighting and Housekeeping/Maintenance***

Inadequate lighting can result in inefficiencies during the order picking and manual search process for packages and item orders. For our initial observations for warehouse lighting, the facility is dark with inconsistent lighting throughout the facility. There are burnt out bulbs and overhead lighting that can be considered as “quick fixes” for the lighting in some of the areas within the facility.

With target values ranging from 200-500 lux, the illuminance for the receiving workstations are sufficient, while being insufficient for both the fulfillment and shipping station. Regarding the receiving dock, lighting is sufficient both when the dock is open and closed, with illuminance ranging between 100-350 lux. For



loading dock (a), the lighting is insufficient both when the dock is open and closed, with illuminance ranging between 50-100 lux. For loading dock (b) the lighting is also insufficient, with illuminance falling below 50 lux.

Lighting was sufficient for three out of eight aisles within the warehouse. However, there exhibited large amounts of variation in lighting within the same aisle. Within the aisles, greater illuminance was observed towards the front of the warehouse, facing the front door and the receiving station. The darker areas tended to be near the wall by dock 2 and the shipping stations. Figure 25 shows a clustered bar graph for warehouse aisle illuminance, where three measures were taken for each aisle using a lux meter. The first measure (in blue) recorded the front - facing the receiving station and entrance to the warehouse, the second measure (in orange) recorded the illuminance for the middle of the aisle, and the third measure (in gray) records the back of the aisle - facing the shipping station and the loading docks. Regarding other locations within the warehouse, the lighting for the entrance, exit, and emergency areas were insufficient.

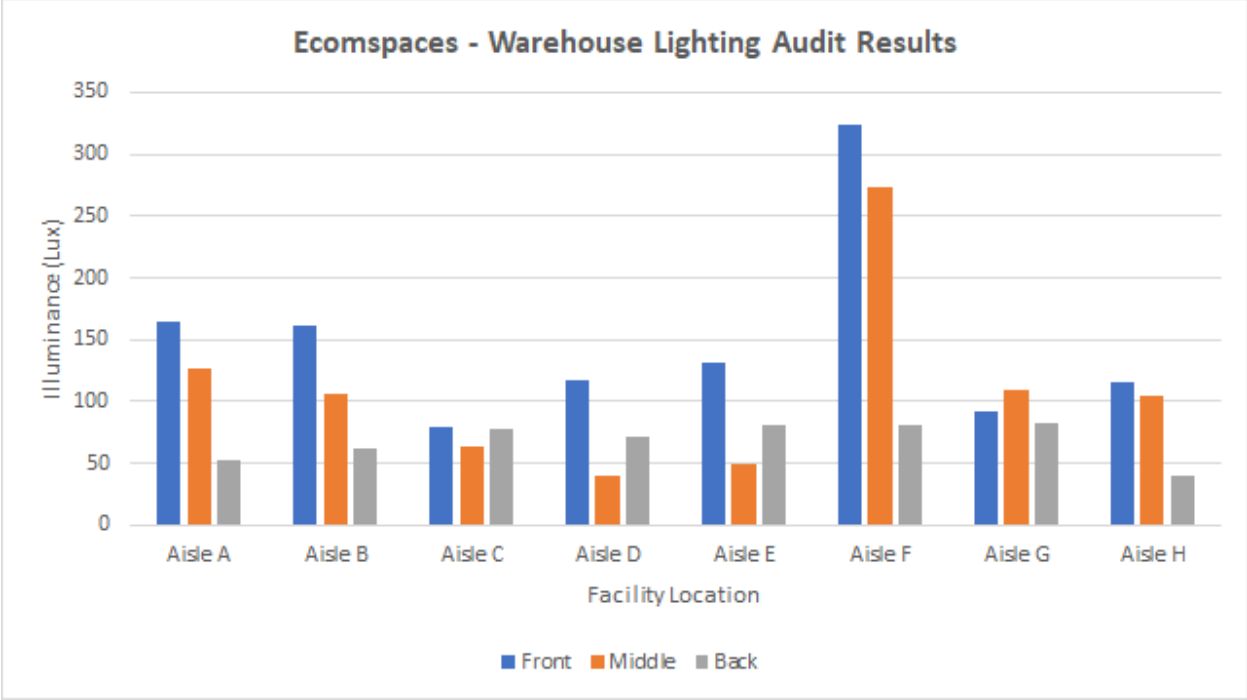


Figure 25: Warehouse Lighting Audit Results by Aisle

Overall, the lighting conditions within the warehouse are poor due to the insufficient and uneven distribution of lights throughout the facility. Overhead lighting by the loading docks need replacement, and additional costs may incur scissor lift rental and electrical work. Lighting inconsistencies are present across the same aisle. Possible solutions for proper lighting may involve the use of external overhead lights similar to the ones found in Aisle F. The completed documentation for the warehouse lighting audit at Ecomspaces can be found in [Appendix S](#).

Completed audit documentation for can be found in [Appendix T](#). Observations for housekeeping and maintenance are as follows:

1. Regarding the *facility interior*, the warehouse is generally disorganized and in need of cleaning. Product is visible on the ground upon entry. There are no windows inside the warehouse. The spacing between shelves is inconsistent due to clutter. Certain areas of the warehouse have products on the ground with no designated locations. There are noticeable water stains and damage on the walls. The floor has many cracks, dents, and stains.
2. Regarding *doors and docks*, doors open and close properly with functional locks. Dock 2 in the shipping area is broken and must be repaired, with excess clutter and debris at that location.
3. Regarding *electrical work*, bulbs in the back dock area are burned out and need replacement. Light switches within the facility operate properly with no burn or flash marks on the outlets. Security/automated lights operate successfully within the facility.
4. Regarding the *receiving station*, there is no sign that indicates the purpose of the station. The exterior lighting is sufficient. The floor area is generally clear of clutter. Waste bins are being utilized correctly. The workstation is cluttered as a result of tools not being assigned to designated locations. There are procedures and instructions written alongside the workstation for employee reference.
5. Regarding the *packing and shipping station*, there are no signs to indicate its purpose as a shipping station. The lighting for the used stations are acceptable, but not for the unused stations. The floor area is somewhat cluttered. Waste bins in this area are being properly used. Tools utilized are stored but not arranged neatly due to a lack of designated locations. The procedures and instructions provided at the workstation are only for exceptions and uncommon steps.
6. Regarding the *fulfillment station*, there are signs indicating that the area is used for order fulfillment. The floor areas are clean and clear of clutter. The waste bins are correctly being used. Tools utilized are both stored and arranged neatly. There are procedural instructions provided at the workstation.
7. Regarding the *receiving ramp area*, the dock door operates both safely and securely. The receiving dock area is free of blockages and is easily accessible. The Ring doorbell, used for security and truck delivery notification, works properly.

8. Regarding the *dock areas*, the door for Dock 1 operates safely and securely, with the area being both accessible and generally free from blockages. The door for Dock 2 does not operate and has access completely blocked by personal items, packaging boxes, and pallets. The Ring doorbell works properly for Dock 1, but not for Dock 2.

### 5.3.6 Spaghetti Diagram

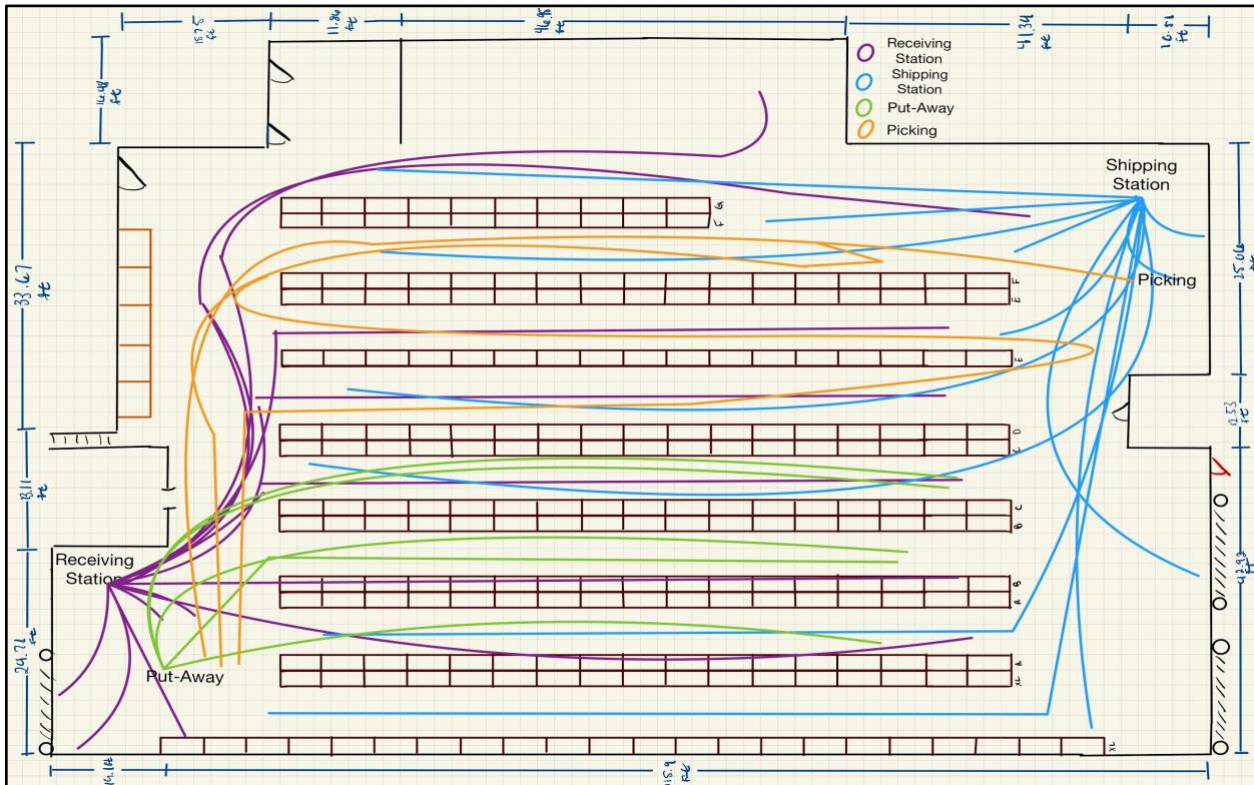


Figure 26: Spaghetti Diagram at Ecomspaces

The spaghetti diagram in Figure 26 above depicts the flow of employee movement from their station to other places in the warehouse. This visual representation helps us understand where employees spend their time throughout the day. Before we created this visualization, we first observed employees on-site as well as asked them to draw it out in blank map to eliminate any bias that might occur from third person observation. After we retrieved all information, we created this spaghetti diagram by including all movement in one map. The purple line color represents receivers movement from their receiving station, the green line color represents put-away workers movement from their put-away station, the blue line color represents shippers movement from their shipping station, and the orange color represents picking movement from their picking station. As seen in the diagram, receivers usually stay at the receiving station to receive order shipment as well as inspect them to ensure items comply with the regulations. Shippers usually do the picking process as well as the shipping process, and pickers do the picking process ahead of time when they have more downtime. Although employees at Ecomspaces usually

work in their workstation, they could also assist in other areas based on needs. For example, sometimes receivers also complete put-away work during their downtime. This visualization also helps us to have a better understanding about employees productivity.

### 5.3.7 TOPSIS

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) describes customer preference in the form of weights for each criterion. This technique was implemented to find the best alternative from analyzing implementation cost, employee safety, efficiency (space utilization, productivity (speed) to the ideal solution.

Ecomspaces warehouse facility was recreated, and three alternative solutions were proposed with the overall goal of increasing warehouse efficiency and effectiveness.

Figure 27 below depicts *Proposed Layout A*. This layout recommends switching aisles D and A. Currently, aisle D is cluttered with pallets of large overstock items and waste. Moving this aisle to the current location of aisle A will keep the large overstock items together and in a single aisle within the warehouse, conveniently between the two loading dock areas. Moreover, switching aisles A and D will cost the least amount of time, work, and money, incurring little to no renovation cost. The pallet jacks in the warehouse can be utilized to move the oversize items during the renovation process, and the shelving racks at aisle A are wheeled and are easily transportable. This proposed layout A also recommends creating a new shipping station near dock 2 as highlighted in green after clearing waste in the existing area and placing rolling shelves for items ready to be shipped between dock 1 and dock 2. By adding this new shipping station, Ecomspaces will have a total of 4 shipping stations, enhancing productivity and efficiency by reducing the time it takes to move ready-to-ship items to docks.

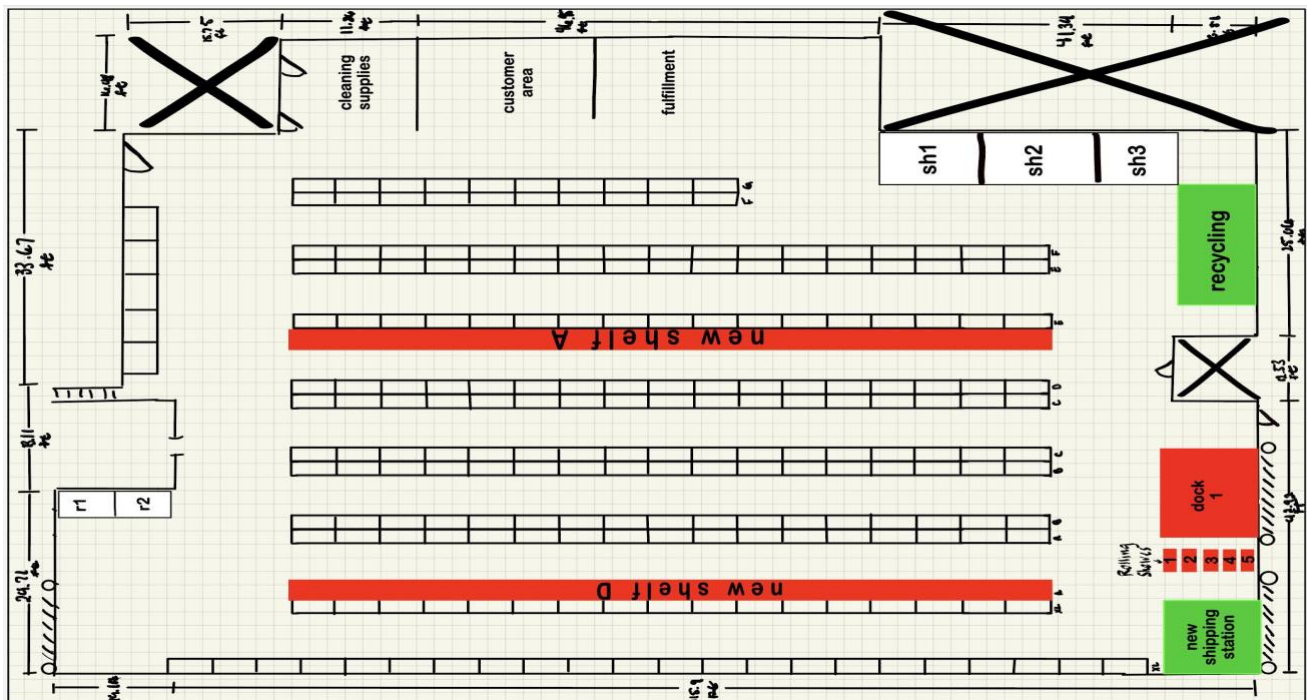


Figure 27: Proposed Layout A







The productivity is retrieved by calculating distance and time walk from shipping station to each aisle. We utilized a stopwatch and laser meter to complete this process. After we collected all the information, we compared each proposed solution to the distance and time walk from the existing shipping station. From the comparison, we obtained productivity for proposed layout A is 8.1, and proposed layout B and C are 8.5. The full comparison distance and time walk from the shipping station to each aisle can be found in [Appendix M](#).

After comparing these four metrics for each proposed solution, we obtained 0.585316 for proposed layout A, 0.252312 for proposed layout B, and 0.569830 for proposed layout C. The final ranking in TOPSIS the best solution is close to 1.0, so proposed A is the best solution for Ecomspaces based on TOPSIS analysis as seen in figure below. The full calculation for TOPSIS can be found in [Appendix L](#).

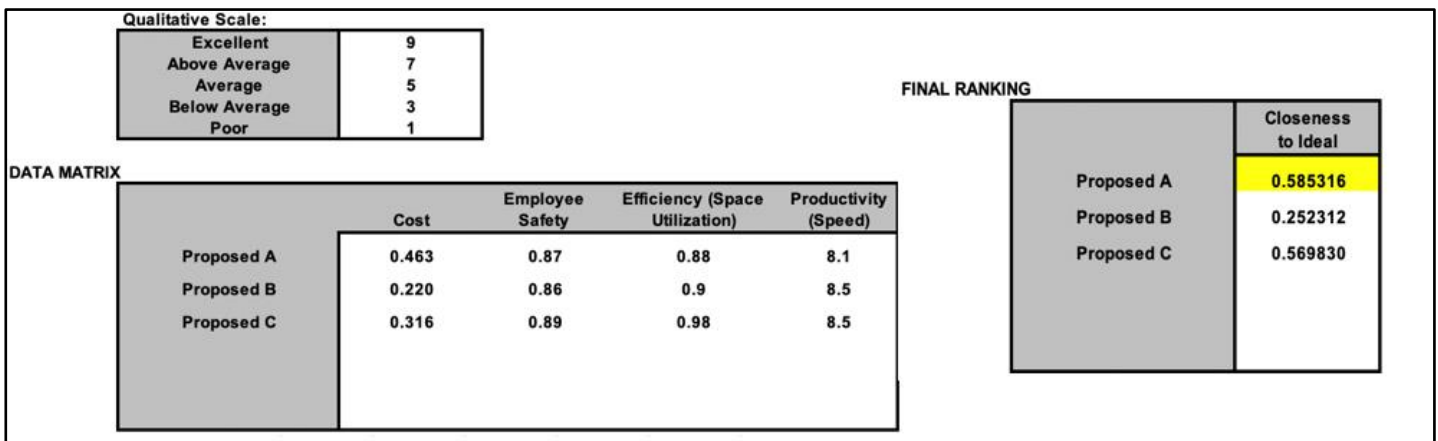


Figure 30: Data and Final Ranking for TOPSIS for Proposed Layout Ecomspaces

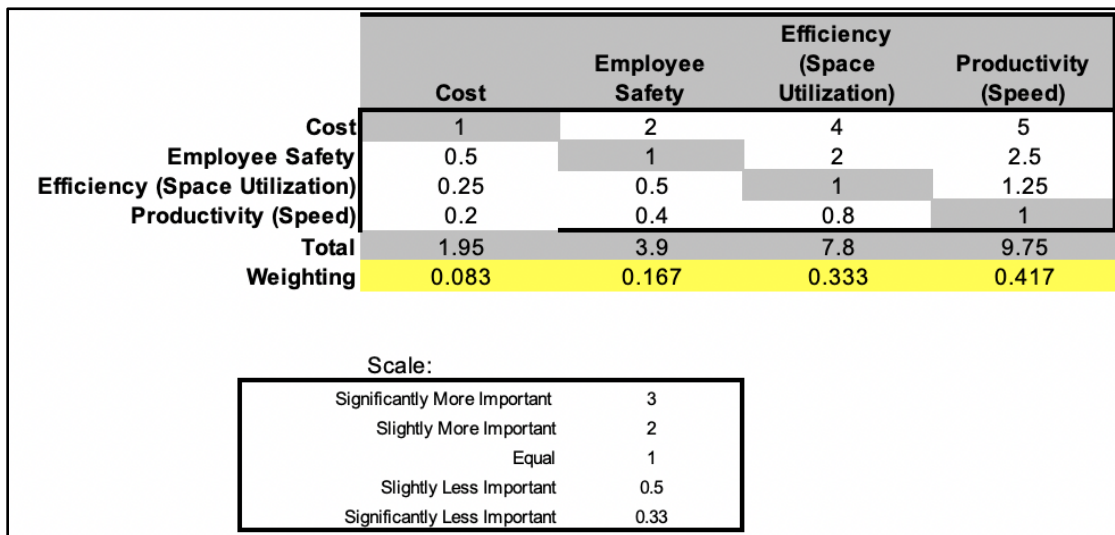


Figure 31: Prioritization Calculation for Criteria Weights TOPSIS



Figure 31 above represents the prioritization that is part of the TOPSIS analysis for each metric. Comparing cost with three other metrics, we set 2 for employee safety, 4 for efficiency (space utilization), and 5 for productivity (speed) because our overall goal is to improve productivity, space utilization, and employee safety. Comparing employee safety with three other metrics, we set 0.5 for cost, 2 for efficiency (space utilization), and 2.5 for productivity (speed). Comparing efficiency (space utilization) with three other metrics, we set 0.25 for cost, 0.5 for employee safety, and 1.25 for productivity (speed). Comparing productivity (speed) with three other metrics, we set 0.2 for cost, 0.4 for employee safety, and 0.8 for efficiency (space utilization). After comparing each metric, we obtained a weight of 0.083 for cost, 0.167 for employee safety, 0.333 for space utilization, 0.417 for productivity (speed).

### 5.3.8 Cost Analysis

<b>The Optimized Brain E-Spaces: Expected Increase in Profit (Monthly)</b>	
Accumulated Total Expenses (Actual)	\$70,106.74
Accumulated Total Income (Actual)	\$72,796.77
Net Income Before Tax (Actual)	\$2,690.02
Proposed Layout A Estimated Implementation Cost	\$6,637.10
Proposed Layout B Estimated Implementation Cost	\$3,630.00
Proposed Layout C Estimated Implementation Cost	\$4,726.05
Accumulated Total Expenses + Proposed Layout A Estimated Implementation Cost	\$76,743.84
Accumulated Total Income + 11% Increase expected in income	\$80,804.41
<b>Net Income Before Tax (Only for the first month after implementation)</b>	<b>\$4,060.57</b>
<b>Net Income Before Tax (After the first month) with 1.5% increase in actual expense</b>	<b>\$9,646.07</b>
Accumulated Total Expenses + Proposed Layout B Estimated Implementation Cost	\$73,736.74
Accumulated Total Income + 6% Increase expected in income	\$77,164.57
<b>Net Income Before Tax (Only for the first month after implementation)</b>	<b>\$3,427.83</b>
<b>Net Income Before Tax (After the first month) with 1.0% increase in actual expense</b>	<b>\$6,356.76</b>
Accumulated Total Expenses + Proposed Layout C Estimated Implementation Cost	\$74,832.79
Accumulated Total Income + 9.5% Increase expected in income	\$79,712.46
<b>Net Income Before Tax (Only for the first month after implementation)</b>	<b>\$4,879.67</b>
<b>Net Income Before Tax (After the first month) with 1.2% increase in actual expense</b>	<b>\$8,203.58</b>

Figure 32: Expected Increase in Profit



The figure 32 above is a cost analysis comparing the amount of profit that will increase by implementing each proposed layout. Currently, the monthly net profit (before tax) is \$2,690.02 that can be found by subtracting the accumulated total monthly income of \$72,796.77 from the accumulated total monthly expense of \$70,106.74. The accumulated total expenses consist of Labor, Utilities, Professional dues and subscriptions, Supplies, Telephone, Payroll, Insurance, Postage, Interests, Bank fees, and Advertising. The accumulated total income consists of Stripe, Square, PayPal, Peerspace, rent offices, Croissant, and Liquidspace. The full calculations for the monthly net profit, accumulated total monthly income, and accumulated total monthly expense can be seen in [Appendix O](#).

By implementing proposed layout A, we estimated Ecomspaces will increase the total monthly income by 11%, total monthly expense by 1.5%, which equates monthly net income of \$9,646.07. By implementing proposed layout B, we estimated Ecomspaces will increase the total monthly income by 6%, total monthly expense by 1.0%, which equates monthly net income of \$6,356.76. By implementing proposed layout C, we estimated Ecomspaces will increase the total monthly income by 9.5%, total monthly expense by 1.2%, which equates monthly net income of \$8,203.58.

Net Income Before Tax (Proposed Layout A)	\$9,646.07
Interest Rate	5%
Term (years)	10
Compounding Periods per Year	12
<b>Future Value Profits</b>	<b>\$15,887.16</b>
Net Income Before Tax (Proposed Layout B)	\$6,356.76
Interest Rate	5%
Term (years)	10
Compounding Periods per Year	12
<b>Future Value Profits</b>	<b>\$10,469.65</b>
Net Income Before Tax (Proposed Layout C)	\$8,203.58
Interest Rate	5%
Term (years)	10
Compounding Periods per Year	12
<b>Future Value Profits</b>	<b>\$13,511.37</b>

*Figure 33: Future Value Profits*

Figure 33 above represents the future value profits looking from 10 years from now with a 5% interest rate for each proposed layout. From the TOPSIS we conducted, we found that Ecomspaces should implement proposed layout A, meaning that their net income expected to be increased to \$9,646.07/month with future value profits of \$15,887.16/month after ten years. Additionally, the future value profits would be \$190,645.92 on an annual basis, rather than on a monthly basis.

## 5.4 Improve

The Improve phase is the fourth step of the DMAIC process where solutions are developed, ideas are implemented, and data is collected to measure and quantify improvement. Generally, the steps leading to the Improve phase are done to reduce process variation and to deliver on the quantifiable target values expressed during the Analyze phase.

Through the implementation of solutions we proposed, Ecomspaces will (1) regain and repurpose entire sections of their facility for reasons such as establishing workstations in convenient locations and providing space for additional storage, (2) benefit through the standardization of safety, housekeeping, and maintenance tasks by providing consistency and reduced variation for visual ergonomics and equipment accessibility throughout the entire facility, and (3) have the capability of measuring and comparing performance improvement to compare against previously established benchmarks and standard times.

From TOPSIS, we propose our three facility layout designs for implementation, and disclose the new SOP documentation for OSHA, fire safety, and maintenance for the warehouse operations at Ecomspaces. After we presented and discussed our proposed solutions with management, we gained insights about the potential solutions that Ecomspaces is willing to consider for implementation. Implementation may take considerable time for employees to become familiar with, and for management to hire third-party services to carry out the proposed changes. Upon completion, performance will be measured to identify any immediate changes, and challenges faced during implementation will be discussed.

### 5.4.1 Accepted/Rejected Solutions

Overall, we highly recommend Ecomspaces to implement each of the six solutions proposed in chapter 4 to establish a solid foundation that focuses on warehouse utilization and organization, safety, and regular maintenance to keep everything in order. However, we understand that these solutions should be ranked in order of importance to help Ecomspaces understand the importance of each solution. To rank each of these solutions, our team utilized TOPSIS analysis with the same prioritization matrix as before. The four metrics that each solution was measured in were (1) cost, (2) space utilization, (3) benefit, and (4) ease of application. Figure 34 shows each solution along with their respective values for each metric and final ranking.

DATA MATRIX					FINAL RANKING	
	Cost	Space utilization	Benefit	Ease of Application		Closeness to Ideal
Regain Floor space	2.00	0	3	9	Regain Floor space	0.862
Floor Identifiers	9.00	1	1	1	Floor Identifiers	0.138
Warehouse Safety	3.00	0	2	7	Warehouse Safety	0.703
Emergency Exit	5.00	1	1	3	Emergency Exit	0.209
Lighting	3.00	0	2	3	Lighting	0.412
SOPs for Maintenance	2	0	3	3	SOPs for Maintenance	0.474

Figure 34: TOPSIS Ranking for Solutions

In the TOPSIS analysis above, each solution under the space utilization was given a 0 or a 1. A value of 0 was given if the solution aided in space utilization, otherwise it was given a 1. In the final ranking, the solution closest to 1 is optimal showing that Ecomspaces should first regain unused floor space in the warehouse, followed by warehouse safety, and SOP development. Given the ranking for these solutions means the company should turn their attention to cleaning the warehouse to regain the floor space, promote safety by ensuring the warehouse workspace is regularly maintained through SOP utilization, and in the future can now look to possibly rearranging their workspace to increase the efficiency of workflows present in the warehouse.

#### ***5.4.2 Proposed Layout A***

Once clutter has been removed and cleanliness of the warehouse is maintained, Ecomspaces can look further into the possible reorganization of the warehouse. This can also be applied as a general guide for how to design the layout of the warehouse if the company were to move into a larger facility. Layout A takes advantage of previously wasted space in the warehouse to create a new workstation for the shipping process to help increase the number of orders gathered each day. Since efficiency in the shipping process would increase, Ecomspaces could see a net profit increase of \$9,646.07 per month which can lead to a net profit increase in ten year of \$15,887.15 per month.

#### ***5.4.3 SOP Updates and Revisions***

Our team has developed three major SOPs for Ecomspaces to utilize on the path of improvement. A key focus of these SOPs is to help the company in maintaining and regulating the workspace after the completion of our project. Ideally these documents promote positive change in the warehouse by empowering the employees of Ecomspaces in creating a reliable and efficient way to succeed by producing results that increase safety, organization, and can result in a higher quality of service to the customers. Each sheet for the SOPs developed can be found in [Appendix U](#).

#### ***5.4.4 Performance Measurement***

Our team has made significant improvement in regaining floorspace around the warehouse. From our initial on-site visit, we particularly focused on clearing up certain sections in the warehouse. In four months, our group contributed to removing 56.81% of the initial clutter and debris within the facility. In other words, we helped clear up 10.15% of the entire warehouse space. Although all the waste in the facility is not completely removed, our team has been working with management to provide them with all the tools necessary for them to continually remove waste and keep it at a minimum.

$$\text{percent change (unutilized)} = \left| \frac{\text{new unutilized space} - \text{original unutilized space}}{\text{original unutilized space}} \right| \times 100\%$$

$$56.81\% = \left| \frac{(872.88 - 2020.82) \text{ ft}^2}{2020.82 \text{ ft}^2} \right| \times 100\%$$

$$\text{percent change (entire facility)} = \frac{\text{new unutilized space} - \text{original unutilized space}}{\text{total facility space}}$$

$$10.15\% = \left| \frac{(872.88 - 2020.82) \text{ ft}^2}{11309.159 \text{ ft}^2} \right| \times 100\%$$

Figure 35: Performance Measurement Calculations

**5.4.5 Implementation**

The last part of the improve phase is implementation of all proposed solutions we discussed above. It is important for Ecomspaces to follow these guidelines and implement each solution sequentially to ensure that they obtain the best results.

- a. Cleanliness: The first step to improve overall productivity is by promoting cleanliness in the workplace. This step needs to be followed by all employees and employers to execute properly and obtain excellent results. Figure 36 below depicts a cleaning poster to remind everyone in the workplace to maintain cleanliness. This poster includes daily jobs, weekly jobs, and monthly jobs. The daily jobs include sweep floors and clear passageways, recycle excess packaging, report and remove damaged products, discard broken pallets, and inspect for visible signs of infestation. The weekly jobs include empty bins, clear racking of empty pallets and crates. The monthly jobs include checking and organizing items in the designated place and dust pallet racking and shelving.



*Figure 36: Cleaning Poster*

- b. **Maintenance:** The next step is to utilize the SOPs and audits we have developed to identify and analyze which areas need to be improved by finding potential problems. This maintenance program not only boosts productivity in the operations sector, but also enhances overall safety in the warehouse, eliminates waste, and avert any accidents in the warehouse and potential violations fees added to business expenses.
- c. **Layout:** The last part is to implement the layout we proposed to improve overall space utilization, eliminate waste, and enhance overall productivity and speed. Furthermore, it is crucial for Ecomspaces to keep identifying and analyzing space utilization throughout the year in order to improve and expand the overall business operations.

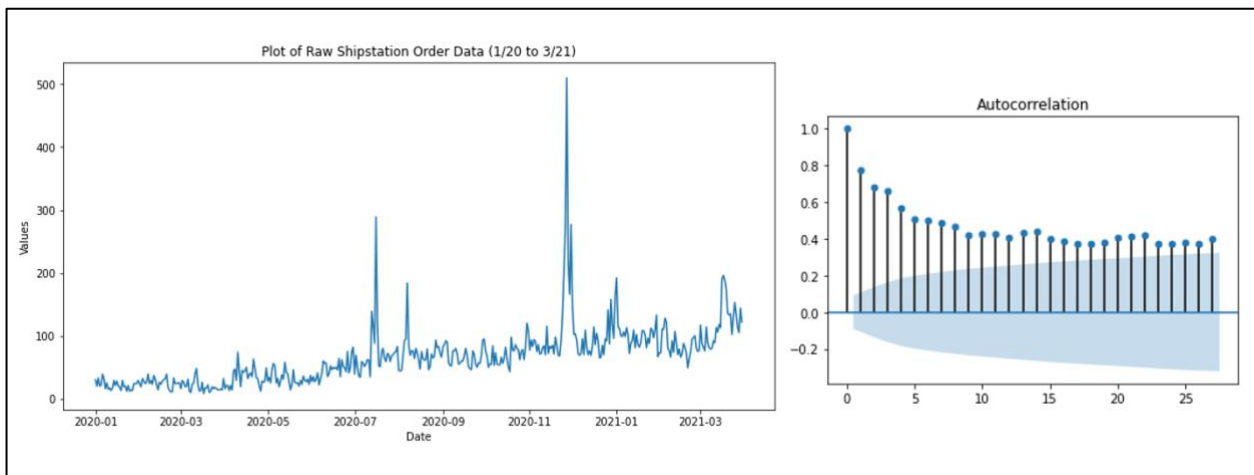
By implementing all of these sequentially, it will help Ecomspaces to minimize errors, enhance overall productivity, and find the most optimal solution for the overall efficiency in the warehouse. It is important for Ecomspaces to keep updating their data and identifying ways to improve for continuous improvement of the business.

## 5.5 Control

The Control stage of the DMAIC model focuses on ensuring the recommendations our team made are successfully implemented and maintained after project completion. For the control step, it is also important to have ease in access to the data required for process and operational analysis in order to measure company growth and improvement. The following subsections emphasize the collection and analysis of data from a variety of sources available to Ecomspaces by conducting time studies and warehouse audits or exporting raw data files from software currently being utilized.

### 5.5.1 Order Demand Forecasts

Forecasts are oftentimes generated by businesses to predict customer demand. Figure 37 below shows a time series plot for 15 months of customer orders from Ecomspaces, alongside an autocorrelation plot for the data. An autocorrelation plot is useful for identifying underlying patterns such as trend and seasonality within a time series, an analysis that is usually done prior to forecasting since many ARMA-type models such as autoregression (AR) and moving average (MA) are incapable of capturing complex patterns from non-stationary time series data, where the mean and variance of a series is not constant over time.



*Figure 37: Time Series Plot of Raw Order Data with Autocorrelation Plot*

Observations from the autocorrelation plot tell us that the demand for orders has a positive trend (indicated by most or all points located above the positive axis) that increases at a decreasing rate. There is slight indication of seasonality (observed by the U-shaped patterns within the autocorrelation plot) that may be emphasized in future works with further preprocessing of the data.

As seen in [Appendix V](#), forecasts have been generated via simple exponential smoothing (ES) and ordinary least squares regression (OLS) using three different time indices (daily, weekly, and monthly) to predict Ecomspaces order demand for the following period, or

the day/week/month of April 1st, 2021. For the ES model, the smoothing factor  $\alpha$  is chosen based on the minimization of the root mean squared error (RMSE) value calculated from the difference in the observed and forecasted values.

Based on the forecasts generated:

- The daily time index has a smoothing factor  $\alpha = 0.5$ , a predicted value of 125.75, and an RMSE of 28.49.
- The weekly time index has a smoothing factor  $\alpha = 0.3$ , a predicted value of 824.93, and an RMSE of 190.05.
- The monthly time index has a smoothing factor  $\alpha = 0.65$ , a predicted value of 3250.96, and an RMSE of 602.63.

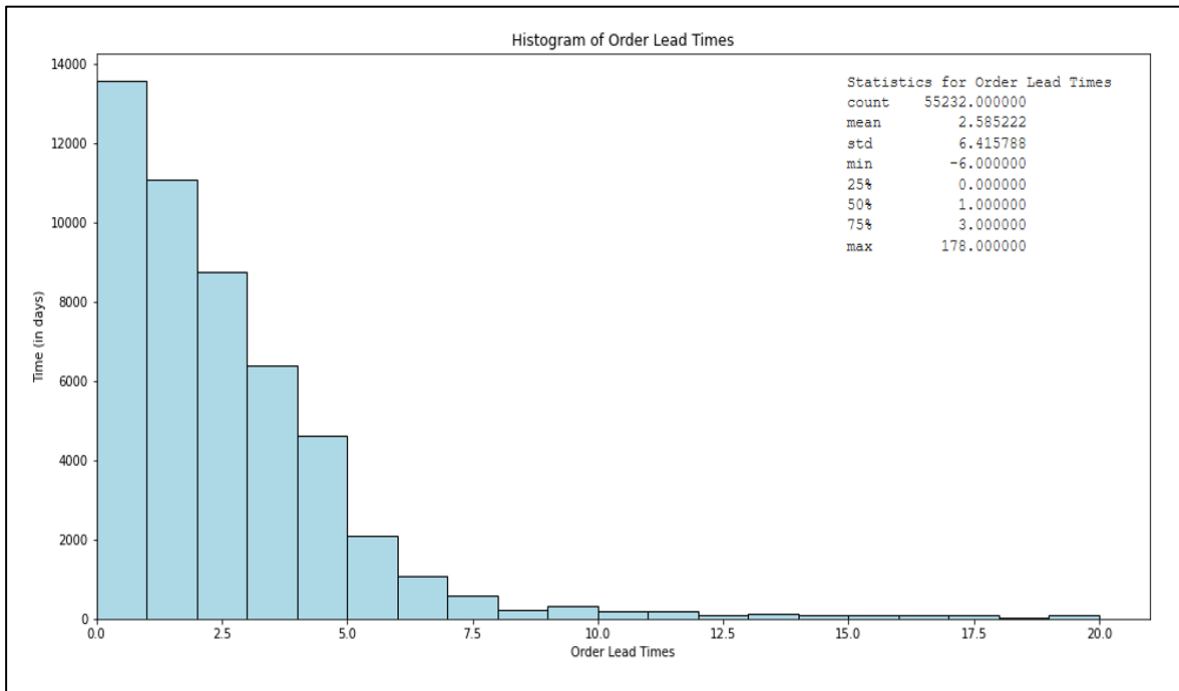
Based on the forecasts generated (OLS):

- The daily time index has a predicted value of 119.85, and an RMSE of 33.90.
- The weekly time index has a predicted value of 844.47, and an RMSE of 175.83.
- The monthly time index has a predicted value of 3700.65, and an RMSE of 419.60.

We observe that while the ES model performs better than OLS to forecast the period with the shorter time index (by day), the OLS model significantly outperforms ES for longer time indices (by week/month).

Regarding limitations, the relatively high RMSE values is likely due to the classical forecasting models chosen for the analysis, since they are unable to capture the complexity of the trend or seasonal components within the data. Further analysis may be conducted using more robust statistical models such as autoregressive integrated moving average (ARIMA) or Holt-Winters' exponential smoothing as well as more computationally complex machine learning models such as support vector regression and artificial neural networks. It is also possible to improve forecast accuracy through further data preprocessing with imputation, time series decomposition, and unconstraining algorithms such as expectation maximization.

By analyzing raw data from Shipstation, it is also possible to analyze order lead times as shown in Figure 38 below. For example, our original order lead time study from the date range 1/20 to 1/21 with 44,646 observations indicated a mean of 2.774 days and a standard deviation of 6.977 days. However, with the recent addition of two months data now ranging from 1/20 to 3/21, we find that the count has increased to 55,232 observations, the mean time has decreased to 2.585 days, and the standard deviation has decreased to 6.416 days.



*Figure 38: Histogram of Order Lead Times using Shipstation Data (1/20 to 3/21)*

This information indicates that the both the average time and variability for how long it takes Ecomspaces to process an order has been improving significantly for the past two months. Refer to [Appendix W](#) for the data analysis code done via Python.

### 5.5.2 Work Process Evaluation

To assist Ecomspaces with monitoring the efficiency and production output of each employee and work-process, a standard time study sheet has been created. Figure 39 below depicts the standard time study sheet that can be utilized by management at Ecomspaces. This time study sheet was created using Microsoft Excel, with a blank workbook that can be found in [Appendix G](#).

This time study sheet can be utilized for any process in the warehouse to evaluate an employee's performance and determine if a process time varies between each worker. The legend on the top right describes in detail how to fill the sheet to record accurate data. Rows and columns can be created or deleted as necessary for the particular process and task times. It is important to note that both the rating factor and percentage allocated for personal fatigue and unavoidable delays (PFD factor) are subjective to the analyst performing the study.



Ecomspaces				1 to 4 = Each Individual Time		8 = Rating Factor (90% = .90, 100% = 1.00, 110% = 1.10)					
				5 = Total of all Times		9 = Base Time (7 multiplied by 8)					
				6 = Number of Time Values		10 = Frequency (1 = every cycle, 1/10 = once per 10 cycles)					
				7 = Average (5 divided by 6)		11 = Normal Time (9 multiplied by 10)					
Element	1	2	3	4	5	6	7	8	9	10	11
Description	Time	Time	Time	Time	Total	No.	Avg.	Rate	Base	Freq.	Norm.
Task 1					0:00:00	1	0:00:00	0.95	0:00:00	1	0:00:00
Task 2					0:00:00	1	0:00:00	0.9	0:00:00	4/1	0:00:00
Task 3					0:00:00	1	0:00:00	0.9	0:00:00	1/4	0:00:00
<b>Operation:</b>			<b>Foreign Element Explanations:</b>					Total Normal Time =		0:00:00	
<b>Employee:</b>								25%P,F,and D =		0:00:00	
<b>Equipment:</b>								Total Standard Time =		0:00:00	
<b>Date:</b>								Standard Time For Process			
<b>Elapsed Time:</b>											

Figure 39: Standard Time Study Sheet

It is also possible to monitor the work processes by analyzing the mean observed times using historical data collected from the warehouse management systems utilized. For example, data for (1) the receiving process can be found on the RelayShopUSA website and (2) the shipping process can be obtained from HalTraxx.

### 5.5.3 Cross Training

The importance of cross training employees should never be overlooked. Cross training employees aids them with understanding the value of work done by others and provides a deeper understanding of the entire operation as well as all the duties that may have been overlooked in the past. Employees benefit from cross training by developing new skills, becoming strong team members, and increasing motivation across departments and divisions. Based on the survey our team conducted, the results show that employees are also aware of the need for cross training.

Not only can the employees of the company better themselves through experience from cross training, but the company also benefits as well. Cross training can help to increase the productivity of the warehouse, mitigate risk, and keep costs down. When employees are able to move between roles that they have been cross trained in, they can fine tune their skills with time and enable them to work efficiently in multiple work processes. If a key employee leaves or takes vacation days, other employees have now been empowered to fill in the vacant role without any disruptions to the quality-of-service Ecomspaces provides to their customer.

### 5.5.4 Control Chart

A control chart is a statistical tool that will help Ecomspaces have a better understanding of the underlying variables influencing each of the major work-processes at Ecomspaces, by seeing whether or not data collected is within an established range. Figure 40 below depicts a control chart for the receiving process for a one-year period. The control chart reveals that the receiving process is under normal state since all the data points are encompassed between the upper control limit (in orange) and the lower control limit (in yellow). This chart can be used for other processes, including putting away, picking, and shipping. If in the future some data points cross the upper or lower control limits, this indicates an issue within the process that must be fixed immediately by finding its root-cause to avert the higher costs in addressing it. Although a control chart is a great tool to utilize, it is important for Ecomspaces to be able to collect data regularly to obtain accurate results and identify problems immediately. Currently, Ecomspaces has no automated tools to collect this data set, so they will have to rely on their workers to manually collect and analyze this data. Nevertheless, it is essential for Ecomspaces to invest in automated tools to collect data in order to avert any potential bias, save time, and enhance business processes efficiently and effectively.

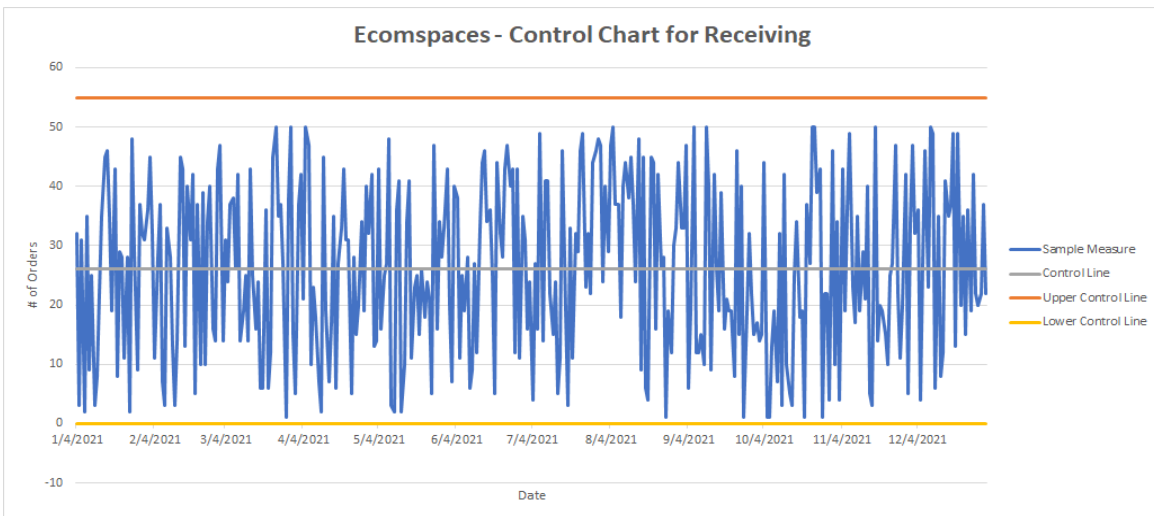


Figure 40: Control Chart for Receiving Process

## Chapter 6: Results & Discussions

### 6.1 Project Findings and Results

Throughout our on-site visits, we found that the root cause of the warehouse inefficiency was due to the excess waste and clutter throughout the warehouse. Additionally, commonly used equipment such as rolling shelves, bins, and packaging boxes did not have designated locations and were scattered throughout the facility. The warehouse contained 2020.82 ft<sup>2</sup> of wasted space that could potentially be used to create more workstations and/or storage areas to benefit the overall organization and efficiency of the warehouse. To address these issues, we utilized the following tools:

1. *Economic Analysis* was used to formulate, estimate, and evaluate the expected economic outcome of alternative design options. We used this tool to examine the annual expenses, annual income, and net income for Ecomspaces. After evaluation, we found that:
  - a. The three most expensive costs were due to supplies, rent, and postage
  - b. The company's main source of income came from Paypal
  - c. The company's highest grossing year was 2018 with an income of \$89815.08
2. *Pareto Charts* were used to prioritize types or sources of problems. We used this tool to survey the warehouse employees and help identify the root cause of common problems. After surveying all eight warehouse employees, we found that most of the warehouse issues came from:
  - a. Incorrect packages being shipped causing delay to fix the issue
  - b. Employees are insufficiently trained in multiple areas
  - c. Technology fails during the day which causes delays
3. *Time and Motion Studies* were utilized for the purpose of work measurement and the establishment of work standards within Ecomspaces operation. Since standardization is a requirement in order to pursue continuous improvement, we performed the following:
  - a. Developed spaghetti diagrams to track excess motion done by workers
  - b. Identified cycle times and productivity levels needed for KPI development
  - c. Utilized input analyzer to calculate expressions for sample data distributions
4. *ARENA Simulation* was used to model and simulate the current operation at Ecomspaces using our collected data. The resource values used in the model can be allocated differently to produce various results. From our ARENA model, we identified that:
  - a. A limitation with the ARENA model involves the initial interdependency for each of the processes, with the receiving process serving as the initial bottleneck.
  - b. Our baseline model is allocated to have 1 receiver, 1 put-away worker, 1 picker, 2 shippers, 2 receiving stations, 1 put-away station, 1 picking station, and 2 shipping stations to produce an end-value of 50.0 completed orders.
  - c. Our optimal model is allocated to have 12 receivers, 3 put-away workers, 3 pickers, 3 shippers, 12 receiving stations, 3 put-away stations, 3 picking stations, and 3 shipping stations to produce an end-value of 72 completed orders.

5. *TOPSIS* was used to identify customer preference in the form of weights for each criterion regarding the three proposed facility layouts. In the final ranking, the solution that is closest to 1 is optimal. Regarding our final rankings, we identified that:
  - a. The metrics for our proposed layout solutions include cost, employee safety, efficiency (space utilization), and productivity (speed).
  - b. Ecomspaces should first consider proposed layout A (0.585), then proposed layout C (0.570), and lastly proposed layout B (0.252)
  - c. The metrics for our six solutions included cost, space utilization, benefit, and ease of application.
  - d. Ecomspaces should first prioritize regaining unused floor space in the warehouse (0.862), followed by warehouse safety (0.703), and SOP development (0.474).
  
6. *Cost Analysis* is a tool for comparison purposes to identify the most cost-effective solutions to a project before implementation. It was applied to the scenario at Ecomspaces to estimate the costs associated with the three proposed layouts and suggestions. We found that:
  - a. The current monthly net profit (before tax) is \$2,690.02
  - b. The accumulated total expenses consist of labor, utilities, professional dues and subscriptions, supplies, telephone, payroll, insurance, postage, interest, bank fees, and advertising.
  - c. The accumulated total income consists of Stripe, Square, PayPal, Peerspace, rent offices, Croissant, and Liquidspace.
  - d. Proposed layout A will increase monthly income by 11% and total monthly expense by 1.5%, resulting in a monthly net income of \$9,646.07.
  - e. Proposed layout B will increase monthly income by 6% and total monthly expense by 1.0%, resulting in a monthly net income of \$6,356.76.
  - f. Proposed layout C will increase monthly income by 9.5% and total monthly expense by 1.2%, resulting in a monthly net income of \$8,203.58.
  
7. *Demand Forecasts* are a tool commonly used by businesses to produce informed estimates of customer demand. Demand forecasts were applied to 15 months of customer orders at Ecomspaces, with data collected from Shipstation. We performed the following:
  - a. Generated forecasts for day, week, and month of April 1st, 2021
  - b. Utilized two forecasting methodologies and found that OLS outperforms ES in the scenario for data with longer time indices.
  - c. The best forecast generated for the daily time index was via ES, with a smoothing factor  $\alpha = 0.5$ , a predicted value of 125.75, and an RMSE of 28.49.
  - d. The best forecast generated for the weekly time index was via OLS, with a predicted value of 844.47, and an RMSE of 175.83.
  - e. The best forecast generated for the monthly time index was via OLS, with a predicted value of 3700.65, and an RMSE of 419.60.
  
8. *Control Charts* are a statistical tool utilized to create better understanding of underlying variables influencing the major work-processes at Ecomspaces. They serve as monitoring

tools for the control step of the DMAIC model, by seeing whether or not data collected is within a pre-established range. For our client, we:

- a. Provided configurable control chart templates for the receiving, put-away, picking, and shipping processes
- b. Identified that Ecomspaces does not currently have the automated tools necessary to facilitate the data collection process.

As a result, our team has been able to meet the minimum success criteria we set at the beginning of the project by increasing space utilization by 10.15% in the entire facility. Additionally, Ecomspaces has improved lighting in the warehouse, eventually leading to improvement in quality of service and the minimization of human errors. Oversized stock previously stored in aisle D has been assigned to a new designated location in the XL area, resulting in more vertical storage being utilized and greater floor space able to be allocated for additional shelving and racks.

## ***6.2 Challenges and Limitations Faced***

Initially when our team went on-site, we immediately noticed several avenues that could be opportunities for improvements. Our team was initially overwhelmed with all the different options that could realistically be achieved during the timeline of the project. This resulted in an original scope that was too broad, encompassing several different processes that would be impossible to complete in a single semester. The team took a step back from our initial scope and decided to approach the project through a wider lens and realized that in order for anything to be changed we needed to address issues as it pertained to the overall warehouse layout. It was apparent that the warehouse was struggling with organization as a whole, which was visible by the abundance of space taken up for excess and unused material. After meeting with Dr. Khalid, our team was finally able to narrow in on a more refined scope that could be accomplished over the necessary timeline.

Once our scope was clearly defined, we also encountered a new set of challenges and potential limitations. These currently include potential resistances to our proposed solutions from stakeholders, finding reliable sources for recycling, and the necessary manpower needed to rearrange the warehouse to reflect the future proposed layout.

Regarding our ARENA simulation model, we encountered limitations with not having initial/starting entity values set for the steps beyond the receiving process. For example, the put-away process will not initialize until a package has been fully received, the picking process will not start until an item has been successfully put-away, and the shipping process will not begin until an item has been picked. This results in our ARENA model indicating that the entire operation at Ecomspaces is bottlenecked by the receiving process, which we do not believe to be true. To account for this receiving station bottleneck in our ARENA model, we set the resource values for the number of *receivers* and *receiving stations* to an arbitrarily large value to jumpstart the model and simulate the other processes acting as the bottleneck.

## Chapter 7: Conclusion

To conclude, this project has provided Ecomspaces with several key areas of improvement that can help enhance their current infrastructure and provide them with solutions to better utilize their current workspace. Our involvement with Ecomspaces has already resulted in the company cleaning and removing excess clutter from unused space within the warehouse. By analyzing all the data collected in time studies, KPI development, warehouse audits, TOPSIS, and economic analysis, we have provided detailed reasonings for our solutions. We have helped create standards in work time, maintenance and safety that the company can utilize regardless of any layout changes done to the warehouse. This will provide a solid foundation for the company to continually expand on with tools and resources that can easily be applied.

Ultimately, we recommend Ecomspaces to continue on the path of improvement in their workspace by ensuring the warehouse is regularly maintained including lighting, fire safety, and cleanliness resulting in a reduced possibility of OSHA violations. We also encourage the company to apply the proposed layout A once the space is regained and clutter throughout the warehouse has been removed and the excess accumulation of clutter is regularly managed with SOP utilization. Additionally, we recommend evaluation of the KPIs on a quarterly basis, to ensure that the KPIs are improving overtime. By implementing the recommendations we propose, Ecomspaces will be able to enhance productivity, increase space utilization, and eliminate waste and clutter throughout the facility. Our project has resulted in a 56.81% decrease in junk/wasted space and an overall increase of space utilization of 10.15% for the entire facility, exceeding our objective of 3% decrease in junk/wasted space in the warehouse.

Following the completion of this project, Ecomspaces can use the information and documents provided in this report to guide them on a path of continuous improvement. Our team recommends cross-training employees, researching possible ways of standardizing product storage in the warehouse, ensuring software is being utilized properly, maintaining progress by using SOPs, and expanding the workforce once demand requires it. Cross training empowers the employees and provides new skills to fill vacancies in work processes throughout the warehouse when needed. If Ecomspaces can find a way to standardize storage of products in the warehouse they can further increase space utilization on the shelves and products for orders can be located with ease. We do feel that in tackling this challenge, Ecomspaces should involve workers from every process since they know most about the work process within the warehouse.

Additionally, the company should reevaluate their warehouse management software to make sure they are getting all the benefits they can from it and are not completing redundant processes when picking orders. SOP utilization is key to maintaining and controlling any improvement made at Ecomspaces for safety, cleanliness, maintenance, and space utilization. As the company continues to grow, they can look to expand their workforce and in line with our recommendations of expanding the receiving work process first, as scenario 40 from Arena analysis shows. These tools can help Ecomspaces grow and make strides in their market.

Overall, we recommend Ecomspaces to:

- Remove obstructions hindering workflows through the removal of waste, and by utilizing more vertical space within the warehouse.
- Implement our proposed layout A, with emphasis on consolidating all oversize inventory to the XL aisle between the dock doors.
- Perform data analysis by continually recording order lead times and updating work-process standard times to measure operational growth and improvement.
- Generate demand forecasts using ordinary least squares regression to understand the overall growth and ordering patterns of customers
- Consolidate all data sources needed for KPI measurement into one system.
- Conduct quarterly audits for regular warehouse maintenance, fire safety, and OSHA compliance.

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## **Appendix A: Acknowledgments**

The Optimized Brain E-Spaces team would like to express our sincere appreciation to the Ecomspaces company and employees who gave their time and guidance to assist in the completion of this successful project. We were provided this valuable opportunity to work with their facility and management to optimize their overall warehouse. We would like to extend our gratitude to our project sponsor, Maire Rosa, who is the CEO of Ecomspaces, and Nicolas Troplent, who is the Operations Analyst at Ecomspaces. Maire and Nicolas provided immense information and flexibility to assist us with industry expertise and wisdom that greatly assisted the successful completion of this project. Even though the pandemic was still ongoing, they managed to make themselves accessible and provide ongoing support through on-site and virtual meetings.

The Optimized Brain E-Spaces team would like to thank the Kennesaw State University faculty, especially for our Senior Design Professor, Dr. Khalid and other instructors in the ISYE department for their guidance, supervision, and support for this priceless experience that prepares us for industry applications and future careers. Additionally, our team would like to extend thanks to Bill Principe for being a contact for us to utilize for any questions regarding OSHA warehouse safety standards and cost of fines. All the methods and techniques we learned in all courses in the ISYE program have prepared us for the successful completion of this project.

The team would also like to extend thanks and appreciation to all Ecomspaces employees who volunteered their time and expertise including:

Ali Safeullah, Facility Manager

Roderick Character, Warehouse Associate

Chaunce Cooper, Warehouse Associate

Valentine Ebunilo, Warehouse Associate

Diamond Square, Warehouse Associate

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## Appendix C: Reflections

**Gustavo Andrade.** During the course of the project, our team faced many obstacles that challenged both our analytical and critical skills. This project has allowed me to work diligently with my group to solve these problems by applying the tools and techniques that we have learned throughout our academic careers. At the start of the project, I knew this was going to be challenging. If there was any group of individuals dedicated enough to handle a project of this caliber, it was definitely our group (The Optimized Brain-E Spaces).

After the first initial on-site meeting, we spoke with the employees and the CEO to help tackle the problems that cause the inefficiencies in the warehouse. There were many opportunities that needed to be addressed, so it was overwhelming at first to think about the amount of work that needed to be done in a short period of time. This was challenging because it was the first time that I have acted as a consultant. Our group did not know where to begin and which problem to tackle first. In order for us to complete this project successfully, our group needed to communicate often and work together. Being in this position allowed me to build my interpersonal communication skills.

The turning point of the project was when our group defined a scope. We decided as a team to apply Lean Six Sigma methodology, something that we were all passionate about, and regain the warehouse floor space. After defining this goal, our team no longer felt overwhelmed, and we were able to create various solutions to help Ecompsaces thrive.

Throughout this project, my favorite part was working with the employees and CEO to help create a solution that is right for them. Every time our group went on-site, we were greeted with a smile and everybody was very welcoming. This made me feel great about what we were accomplishing. I am thankful for the hands-on experience I have learned throughout my time here and I look forward to seeing Ecompsaces succeed in the future.

**Edwin Lim.** I was very motivated and excited to work on this project because I have a strong interest in Optimization, Logistics & Supply Chain, Quality, and Data Analytics. At the beginning of the project, we were not sure if we would find an organization to partner with us. After contacting more than 30 organizations, we finally found one organization that had a project that matched with our interests and skill sets. Ecomspaces was the organization that responded to our inquiries and pleased to partner with us. At the first meeting, Maire (CEO of Ecomspaces) and Nicolas Troplent (Operations Analyst) provided us with all the information and details on some of the potential projects we could work on to help them improve their overall business.

After the first meeting, Gustavo, Melanie, Nicolai, and I discussed and decided to focus on the warehousing sector to help our client to enhance overall workers productivity and optimal space utilization. Then, we needed to define our scope because there were so many areas we could touch in the warehouse so that we fully understood how to tackle this project appropriately. After discussing with our advisor, Dr. Khalid, we presented our scope to our clients covering layout, organization and overall productivity.

After defining the scope, we went on-site regularly to collect data sets, conduct multiple time studies and employee surveys, observed employees and the overall warehouse to identify and analyze the root-cause of the problem. This project has allowed me to fully utilize Six Sigma knowledge and implement all the knowledge I have learned throughout my college journey, and broaden my knowledge in other areas, such as Logistics & Supply Chain, Optimization, and Data Analytics to optimize the warehouse effectively and efficiently.

Throughout this project I was able to learn immense information and utilize all the tools and techniques I learned for real-world importance and Industrial Engineering applications. I am grateful for all the valuable experiences, partnering with Ecomspaces, and the learning opportunities provided to us. Lastly, I am pleased to be working with this great team and I hope we can work together in the future.

***Melanie Cardenas.*** At the start of the project, I was concerned that our team was taking on an overwhelming amount of work trying to solve all the areas for improvement at Ecomspaces. This gave me a chance to share my knowledge and experience I had in project development from my previous career, with my team. The project provided me with a great opportunity to apply everything I have learned throughout my academic courses within the ISYE major to a corporate environment and created a fantastic chance to merge my real-world work experience and course material together in providing Ecomspaces with attainable solutions. Once our team re-evaluated defined our project scope, we were a well-oiled machine with outstanding coordination.

The project provided its own unique challenges that tended to revolve around ensuring our team was applying tools and techniques correctly. However, we approached each challenge collectively as a team and were always able to overcome and turn out even better work than we expected. Another challenge our team faced was COVID-19. I am an individual who is high risk and was not able to be on-site and I was always able to be filled in and kept in the loop due to how well my team was able to record details of each visit.

This project has been a great experience to see our team grow together. As time went on our teamwork continued to mesh very well together and made the two months of our project a seamless transition to our final report. Overall, I am extremely pleased with what we have been able to offer to Ecomspaces and that our involvement with the company has already resulted in the warehouse being cleaned and excess boxes being removed.

***Nicolai Sison.*** I am so grateful for all the excellent learning opportunities provided to us by the wonderful people working at Ecomspaces, especially with regard to both management and employees explaining their systems and work-processes in vivid detail.

At the start of the project, I had growing concerns about the project scope and figuring out exactly how much our team would be able to both accomplish and implement in such a short period of time. But as development continued, our team's on-site visits and meetings became increasingly productive with the excellent coordination between all parties involved. Thanks to

the flexibility and willingness of those working at Ecomspaces, the ideas for our design proposal were limited only by our knowledge and capability to perform the tasks at hand. We were free to allow our creativity and diverse set of both soft and technical skills to be applied into our work.

Furthermore, I am excited to refine all the new skills I have been taught in practice to solve real-world engineering problems and scenarios in the future. With this project now under my belt, I am proud to showcase to those interested the numerical results that have contributed to the long-term growth of Ecomspaces' business and operation.

## Appendix D: Team Contributions

***Gustavo Andrade.*** Constantly connected with Maire (CEO of Ecomspaces) to build rapport, plan visits, discuss operations, and provide findings with new implementation ideas. Engaged in various conversations with the warehouse employees to gather information about each process and its significance to the warehouse. Created employee surveys and gathered response results to help identify the root problem. Performed six direct time studies for the picking process to evaluate employee efficiency. Took the measurements of warehouse dimensions as well as junk/unorganized areas to create a current layout. Conducted warehouse safety and fire audits. Contributor of section 1.2 (initial findings and project focus), 2.7 (Gaining competitive advantage through Ergonomics improvements), 2.8 (order picking operations), 3.6 (Financial Plan/ Budget), 5.3 (Analyze), and 6.1 (Project findings and Results). Researched six articles related to warehouse organization and ergonomics to justify the ideas for our proposed layouts and implementation. Observed employees to create a spaghetti diagram. Proposed all the documents with implemented solutions to the warehouse employees and CEO.

***Edwin Lim.*** Formatted the overall report, updated our progress with Maire (CEO of Ecomspaces) and Nicolas (Operations Analyst), added literature review, and filled out appendices. Constructed ARENA simulation model, including 40 scenarios in process analyzer, input analyzer, animations, and variables. Conducted audits for fire safety and maintenance housekeeping and took the measurements of warehouse dimensions. The main contributors of Chapter 1: Project background, except Introduction and Initial Findings and Project Focus, Chapter 3.2 System Overview, Chapter 3.7 Economic Analysis, Chapter 5.2 Measure, Chapter 5.3.6 Spaghetti Diagram, Chapter 5.3.7 TOPSIS, 5.3.8 Cost analysis, Chapter 5.4.5 Implementation, and Chapter 5.5.4 Control Chart. Additionally, contributed to creating a cause-and-effect diagram, cleaning poster, and Ecomspaces warehouse workflow processes diagram. Researched six articles related to warehouse maintenance, KPI, and work measurement in warehouse for literature review.

***Melanie Cardenas.*** Ensured the overall tone of the paper is cohesive and consistent throughout, and main contributor of Chapter 4: Proposed Solutions. Also created items in Chapter 3: Project Management including WBS, Gantt Chart, Project Charter and writing the responsibilities. Researched completed audits to see which OSHA sections were in violation. Contributed to Chapter 6 section 5: Control and Chapter 7 the conclusion of our project. Wrote and created the format for the SOP deliverables for Ecomspaces, used TOPSIS to rank our solutions, and wrote section 5.4.1- 5.4.3. Main contributor to section 5.5.3 discussing cross training employees. Formatted Input Analyzer results into readable charts. Wrote the OSHA/Fire safety for the warehouse. Helped to condense graphs and charts into a cleaner format to reduce the space in the paper.

***Nicolai Sison.*** Involved in video recording for receiving process time study data collection, provided statistical analysis using raw data exports from warehouse management systems utilized by Ecomspaces via Python programming, and conducted audits for OSHA warehouse safety and facility lighting. Primary contributor for the Executive Summary as well as literature review sections 2.1, 2.2, and 2.3. Responsible for the Requirements and Specifications section in

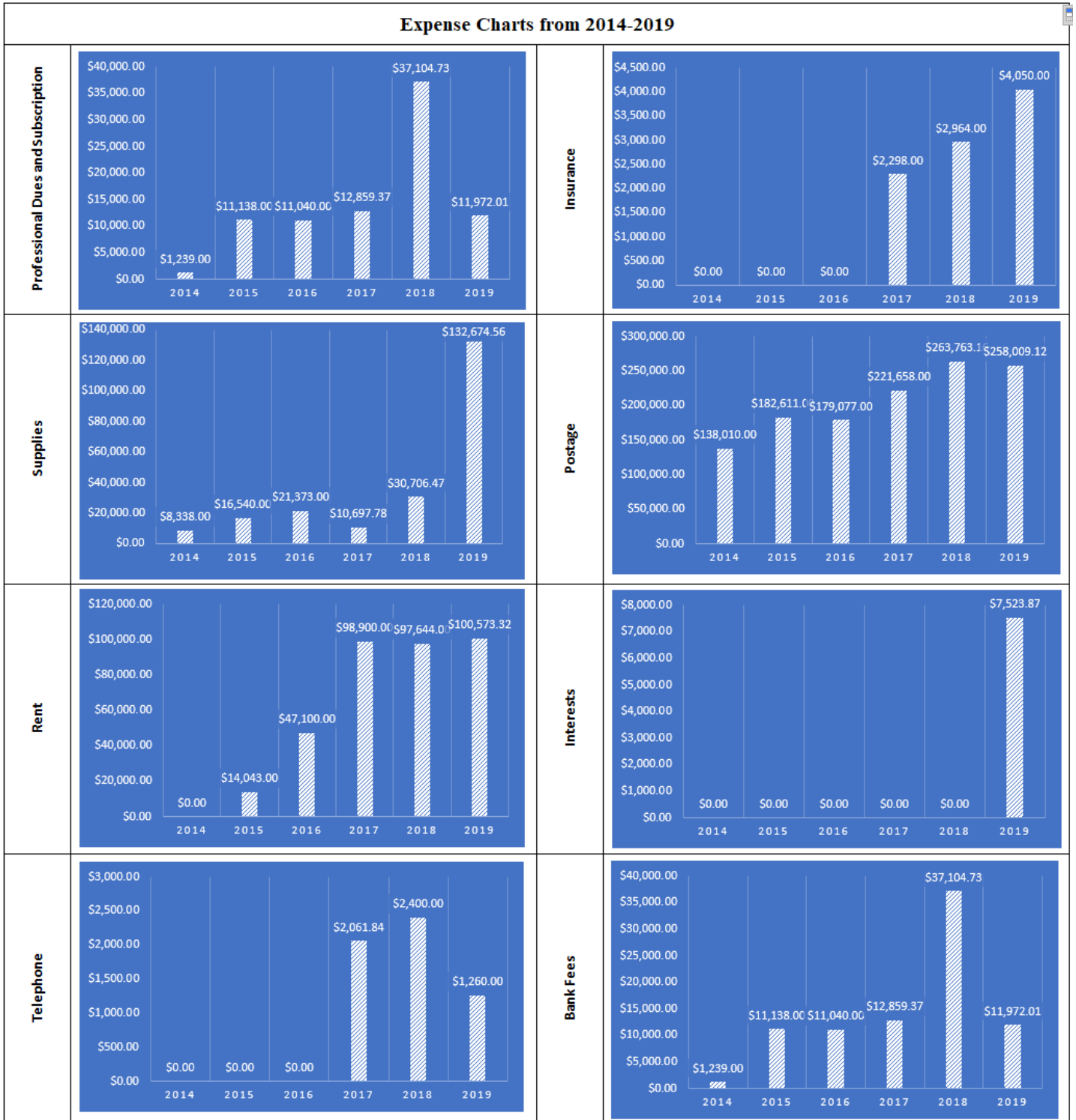


Chapter 3.1, the establishment of KPIs and CTQ diagram as seen in Chapter 5.1 Define, as well as the creation of standard times discussed in Chapter 5.3.4. Main contributor for the time series analysis and order demand forecasts, as well as the calculation for order lead times across two periods seen in Chapter 5.5.1.

Notes: We effectively collaborated in the process and this project has helped us to have a better understanding of the importance of teamwork, cooperation, and effective communication.

## Appendix E: Annual Expense

**Expense Charts from 2014-2019**





## Appendix F: Key Performance Indicators

<b>List of Key Performance Indicators</b>		
<b>KPI</b>	<b>Data Collection Source</b>	<b>Description</b>
Visible Signs and Labels	On-site visit/investigation	Clear labeling and signage for stations, aisles, exits, etc.
Personal Protective Equipment (PPEs)	On-site visit/investigation	Personnel requirements for gloves, hard hats, eyewear, ear protection, footwear etc.
First-Aid Kits & Fire Extinguishers	On-site visit/investigation	Quantity of first-aid kits and fire extinguishers easily visible and accessible in the warehouse.
Number of Accidents	On-site visit/investigation	Occurrence of accidents within the facility per month.
SOP Utilization	On-site visit/investigation	Number of standard operating procedures (SOPs) currently being utilized by workers.
Dock Door Utilization	On-site visit/investigation	Number of dock doors currently being utilized in the facility.
Receiving Productivity	Time and motion study, WMS	Average number of items received per hour.
Receiving Cycle Time	Time and motion study, WMS	Time (MM:SS) to process each item in the receiving station.
Put-Away Productivity	Time and motion study, WMS	Number of inventory items able to be put away per hour.

Put-Away Cycle Time	Time and motion study, WMS	Time (MM:SS) to process each item during put-away.
Picking Productivity	Time and motion study, WMS	Number of inventory items able to be picked per hour.
Picking Cycle Time	Time and motion study, WMS	Time (MM:SS) to process each order while picking.
Shipping Productivity	Time and motion study, WMS	Number of orders able to be prepared for shipment per hour.
Shipping Cycle Time	Time and motion study, WMS	Time (MM:SS) to process each order during shipping.
Order Lead Time	Warehouse management system (WMS)	Time (in days) for items to be processed and ready for shipment once an order is placed.
Receiving Workstations	On-site visit/investigation	Number of workstations for receiving.
Shipping Workstations	On-site visit/investigation	Number of workstations for shipping.
Clearable Floor Space	On-site visit/investigation	Amount of floor space able to be cleared from debris.
Space Utilization	On-site visit/investigation	Ratio of space being utilized over the total amount of facility space.

## **Appendix G: Time Studies (Arrival Packages, Receiving, Putting Away, Order Received, Picking, Shipping)**

All of these time studies will be used in Input Analyzer in Arena Simulation Software to find each statistical expression for each process.

### Time Study 1: Package Arrivals From Front

Link for time study for arrival packages (receiving front door):

<https://drive.google.com/file/d/17H3QRb6hhwYoKBiFRrHf1H8ymGhcYrHg/view?usp=sharing>

### Time Study 2: Package Arrivals From Dock

Link for time study for arrival packages (dock):

[https://drive.google.com/file/d/1PKOZEJkT6n0DBpeuptlUhqWcH-G\\_jrl/view?usp=sharing](https://drive.google.com/file/d/1PKOZEJkT6n0DBpeuptlUhqWcH-G_jrl/view?usp=sharing)

### Time Study 3: Receiving

Link for time study for receiving:

<https://drive.google.com/file/d/1V5kD4BalLISJFRwu0g35oKW03sPGx4B1/view?usp=sharing>

### Time Study 4: Putaway

Link for time study for putaway:

<https://drive.google.com/file/d/1rzPQUKL3UWsDt8Xx8tN02I1YfQMUF2EF/view?usp=sharing>

### Time Study 5: Order Received

Link for time study for order received:

[https://drive.google.com/file/d/1kOUgn4RzOwUN\\_p5wLd1-ytkJACOE1HyI/view?usp=sharing](https://drive.google.com/file/d/1kOUgn4RzOwUN_p5wLd1-ytkJACOE1HyI/view?usp=sharing)

### Time Study 6: Picking

Link for time study for picking:

[https://drive.google.com/file/d/1raMRoQeEdRI\\_r5yMjhPXGgY1brlpAx0o/view?usp=sharing](https://drive.google.com/file/d/1raMRoQeEdRI_r5yMjhPXGgY1brlpAx0o/view?usp=sharing)

### Time Study 7: Shipping

Link for time study for shipping:

<https://drive.google.com/file/d/1HpY0I6-qswYIViQbGycLT5fZFgM0FEti/view?usp=sharing>

### Blank Time Study Sheet

Link for the blank time study sheet:

[https://drive.google.com/file/d/10\\_Fb6hVyefWnQukhKxI9-enLdAf6po9M/view?usp=sharing](https://drive.google.com/file/d/10_Fb6hVyefWnQukhKxI9-enLdAf6po9M/view?usp=sharing)

## Appendix H: OSHA Warehouse Safety Checklist

Date:

Auditor:

General Safety	Yes	No	N/A	Comments
Exposed or open loading dock doors and other areas that employees could fall 4 feet or more or walk off should be chained off, roped off or otherwise blocked.				
Floors and aisles are clear of clutter, electrical cords, hoses, spills, and other hazards that could cause employees to slip, trip or fall.				
Proper work practices are factored into determining the time requirements for an employee to perform a task.				
Employees performing physical work have adequate periodic rest breaks to avoid fatigue levels that could result in greater risk of accidents and reduced quality of work.				
Newly hired employees receive general ergonomics training and task-specific training.				
The warehouse is well ventilated.				
Employees are instructed on how to avoid heat stress in hot, humid environments.				
Employees are instructed on how to work in cold environments.				
Material Handling Safety	Yes	No	N/A	Comments
There are appropriately marked and sufficiently safe clearances for aisles.				
Loose/unboxed materials which might fall from a pile are properly stacked by blocking, interlocking, or limiting the height of the pile to prevent falling hazards.				

Bags, containers, bundles, etc. are stored in tiers that are stacked, blocked, interlocked, and limited in height so that they are stable and secure to prevent sliding or collapse.				
Storage areas are kept free from accumulation of materials that could lead to tripping, fire, explosion, or pest infestations.				
Personnel use proper lifting techniques.				
<b>Hazard Communication Safety</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
All hazardous materials containers are properly labeled, indicating the chemical's identity, the manufacturer's name and address, and appropriate hazard warnings.				
There is an updated list of hazardous chemicals.				
All employee training is documented.				
Procedures have been established to maintain and evaluate the effectiveness of the current program.				
Employees use proper personal protective equipment when handling chemicals.				
All chemicals are stored according to the manufacturer's recommendations and local or national fire codes.				

Recommendations:



## Appendix I: Maintenance Housekeeping Audit

Date:  
 Auditor:  
 Maximum Score:  
 Actual Score:  
 Percentage:

Facility Exterior	0 Poor	1 Good	Comments
<b>General</b>			
Overall appearance			
Concrete drive and parking lots			
Concrete sidewalks, steps, and landings			
Sign, damaged? Visible?			
<b>Doors and Windows</b>			
Are all doors operating safely? Securely?			
Any broken windows?			
Are all doors locked working properly?			
<b>Lightning</b>			
Are all exterior lights and power receptacles/outlets working properly?			
Are the sign working properly?			
Facility Interior	0 Poor	1 Good	Comments
<b>General</b>			
Overall warehouse appearance			
Warehouse floors, need cleaning? Repair?			
Windows, dirty? Cracked? Air leakage?			
Are the floors between shelving units clean and free of clutter?			

Walls, damage? Stains? paint touchup?			
Ceiling tiles? Missing? Water stained?			
<b>Doors and Dock</b>			
Doors opening and closing properly?			
Door locks functional?			
Dock door opening and closing properly?			
<b>Electrical</b>			
Are all lights working? Bulbs burned out?			
Are light switches operating properly?			
Do the diffusers need cleaning?			
Are all outlets working properly? Burnt or flash marks?			
Are nighttime security lights working properly?			
<b>Receiving Station</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the signage correct, clean, and visible?			
Is the exterior lighting correct, suitable and sufficient?			
Are the floor areas clean and free of clear clutter?			
Are the waste bins being used correctly, is there any contamination?			
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?			
Are there procedures or instructions at the workstation?			
<b>Pack and Shipping Station</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the signage correct, clean, and visible?			
Is the exterior lighting correct, suitable and sufficient?			
Are the floor areas clean and free of clear clutter?			

Are the waste bins being used correctly, is there any contamination?			
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?			
Are there procedures or instructions at the workstation?			
<b>Fulfillment Station</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the signage correct, clean, and visible?			
Is the exterior lighting correct, suitable and sufficient?			
Are the floor areas clean and free of clear clutter?			
Are the waste bins being used correctly, is there any contamination?			
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?			
Are there procedures or instructions at the workstation?			
<b>Receiving Ramp Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?			
Is the access area free of blockages?			
Is the Ring doorbell working properly?			
<b>Dock 1 Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?			
Is the access area free of blockages?			
Is the Ring doorbell working properly?			
<b>Dock 2 Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?			
Is the access area free of blockages?			
Is the Ring doorbell working properly?			

## Appendix J: Fire Safety Checklist

Date:

Auditor:

Main Fire Alarm Panel	Yes	No	N/A	Comments
Is the indicator light on the main fire alarm panel showing “normal”?				
Is there an “emergency and safety information” box near the fire alarm panel?				
Does the above box have a spare key fixed to the front?				
Does the box contain the fire precautions log book?				
Does the box contain the latest building fire risk assessment?				
Does the box contain up to date plans of the building?				
Key Personnel	Yes	No	N/A	Comments
Has one or more people been nominated as fire inspector for the building?				
Have sufficient numbers of people been nominated to ensure weekly tests or call points are carried out?				
Fire Doors	Yes	No	N/A	Comments
Is there a fire door in the warehouse?				
Are all fire doors marked with mandatory keep shut signs?				
Is the exit free of obstructions?				
Smoking	Yes	No	N/A	Comments
Is smoking prohibited in warehouse storage areas and other hazardous areas?				

Emergency Lightning	Yes	No	N/A	Comments
Where fitted, are emergency light test switches operated properly?				
Is the emergency lightning operating properly?				
Fire Extinguishers	Yes	No	N/A	Comments
Have the correct fire extinguishers for the hazards been installed?				
Has appropriate signage been fixed near the extinguishers?				
Are the fire extinguishers in good condition?				

Recommendations:

## Appendix K: Warehouse Lighting Audit

Organization:

Auditor:

Date:

Location	Target (Lux)	Measured (Lux)	Comments
<b>Stations</b>			
Receiving	200-500		
Fulfillment	200-500		
Shipping	200-500		
<b>Docks</b>			
Receiving	100-200		
Loading (a)	100-200		
Loading (b)	100-200		
<b>Aisles</b>			
A  Average:	300		
B  Average:	300		
C  Average:	300		
D  Average:	300		

E	300		
Average:			
F	300		
Average:			
G	300		
Average:			
XL	100-200		
Average:			
<b>Other</b>			
First Aid / Emergency	300		
Entrance	100-200		
Exit	100-200		

## Appendix L: TOPSIS for Proposed Layout Ecomspaces

**Qualitative Scale:**

Excellent	9
Above Average	7
Average	5
Below Average	3
Poor	1

**DATA MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)
Proposed A	0.463	0.87	0.88	8.1
Proposed B	0.220	0.86	0.9	8.5
Proposed C	0.316	0.89	0.98	8.5

**NORMALIZED MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)
Proposed A	0.7689	0.5751	0.5516	0.5588
Proposed B	0.3653	0.5685	0.5642	0.5864
Proposed C	0.5248	0.5883	0.6143	0.5864

**CRITERIA WEIGHTS**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)
Raw Weight	1.95	3.9	7.8	9.75
Weights	0.083	0.167	0.333	0.417

**WEIGHTED DATA MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)
Proposed A	0.0641	0.0958	0.1839	0.2328
Proposed B	0.0304	0.0947	0.1881	0.2443
Proposed C	0.0437	0.0981	0.2048	0.2443



**IDEAL SOLUTION MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)
Positive Ideal	0.0641	0.0947	0.2048	0.2443
Negative Ideal	0.0304	0.0981	0.1839	0.2328

**DIST FROM POSITIVE MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)	S*
Proposed A	0.000000	0.000001	0.000437	0.000132	0.023876
Proposed B	0.001131	0.000000	0.000279	0.000000	0.037553
Proposed C	0.000414	0.000011	0.000000	0.000000	0.020609

**DIST FROM NEGATIVE MATRIX**

	Cost	Employee Safety	Efficiency (Space Utilization)	Productivity (Speed)	S-
Proposed A	0.001131	0.000005	0.000000	0.000000	0.033700
Proposed B	0.000000	0.000011	0.000017	0.000132	0.012673
Proposed C	0.000176	0.000000	0.000437	0.000132	0.027300

**FINAL RANKING**

	Closeness to Ideal
Proposed A	0.585316
Proposed B	0.252312
Proposed C	0.569830

## Appendix M: Distance and Time Walk from Shipping Station to Each Aisle

### Distance and Time Walk from Shipping Station

	Current Warehouse		Proposed A		Proposed B		Proposed C	
	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)
Aisle XL	61.41667	16.43	30.33333	10.58	55.66667	17.5	55.66667	17.5
Aisle A	52.75	14.12	31	11.66	45.66667	14.23	45.66667	14.23
Aisle B	47	12.04	38.33333	12.5	36.58333	12.1	36.58333	12.1
Aisle C	30.33333	9.58	42.58333	13.4	24.83333	10.02	24.83333	10.02
Aisle D	19	7.14	49.91667	16.39	15.66667	7.2	15.66667	7.2
Aisle E	14.5	5	57.16667	17.75	18.16667	6.09	18.16667	6.09
Aisle F	13.08333	4.55	60.33333	19.98	21.08333	5.15	21.08333	5.15
Aisle G	30.41667	11.46	72.16667	21.87	51	12.4	51	12.4

### Comparison

Goal: Minimize Distance and Reduce Walking Time

	Current Warehouse		Proposed A		Proposed B		Proposed C	
	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)	Distance (ft)	Time (sec)
Aisle XL	61.41667	16.43	0.4939	0.6439	0.9064	1.0651	0.9064	1.0651
Aisle A	52.75	14.12	0.5877	0.8258	0.8657	1.0078	0.8657	1.0078
Aisle B	47	12.04	0.8156	1.0382	0.7784	1.0050	0.7784	1.0050
Aisle C	30.33333	9.58	1.4038	1.3987	0.8187	1.0459	0.8187	1.0459
Aisle D	19	7.14	2.6272	2.2955	0.8246	1.0084	0.8246	1.0084
Aisle E	14.5	5	3.9425	3.5500	1.2529	1.2180	1.2529	1.2180
Aisle F	13.08333	4.55	4.6115	4.3912	1.6115	1.1319	1.6115	1.1319
Aisle G	30.41667	11.46	2.3726	1.9084	1.6767	1.0820	1.6767	1.0820

## Appendix N: Estimated Implementation Cost for Proposed A, B, and C

Estimated Implementation Cost (Proposed A)			
Description	Quantity	Cost	Total
<b>Labor</b>			
Workers	5	14	2800
<b>Equipment</b>			
Table	2	\$282.00	\$564.00
Camera	2	\$27.05	\$54.10
Computer	1	\$350.00	\$350.00
Scanner	1	\$169.00	\$169.00
<b>Miscellaneous Expenses</b>			
Internet (increase in price)	1	\$50.00	\$50.00
Electricity	1	\$600.00	\$600.00
Insurance	1	\$200.00	\$200.00
Other Supplies	1	\$350.00	\$350.00
Unexpected Expenses	1	\$2,500.00	\$1,500.00
<b>Accumulated Total Expenses</b>			\$6,637.10

Estimated Implementation Cost (Proposed B)			
Description	Quantity	Cost	Total
<b>Labor</b>			
Workers	3	14	1680
<b>Miscellaneous Expenses</b>			
Renovation	1	\$500.00	\$500.00
Insurance	1	\$100.00	\$100.00
Other Supplies	1	\$350.00	\$350.00
Unexpected Expenses	1	\$1,000.00	\$1,000.00
<b>Accumulated Total Expenses</b>			\$3,630.00

Estimated Implementation Cost (Proposed C)			
Description	Quantity	Cost	Total
<b>Labor</b>			
Workers	3	14	1680
<b>Equipment</b>			
Camera	1	\$27.05	\$27.05
Computer	1	\$350.00	\$350.00
Scanner	1	\$169.00	\$169.00
<b>Miscellaneous Expenses</b>			
Renovation	1	\$500.00	\$500.00
Insurance	1	\$150.00	\$150.00
Other Supplies	1	\$350.00	\$350.00
Unexpected Expenses	1	\$2,000.00	\$1,500.00
<b>Accumulated Total Expenses</b>			\$4,726.05

## Appendix O: Cost Analysis (Actual) (Monthly)

<b>Cost Analysis (Actual) (Monthly)</b>			
Description	Quantity	Cost	Total
<b>Labor</b>			
Warehouse Associate	3	\$12.00	\$5,160.00
Shipping Associate	1	\$13.00	\$1,040.00
Warehouse Associate	1	\$14.00	\$2,240.00
Shipping Worker	1	\$12.00	\$960.00
Shipping Worker	1	\$14.00	\$1,120.00
Logistics Fulfillment Specialist	1	\$14.00	\$1,120.00
<b>Total</b>			<b>\$11,640.00</b>
<b>Utilities</b>			
GA POWER 600 bronner	1	\$883.27	\$883.27
WATER ATLANTA	1	\$94.24	\$94.24
GAS	1	\$212.52	\$212.52
COMCAST 675 metrop	1	\$0.00	\$0.00
COMCAST 600 Bronner	1	\$143.94	\$143.94
WATER.COM	1	\$84.00	\$84.00
RUBICON GLOBAL	1	\$52.80	\$52.80
COOLRAY	1	\$112.36	\$112.36
SimpliSafe	1	\$30.00	\$30.00
Alarm Electronics 5	1	\$42.00	\$42.00
<b>Total</b>			<b>\$1,655.12</b>
<b>Professional Dues and Subscriptions</b>			
eBAY sellers fees	1	\$152.83	\$152.83
SHIPSTATION	1	\$150.00	\$150.00
Shipinsurance	1	\$157.12	\$157.12
CANVA	1	\$66.00	\$66.00
emailmeform	1	\$38.00	\$38.00
WEVIDEO	1	\$5.75	\$5.75
GODADDY	1	\$60.61	\$60.61
WIX	1	\$135.30	\$135.30
MAIL UP/Sendiblu	1	\$194.40	\$194.40
Spotify	1	\$48.00	\$48.00
BOOMR	1	\$72.00	\$72.00
GUSTO	1	\$104.40	\$104.40
TaxAct	1	\$12.79	\$12.79
<b>Total</b>			<b>\$1,197.20</b>
<b>Supplies</b>			
Instacart	1	\$198.50	\$198.50
ULINE	1	\$428.60	\$428.60
Amazon supplies	1	\$12,473.43	\$12,473.43
eBay Supplies	1	\$141.94	\$141.94
Misc Supplies	1	\$25.00	\$25.00
<b>Total</b>			<b>\$13,267.46</b>
<b>Transportation</b>			
Transportation Uber	1	\$0.00	\$0.00
RENT 600 Bronner	1	\$10,057.33	\$10,057.33
<b>Total</b>			<b>\$10,057.33</b>



<b>Telephone</b>			
Nest Subscription	1	\$0.00	\$0.00
ATT	1	\$126.00	\$126.00
Ring Subscription	1	\$0.00	\$0.00
<b>Total</b>			\$126.00
<b>Payroll</b>			
1099 / freelance (Operations Manager + Project Manager + Customer Service + Community Management + Developer)	1	\$2,110.70	\$2,110.70
<b>Total</b>			\$2,110.70
<b>Insurance</b>			
Liberty Mutual Insurance	1	\$191.10	\$191.10
Workers Comp	1	\$213.90	\$213.90
<b>Total</b>			\$405.00
<b>Postage</b>			
Postage	1	\$25,440.91	\$25,440.91
WMS HAL TRAXX	1	\$360.00	\$360.00
<b>Total</b>			\$25,800.91
<b>Interests</b>			
Paypal working capital fees	1	\$0.00	\$0.00
Square working capital fees	1	\$77.50	\$77.50
Credit Card fees	1	\$137.39	\$137.39
Clearbanc fees	1	\$537.50	\$537.50
<b>Total</b>			\$752.39
<b>Bank Fees</b>			
Bank fees	1	\$66.50	\$66.50
Paypal Processing Fees	1	\$1,863.51	\$1,863.51
Square processing fees	1	\$389.75	\$389.75
Stripe processing fees	1	\$35.04	\$35.04
<b>Total</b>			\$2,354.81
<b>Advertising</b>			
Facebook Ads	1	\$739.83	\$739.83
<b>Total</b>			\$739.83
<b>Accumulated Total Expenses</b>			\$70,106.74
<b>Income</b>			
Stripe	1	\$3,313.90	\$3,313.90
Square	1	\$14,703.48	\$14,703.48
Paypal	1	\$45,794.22	\$45,794.22
Peerspace	1	\$3,959.79	\$3,959.79
Rent offices	1	\$5,011.88	\$5,011.88
Croissant	1		\$0.00
Liquidspace	1	\$13.50	\$13.50
<b>Total</b>		\$2,638.89	\$72,796.77
<b>Accumulated Total Income</b>			\$72,796.77
<b>Net Income Before Tax</b>			\$2,690.02
Potential OSHA Violation Cost	6	\$13,653.00	\$81,918.00

## Appendix P: Completed KPI

KPI Report - Ecomspaces				
KPI	Target	Progress	KPI Type	Commentary
<i>KPI name and details</i>	<i>Numerical target</i>	<i>Numerical current progress to target</i>	<i>Leading or lagging?</i>	<i>Comments and exceptions</i>
Visible Signs and Labels	35 signs/labels	20 signs/labels	Lagging	Some areas do not have clear labels and signs. Each station and aisle needs to be labeled so that it is easy to identify. Clearly labeled exits.
Personal Protective Equipment	3-5 PPEs	1 PPEs	Lagging	Some warehouse employees do not wear appropriate gloves and masks. There are no hard hats, face shields, eyewears, ear protections, and vests seen in the warehouse.
First-Aid Kits & Fire Extinguishers	8 fire extinguishers, 4 first aid kits	8 fire extinguishers, 4 first-aid kits	Leading	Clearly visible and accessible first-aid kits and fire extinguishers.
Number of Accidents	0 accidents	0 accidents	Leading	There were no accidents at the warehouse.
Accurate SOPs usage	5	3	Lagging	Standard Operating Procedures (SOPs) need to be revised to help provide accurate and easy-to-use information for worker training.
Dock Door Utilization	3 doors	2 doors	Lagging	One of the dock door access was blocked by personal items, styrofoam, and other recycled boxes.
Receiving Productivity	20 items/hour	17 items/hour	Lagging	Average number of items received per hour.
Receiving Cycle Time	3 minutes	3.46 minutes	Lagging	Time to process each item in receiving station.
Put-Away Productivity	120 items/hour	102.44 items/hour	Lagging	Number of inventory items able to be put away per hour.
Put-Away Cycle Time	0.50 minutes	0.59 minutes	Lagging	Time to process each item during put-away.
Picking Productivity	60 orders/hour	41.67 orders/hour	Lagging	Number of orders able to be picked per hour.
Picking Cycle Time	1 minute	1.44 minutes	Lagging	Time taken to process each order while picking.
Shipping Productivity	5 orders/hour	3.45 orders/hour	Lagging	Number of orders ready for shipment per hour.
Shipping Cycle Time	12 minutes	17.4 minutes	Lagging	Time taken to process each order during shipping.
Order Lead Time	2 days	2.77 days	Lagging	The average time for items to be processed and ready for shipment once order is placed.
Receiving Workstations	2 workstations	2 workstations	Leading	Number of workstations for receiving.
Shipping Workstations	3 workstations	2 workstations	Lagging	Number of workstations for shipping (RSU)
Clearable Floor Space	0 square feet	1190 square feet	Lagging	Amount of floor space able to be cleared from debris.
Space Utilization	85% utilization	82% utilization	Lagging	Ratio of space being utilized over total facility space.

Notes:  
 Leading indicator --> an indicator of performance that might predict future success.  
 Lagging indicator --> an indicator of past performance that measures how we performed.

## Appendix Q: Completed Warehouse Safety Audits

### OSHA Warehouse Safety Checklist

Date: 02/17/2021  
Auditor: Gustavo Andrade

General Safety	Ye s	No	N/ A	Comments	Code
Exposed or open loading dock doors and other areas that employees could fall 4 feet or more or walk off should be chained off, roped off or otherwise blocked.		✓		Shipping dock 1 was not secured when open. No signs to indicate that it can be dangerous when doors open.	
Floors and aisles are clear of clutter, electrical cords, hoses, spills, and other hazards that could cause employees to split, trip or fall.		✓		Floors are aisles are not clear. Aisle D has clutter and waste on the ground.	<u>1910.22(a)(1)</u> All places of employment, passageways, storerooms, service rooms, and walking-working surfaces are kept in a clean, orderly, and sanitary condition.
Proper work practices are factored into determining the time requirements for an employee to perform a task.	✓			Receiving station has standards in place. Other stations do not.	
Employees performing physical work have adequate periodic rest breaks to avoid fatigue levels that could result in greater risk of accidents and reduced quality of work.	✓			Employees receive a 15-minute break and a 30-minute lunch break.	
Newly hired employees receive general ergonomics training and task-specific training.		✓		No ergonomics training. Employees receive 1-week specific task training.	The following training requirements have been excerpted from Title 29, Code of Federal Regulations Part 1910 1910.30(d) <i>Training must be understandable.</i> The employer must provide information and training to each employee in a manner that the employee understands.

The warehouse is well ventilated.	✓				
Employees are instructed on how to avoid heat stress in hot, humid environments.			✓		1910.151(a) The employer shall ensure the ready availability of medical personnel for advice and consultation on matters of plant health.
Employees are instructed on how to work in cold environments.	✓				
Material Handling Safety	Ye s	No	N/ A	Comments	
There are appropriately marked and sufficiently safe clearances for aisles.		✓		Some aisles have clutter or objects in the way that workers have to work around.	1910.22(d)(1) Walking-working surfaces are inspected, regularly and as necessary, and maintained in a safe condition;
Loose/unboxed materials which might fall from a pile are properly stacked by blocking, interlocking, or limiting the height of the pile to prevent failing hazards.		✓			1910.22(d)(1) Walking-working surfaces are inspected, regularly and as necessary, and maintained in a safe condition;
Bags, containers, bundles, etc. are stored in tiers that are stacked, blocked, interlocked, and limited in height so that they are stable and secure to prevent sliding or collapse.			✓	The waste in dock 2 has overflowing trash. Also, overstock supplies of boxes not stacked properly.	
Storage areas are kept free from accumulation of materials that could lead to tripping, fire, explosion, or pest infestations.		✓		Multiple locations in the warehouse have excessive waste.	1910.22(d)(1) Walking-working surfaces are inspected, regularly and as necessary, and maintained in a safe condition;
Personnel use proper lifting techniques.	✓				
Hazard Communication Safety	Ye s	No	N/ A	Comments	
All hazardous materials containers are properly labeled, indicating the chemical's			✓		



identity, the manufacturer's name and address, and appropriate hazard warnings.					
There is an updated list of hazardous chemicals.			✓		
All employee training is documented.	✓				
Procedures have been established to maintain and evaluate the effectiveness of the current program.		✓		There are no current procedures in place to track the overall performance of employees.	
Employees use proper personal protective equipment when handling chemicals.			✓		
All chemicals are stored according to the manufacturer's recommendations and local or national fire codes.			✓		

Recommendations:

Remove the waste as soon as possible. These areas can potentially cause an accident if employees are not careful. If the clutter and waste is not removed, there is a possibility of pest infestation. There are also multiple locations for overstock items. The items need to be placed in one or two specific locations. Having multiple locations for multiple items can take up potential storage or working space. Additionally, it makes the warehouse look disorganized.

### OSHA Warehouse Safety Checklist

Date: 2/17/2021

Auditor: Nicolai Sison

General Safety	Ye s	No	N/ A	Comments	Code:
Exposed or open loading dock doors and other areas that employees could fall 4 feet or more or walk off should be chained off, roped off or otherwise blocked.	✓			Dock doors kept closed when not in use.	
Floors and aisles are clear of clutter, electrical cords, hoses, spills, and other hazards that could cause employees to split, trip or fall.	✓			High-traffic areas are generally free from clutter.	
Proper work practices are factored into determining the time requirements for an employee to perform a task.			✓	No established time standard currently in place.	
Employees performing physical work have adequate periodic rest breaks to avoid fatigue levels that could result in greater risk of accidents and reduced quality of work.	✓			Employees are provided with 15 min break and 30 min lunch.	
Newly hired employees receive general ergonomics training and task-specific training.	✓			Newly hired employees generally spend a week for task-specific training.	
The warehouse is well ventilated.	✓				
Employees are instructed on how to avoid heat stress in hot, humid environments.			✓		
Employees are instructed on how to work in cold environments.	✓				
Material Handling Safety	Ye s	No	N/ A	Comments	
There are appropriately marked and sufficiently safe clearances for aisles.		✓		Some aisles have obstructions which include overhanging	

				inventory from racks and pallets stored within.	
Loose/unboxed materials which might fall from a pile are properly stacked by blocking, interlocking, or limiting the height of the pile to prevent falling hazards.	✓			Generally satisfactory. Some hazards can be observed in low-traffic areas such as oversize and entrance areas.	
Bags, containers, bundles, etc. are stored in tiers that are stacked, blocked, interlocked, and limited in height so that they are stable and secure to prevent sliding or collapse.	✓			Generally satisfactory. Some boxes stacked 4-5 high without interlocking.	
Storage areas are kept free from accumulation of materials that could lead to tripping, fire, explosion, or pest infestations.		✓		Problems in XL (oversize) areas and in second floor storage.	
Personnel use proper lifting techniques.	✓				
<b>Hazard Communication Safety</b>	<b>Ye s</b>	<b>No</b>	<b>N/ A</b>	<b>Comments</b>	
All hazardous materials containers are properly labeled, indicating the chemical's identity, the manufacturer's name and address, and appropriate hazard warnings.			✓	Not enough chemical products require labeling as hazardous. Products mostly consist of consumer-level household cleaning supplies.	
There is an updated list of hazardous chemicals.		✓			
All employee training is documented.	✓				
Procedures have been established to maintain and evaluate the effectiveness of the current program.		✓		No evaluation criteria has been set.	
Employees use proper personal protective equipment when handling chemicals.			✓	Chemical products are seldom received.	

All chemicals are stored according to the manufacturer's recommendations and local or national fire codes.			✓		
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**Recommendations:**

- 1. Measure and establish standard time for task performance for receiving, put-away, picking, and shipment, while factoring in personal needs, fatigue, and unavoidable delays allowance.
- 2. Minimize obstructions within the warehouse and ensure visibility as precaution if unavoidable.
- 3. Provide checklist of chemical products used for housekeeping/maintenance purposes.

## Appendix R: Completed Fire Safety Audits

### Fire Safety Checklist

Date: 02/17/21  
Auditor: Edwin Lim

Main Fire Alarm Panel	Y es	N o	N/ A	Comments	Code:
Is the indicator light on the main fire alarm panel showing "normal"?			✓	Currently is unavailable because it is not required.	
Is there an "emergency and safety information" box near the fire alarm panel?			✓	Currently is unavailable because it is not required.	
Does the above box have a spare key fixed to the front?			✓	Currently is unavailable because it is not required.	
Does the box contain the fire precautions log book?			✓	Currently is unavailable because it is not required.	
Does the box contain the latest building fire risk assessment?			✓	Currently is unavailable because it is not required.	
Does the box contain up to date plans of the building?			✓	Currently is unavailable because it is not required.	
Key Personnel	Y es	N o	N/ A	Comments	
Has one or more people been nominated as fire inspector for the building?		✓			1910.39(c)(2) Procedures to control accumulations of flammable and combustible waste materials; 1910.39(c)(3) Procedures for regular maintenance of safeguards installed on heat-producing equipment to prevent the accidental ignition of combustible materials;

Have sufficient numbers of people been nominated to ensure weekly tests or call points are carried out?		✓			1910.38 Employee emergency plans 4. "Fire prevention housekeeping." The standard calls for the control of accumulations of flammable and combustible waste materials.
<b>Fire Doors</b>	<b>Y es</b>	<b>N o</b>	<b>N/ A</b>	<b>Comments</b>	
Is there a fire door in the warehouse?			✓	Currently is unavailable	
Are all fire doors marked with mandatory keep shut signs?			✓	Currently is unavailable	
Is the exit free of obstructions?		✓		They are not easily accessible. The exit near the dock full of personal items, recycle boxes, and packaging boxes.	1910.37(a) <b>The danger to employees must be minimized.</b> 1910.37(a)(3) Exit routes must be free and unobstructed. No materials or equipment may be placed, either permanently or temporarily, within the exit route. The exit access must not go through a room that can be locked, such as a bathroom, to reach an exit or exit discharge, nor may it lead into a dead-end corridor. Stairs or a ramp must be provided where the exit route is not substantially level.
<b>Smoking</b>	<b>Y es</b>	<b>N o</b>	<b>N/ A</b>	<b>Comments</b>	
Is smoking prohibited in warehouse storage areas and other hazardous areas?	✓				
<b>Emergency Lightning</b>	<b>Y es</b>	<b>N o</b>	<b>N/ A</b>	<b>Comments</b>	

Where fitted, are emergency light test switches operated properly?	✓				
Is the emergency lightning operating properly?	✓				
Fire Extinguishers	Y es	N o	N/ A	Comments	
Have the correct fire extinguishers for the hazards been installed?	✓			Yes, but not easy to find. There are 2 in the facility exterior, 5 in the facility interior, and 1 on the 2 <sup>nd</sup> floor	
Has appropriate signage been fixed near the extinguishers?		✓		Not all of them. Only 1 in the facility exterior and 1 in the facility interior have the appropriate signage.	
Are the fire extinguishers in good condition?	✓			All of them are in good condition.	

Recommendations:

Install proper signage for each fire extinguisher and first aid location. There are three total first aids in the facility interior (warehouse) and only one first aid location near the shipping has proper signage. The exit area should be clear and open for easy access.

1910.37(b)(4)

If the direction of travel to the exit or exit discharge is not immediately apparent, signs must be posted along the exit access indicating the direction of travel to the nearest exit and exit discharge. Additionally, the line-of-sight to an exit sign must clearly be visible at all times.

### Fire Safety Checklist

Date: 2/17/2021

Auditor: Nicolai Sison

Main Fire Alarm Panel	Yes	No	N/A	Comments
Is the indicator light on the main fire alarm panel showing "normal"?			✓	
Is there an "emergency and safety information" box near the fire alarm panel?			✓	
Does the above box have a spare key fixed to the front?			✓	
Does the box contain the fire precautions log book?			✓	
Does the box contain the latest building fire risk assessment?			✓	
Does the box contain up to date plans of the building?			✓	Building code does not require centralized fire alarm due to age.
Key Personnel	Yes	No	N/A	Comments
Has one or more people been nominated as fire inspector for the building?		✓		No person in the facility has been assigned as fire inspector for the building.
Have sufficient numbers of people been nominated to ensure weekly tests or call points are carried out?		✓		No weekly tests of call points are carried out.
Fire Doors	Yes	No	N/A	Comments
Is there a fire door in the warehouse?		✓		
Are all fire doors marked with mandatory keep shut signs?			✓	No dedicated fire door in place.
Is the exit free of obstructions?		✓		Debris/pallets obstructing exit.
Smoking	Yes	No	N/A	Comments
Is smoking prohibited in warehouse storage areas and other hazardous areas?	✓			



Emergency Lighting	Yes	No	N/A	Comments
Where fitted, are emergency light test switches operated properly?	✓			
Is the emergency lighting operating properly?	✓			
Fire Extinguishers	Yes	No	N/A	Comments
Have the correct fire extinguishers for the hazards been installed?	✓			
Has appropriate signage been fixed near the extinguishers?		✓		
Are the fire extinguishers in good condition?	✓			Fire extinguishers are properly maintained. Last inspection: Nov. 2020

**Recommendations:**

1. All fire extinguishers within the facility should be free from obstruction.
2. Employees should be made aware of all fire extinguisher locations in the building.
3. Existing fire extinguishers should be maintained every six years and inspected annually.
4. Fire extinguisher locations should include a first-aid station and have appropriate signage to increase their visibility.

## Appendix S: Completed Lighting Audit

### Warehouse Lighting Audit

Date: 3/9/21  
Auditor: Nicolai Sison

Location	Target (Lux)	Measured (Lux)	Comments
<b>Stations</b>			
Receiving	200-500	200-550	Lighting is sufficient at this station.
Fulfillment	200-500	100-250	Lighting is insufficient at this station.
Shipping	200-500	100-250	Lighting is insufficient at this station.
<b>Docks</b>			
Receiving	100-200	100-350	Lighting is sufficient both when dock is open and closed.
Loading (a)	100-200	50-100	Lighting is insufficient both when dock is open and closed.
Loading (b)	100-200	>25-50	Lighting is insufficient in this area.
<b>Aisles</b>			
A	100-300	165	Sufficient lighting. Lights near the loading docks need replacement. Range: 40-208
Average: 114.67		127	
		52	
B	100-300	161	Lighting is sufficient. Range: 50-169
Average: 109.67		106	
		62	
C	100-300	80	Lighting is insufficient. Range: 40-89
Average: 73.67		64	
		77	
D	100-300	117	Lighting is insufficient. Range: 45-130
Average: 76.33		40	
		72	
E	100-300	131	Lighting is insufficient. Range: 45-128
Average: 87.00		49	
		81	
F	100-300	324	Lighting is sufficient. Aisle contains external lights overhead. Range: 80-550
Average: 226.33		274	
		81	

G Average: 95.00	100-300	92	Lighting is insufficient. Range: 77-130
		110	
		83	
XL Average: 86.67	100-200	115	Lighting is insufficient. Range: >25-150
		105	
		40	
<b>Other</b>			
First Aid / Emergency	300	90-110	Insufficient lighting for emergency supplies.
Entrance	100-200	50-100	Entrance lighting is insufficient.
Exit	100-200	>25-50	Exit lighting is insufficient.

**Additional Comments:** Warehouse lighting conditions are poor. Lighting is not evenly distributed throughout the facility. Lights by the loading docks need replacement; cost may incur scissor lift rental and electrical work. Lighting inconsistencies are present across the same aisle. Possible solutions for proper lighting may involve the use of external overhead lights similar to the ones found in Aisle F.

## Appendix T: Completed Maintenance Audits

### Maintenance Housekeeping Audit

Date: 02/17/21  
 Auditor: Edwin Lim  
 Maximum Score: 50  
 Actual Score: 34  
 Percentage: 68%

Facility Exterior	0 Poor	1 Good	Comments
<b>General</b>			
Overall appearance		1	Great appearance
Concrete drive and parking lots		1	Have sufficient parking lot for employees
Concrete sidewalks, steps, and landings		1	They are organized and arranged properly
Sign, damaged? Visible?		1	Signs are visible, but may need to be expanded for easy reading.
<b>Doors and Windows</b>			
Are all doors operating safely? Securely?		1	Yes, all doors are operating safely
Any broken windows?		1	There is a crack in one of the windows, but it still works fine.
Are all doors locked working properly?		1	Yes, they are
<b>Lightning</b>			
Are all exterior lights and power receptacles/outlets working properly?		1	Yes, they are. One of the exterior outlets isn't fully covered.
Are the sign working properly?		1	Yes, they are
Facility Interior	0 Poor	1 Good	Comments
<b>General</b>			
Overall warehouse appearance	0		Unorganized
Warehouse floors, need cleaning? Repair?	0		Yes, needs to be cleaned
Windows, dirty? Cracked? Air leakage?		1	No window

Are the floors between shelving units clean and free of clutter?	0		Not having consistent space between shelves.
Walls, damage? Stains? paint touchup?		1	It's overall good. There're water stains in several areas.
Ceiling tiles? Missing? Water stained?	0		Paint stains, dents
<b>Doors and Dock</b>			
Doors opening and closing properly?		1	Yes, they are working properly
Door locks functional?		1	Yes, they are working properly
Dock door opening and closing properly?		1	Yes, they are working properly
<b>Electrical</b>			
Are all lights working? Bulbs burned out?	0		Only one bulb burned out in the corner near the dock area.
Are light switches operating properly?		1	Yes, they are.
Do the diffusers need cleaning?		1	No diffusers in the warehouse
Are all outlets working properly? Burnt or flash marks?		1	Yes, they are
Are nighttime security lights working properly?		1	Yes, automated lights
<b>Receiving Station</b>	<b>0</b>	<b>1</b>	<b>Comments</b>
	Poor	Good	
Is the signage correct, clean, and visible?	0		No sign
Is the exterior lighting correct, suitable and sufficient?		1	Yes, adequate lightning
Are the floor areas clean and free of clear clutter?	0		Somewhat dirty
Are the waste bins being used correctly, is there any contamination?		1	It's full of paper
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?	0		It's placed on the table, but not neat
Are there procedures or instructions at the workstation?		1	Yes, but not all the instructions. Only instruction for exception.
<b>Pack and Shipping Station</b>	<b>0</b>	<b>1</b>	<b>Comments</b>
	Poor	Good	
Is the signage correct, clean, and visible?	0		No sign

Is the exterior lighting correct, suitable and sufficient?		1	Yes, except for unused shipping station.
Are the floor areas clean and free of clear clutter?	0		Somewhat clutter
Are the waste bins being used correctly, is there any contamination?		1	Yes
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?	0		Yes, but not arranged neatly
Are there procedures or instructions at the workstation?	0		Yes, but only exceptions
<b>Fulfillment Station</b>	<b>0</b> Poor	<b>1</b> Good	<b>Comments</b>
Is the signage correct, clean, and visible?	0		No sign
Is the exterior lighting correct, suitable and sufficient?		1	Adequate lightning
Are the floor areas clean and free of clear clutter?		1	Yes, it's clean
Are the waste bins being used correctly, is there any contamination?		1	Yes, they're
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?		1	Yes, they are arranged neatly
Are there procedures or instructions at the workstation?		1	Yes, there are instructions
<b>Receiving Ramp Area</b>	<b>0</b> Poor	<b>1</b> Good	<b>Comments</b>
Is the door operating safely? Securely?		1	Yes, it works properly
Is the access area free of blockages?		1	Somewhat easily accessible
Is the Ring doorbell working properly?		1	Yes, it's working properly
<b>Dock 1 Area</b>	<b>0</b> Poor	<b>1</b> Good	<b>Comments</b>
Is the door operating safely? Securely?		1	Yes, it works properly
Is the access area free of blockages?		1	Somewhat easily accessible
Is the Ring doorbell working properly?		1	Yes, it's working properly
<b>Dock 2 Area</b>	<b>0</b> Poor	<b>1</b> Good	<b>Comments</b>
Is the door operating safely? Securely?	0		It's not working currently

Is the access area free of blockages?	0		No, they are blocked by personal items and packaging boxes
Is the Ring doorbell working properly?	0		No ring for dock 2

### Maintenance Housekeeping Audit

Date: 02/17/21  
 Auditor: Gustavo Andrade  
 Maximum Score: 50  
 Actual Score: 34  
 Percentage: 68%

Facility Exterior	0 Poor	1 Good	Comments
<b>General</b>			
Overall appearance		1	
Concrete drive and parking lots		1	
Concrete sidewalks, steps, and landings		1	
Sign, damaged? Visible?		1	
<b>Doors and Windows</b>			
Are all doors operating safely? Securely?		1	
Any broken windows?		1	
Are all doors locked working properly?		1	
<b>Lighting</b>			
Are all exterior lights and power receptacles/outlets working properly?		1	
Are the sign working properly?		1	
Facility Interior	0 Poor	1 Good	Comments
<b>General</b>			
Overall warehouse appearance	0		Disorganized. There is product on the ground as soon as you walk in.
Warehouse floors, need cleaning? Repair?	0		The warehouse can use some cleaning and some floors are cracked.
Windows, dirty? Cracked? Air leakage?		1	This warehouse has no windows.



Are the floors between shelving units clean and free of clutter?	0		Certain areas of the warehouse have product on the ground with no designated location.
Walls, damage? Stains? paint touchup?	0		Some walls need maintenance and paint touchup.
Ceiling tiles? Missing? Water stains?	0		Some areas have water stains.
<b>Doors and Dock</b>			
Doors opening and closing properly?		1	
Door locks functional?		1	
Dock door opening and closing properly?	0		Dock 2 in shipping area does not open. It also has a lot of clutter.
<b>Electrical</b>			
Are all lights working? Bulbs burned out?	0		The lights in the back are not working / burned out.
Are light switches operating properly?		1	
Do the diffusers need cleaning?		1	
Are all outlets working properly? Burnt or flash marks?		1	
Are nighttime security lights working properly?		1	
<b>Receiving Station</b>	<b>0</b>	<b>1</b>	<b>Comments</b>
	Poor	Good	
Is the signage correct, clean, and visible?	0		No sign that indicates that it is a receiving station.
Is the exterior lighting correct, suitable and sufficient?		1	
Are the floor areas clean and free of clear clutter?		1	
Are the waste bins being used correctly, is there any contamination?		1	
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?	0		The workplace looks messy. Tools do not have a designated location.
Are there procedures or instructions at the workstation?		1	
<b>Pack and Shipping Station</b>	<b>0</b>	<b>1</b>	<b>Comments</b>
	Poor	Good	
Is the signage correct, clean, and visible?	0		No sign to indicate that it is a shipping station.

Is the exterior lighting correct, suitable and sufficient?		1	
Are the floor areas clean and free of clear clutter?	0		This station seems to be the least organized.
Are the waste bins being used correctly, is there any contamination?		1	
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?	0		The workplace looks messy. Tools do not have a designated location.
Are there procedures or instructions at the workstation?		1	
<b>Fulfillment Station</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the signage correct, clean, and visible?	0		No sign to indicate that it is a fulfillment station.
Is the exterior lighting correct, suitable and sufficient?		1	
Are the floor areas clean and free of clear clutter?		1	
Are the waste bins being used correctly, is there any contamination?		1	
Are the tools (i.e. tape measure, box cutter, and packaging tape) stored neatly?		1	
Are there procedures or instructions at the workstation?		1	
<b>Receiving Ramp Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?		1	
Is the access area free of blockages?		1	
Is the Ring doorbell working properly?		1	
<b>Dock 1 Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?		1	
Is the access area free of blockages?		1	
Is the Ring doorbell working properly?		1	
<b>Dock 2 Area</b>	<b>0 Poor</b>	<b>1 Good</b>	<b>Comments</b>
Is the door operating safely? Securely?	0		Not operating at all

Is the access area free of blockages?	0		This area is completely blocked
Is the Ring doorbell working properly?	0		Not functioning.

## Appendix U: SOPs



Document Number: SOP-01-001	Page 1 of 5
Effective Date: --/--	Revision No.: 000

<b>Standard Operation Procedure</b> <b>OSHA &amp; Fire Safety</b>		
SOP NO.	Author	Last Revision Date:
SOP-01-001/Rev.000		
<b>PURPOSE</b>	<b>Describe who the SOP is for and why it is necessary.</b>	
	<p>This SOP is to maintain warehouse safety for employees as it pertains OSHA workplace standard and fire safety as Ecomspaces. Evaluation should take place once a month.</p>	
<b>SCOPE</b>	<b>Describe the types of documents to be included in a version control system.</b>	
	<p>This procedure applies to the warehouse workspace. The work area will be a safe working environment and free of workplace hazards such as obstructions, and accumulation of items that create fire hazards.</p>	
<b>RESPONSIBILITIES</b>	<b>Detail who will maintain the document control system and this SOP.</b>	
	<p>It is the responsibility of all Ecomspaces supervisors, managers, and employees for each workstation to follow the procedures outlined in this Standard Operating Procedure (SOP-01-001).</p>	
<b>ARCHIVING CONVENTIONS</b>	<b>Describe how and when documents are archived.</b>	
	<p>When completing audit fill out the auditor's name and date audit was carried out. If any revisions are made to this SOP, including the respective Audit checklists please note on this page. Update revision number, author who made updates, and the revision date at top. When audit is complete archive document with all three sheets by either scanning or stapling together.</p>	
<b>REFERENCES</b>	<b>List any referral documents, if required.</b>	
	<p>In the SOP two audit checklists will be accompanied behind. <b>One: OSHA Warehouse Safety Checklist. Two: Fire Safety Checklist.</b></p>	



Document Number: SOP-02-001	Page 1 of 6
Effective Date: --/--	Revision No.: 000

## Standard Operation Procedure Lighting & Maintenance

SOP NO.	Author	Last Revision Date:
SOP-02-001/Rev.000		

<b>PURPOSE</b>	<p>Describe who the SOP is for and why it is necessary.</p> <p>This SOP is to be utilized for the purpose of standardizing the housekeeping, maintenance, ergonomic, and visual management systems for Ecomspaces buildings and facilities.</p>
<b>SCOPE</b>	<p>Describe the types of documents to be included in a version control system.</p> <p>This procedure applies to both Ecomspaces office and warehouse space. The work areas are to be clean and visually appealing, while promoting an efficient and ergonomic workspace environment for personnel and employees.</p>
<b>RESPONSIBILITIES</b>	<p>Detail who will maintain the document control system and this SOP.</p> <p>It is the responsibility of all Ecomspaces supervisors, managers, and employees to follow the procedures outlined in this Standard Operating Procedure (SOP-02-001).</p>
<b>ARCHIVING CONVENTIONS</b>	<p>Describe how and when documents are archived.</p> <p>When completing audit fill out the auditor's name and date audit was carried out. If any revisions are made to this SOP, including the respective Audit checklists please note on this page. Update revision number, author who made updates, and the revision date at top. When audit is complete archive document with all three sheets by either scanning or stapling together.</p>
<b>REFERENCES</b>	<p>List any referral documents, if required.</p> <p>In the SOP, two audit checklists will be accompanied behind. <b>One: Warehouse Lighting Audit. Two: Maintenance Housekeeping Audit</b></p>



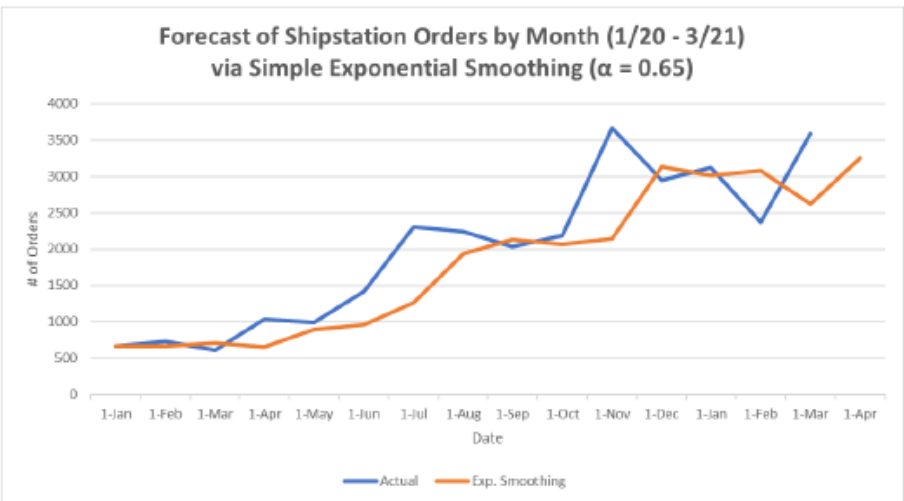
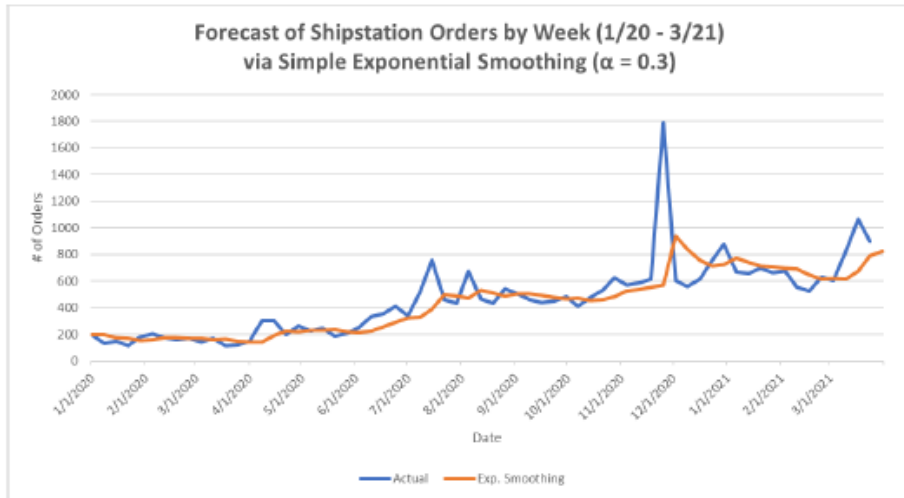
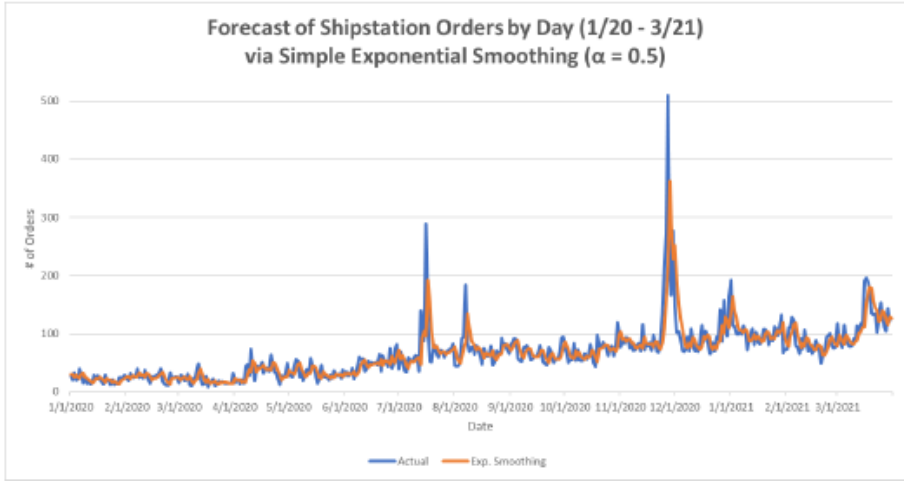
Document Number: SOP-03-001	Page 1 of 2
Effective Date: --/--/--	Revision No.: 000

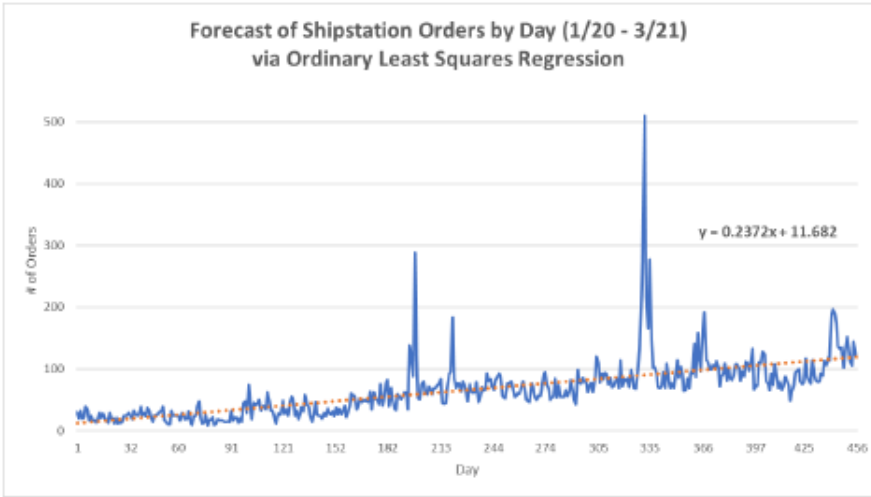
## Standard Operation Procedure KPI Evaluation

SOP NO.	Author	Last Revision Date:
SOP-03-001/Rev.000		

PURPOSE	<b>Describe who the SOP is for and why it is necessary.</b>
	This SOP is to continually evaluate and measure the improvements of the KPIs. This evaluation should take place once a quarter.
SCOPE	<b>Describe the types of documents to be included in a version control system.</b>
	This procedure applies to key performance indicators used to quantify and evaluate the processes at Ecomspaces. KPIs help assess how well the company is doing on continuous improvement.
RESPONSIBILITIES	<b>Detail who will maintain the document control system and this SOP.</b>
	It is the responsibility of all Ecomspaces supervisors, managers, and employees for each workstation to follow the procedures outlined in this Standard Operating Procedure (SOP-03-001).
ARCHIVING CONVENTIONS	<b>Describe how and when documents are archived.</b>
	When completing audit fill out the auditor's name and date audit was carried out. If any revisions are made to this SOP, including the respective Audit checklists please note on this page. Update revision number, author who made updates, and the revision date at top. When audit is complete archive document with all three sheets by either scanning or stapling together.
REFERENCES	<b>List any referral documents, if required.</b>
	In the SOP one audit sheet will be accompanied behind titled <b>KPI Report- Ecomspaces.</b>

## Appendix V: Order Demand Forecasts

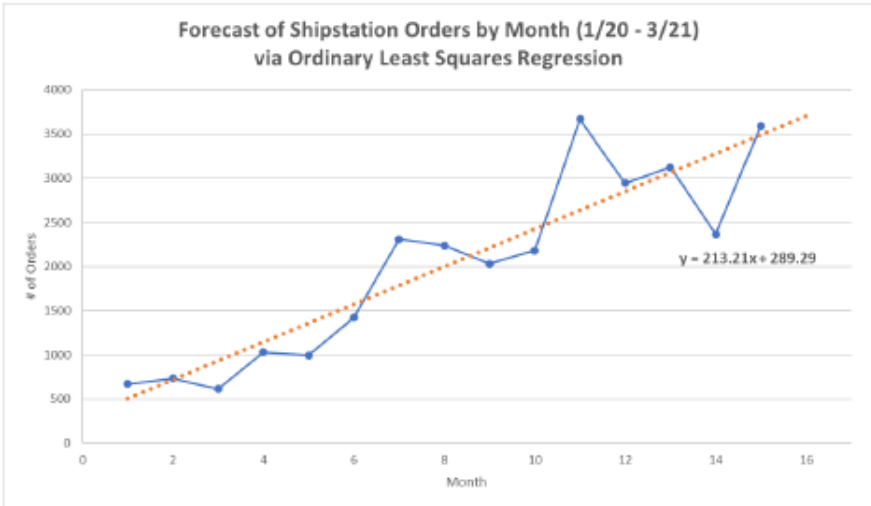




<b>4/1/2021</b>	<b>119.85</b>
<b>MSE =</b>	<b>1149.23</b>
<b>RMSE =</b>	<b>33.90</b>



<b>4/1/2021</b>	<b>844.47</b>
<b>MSE =</b>	<b>30724.35</b>
<b>RMSE =</b>	<b>175.28</b>



<b>4/1/2021</b>	<b>3700.65</b>
<b>MSE =</b>	<b>176063.14</b>
<b>RMSE =</b>	<b>419.60</b>



## Appendix W: Shipstation Data Analysis (Python Code)

### Notes:

Raw Shipstation data from 1/1/20 to 3/31/21

Analyze the following:

Summary of order weights and volumes

Order lead time ~ Processing time as soon as customer order is placed

Total number of orders for each date (can be found on Shipstation)

Assumptions:

Removal of unused columns/variables

~ Remove all except ['OrderStatus', 'OrderLength', 'OrderWeightOz', 'OrderWidth', 'OrderShipDate', 'OrderHeight', 'OrderDate', 'OrderID']

Dropped rows with missing/zero values, OrderStatus='Cancelled', duplicates(subset='OrderID')

Original Data Columns (total 86 columns):

RangeIndex: 60974 entries, 0 to 60874

Code:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import datetime

# Read in the csv files
df1= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/dec_jan.csv')
df2= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/sept_nov.csv')
df3= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/jun_aug.csv')
df4= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/mar_may.csv')
df5= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/jan_feb.csv')
df6= pd.read_csv(r'/content/drive/MyDrive/Shipstation Raw Data/feb_mar.csv')

# Concatenating the data into one single dataframe (01/01/2020 - 03/31/2021)
df = pd.concat([df1,df2,df3,df4,df5,df6], ignore_index=True)

# Printing first five observations
df[:5]

# Checking variable names
df.info()

# Checking column information
df.columns

# Declaring unused variables from dataframe
unused_variables = ['OrderPackageType', 'OrderPayDate', 'OrderOtherCosts',
                    'OrderProvider', 'OrderResidentialIndicator', 'OrderSaturdayDelivery',
                    'OrderRateError', 'OrderRequestedShippingService',
                    'OrderMarketplaceName', 'OrderItemWarehouse',
```

```

'OrderItemWeight', 'OrderModifyDate', 'OrderNumber',
'OrderNotesFromBuyer', 'OrderNotesToBuyer', 'OrderNonDelivery',
'OrderNonMachinable', 'OrderService', 'OrderShowPostage',
'OrderStoreName', 'OrderShipStreet2', 'OrderShipStreet3', 'OrderTotal',
'OrderWeightOz', 'OrderWeight', 'OrderUserName',
'OrderWarehouse', 'OrderShipStreet1', 'OrderShipCountryCode',
'OrderShipCity', 'OrderShipCompany', 'OrderShipName',
'OrderShipPostalCode', 'OrderShipState', 'OrderShipPhone',
'OrderShippingAmount', 'OrderItemUPC', 'OrderExternalURL',
'OrderExternalPaymentID', 'OrderHoldUntil',
'OrderImportKey', 'OrderInsuranceCost', 'OrderImportBatch',
'OrderCustomsContents', 'OrderAddressVerified', 'OrderAmountPaid',
'OrderActive', 'OrderAdditionalHandling', 'OrderBuyerEmail',
'OrderCreateDate', 'OrderCustomer', 'OrderConfirmation',
'OrderConfirmationCost', 'OrderInsuranceProvider', 'OrderItemQuantity',
'OrderItemShippingAmount', 'OrderItemOptions', 'OrderItemOrderId',
'OrderItemSku', 'OrderItemUnitCost', 'OrderItemUnitPrice',
'OrderItemTaxAmount', 'OrderItemThumbNailUrl', 'OrderItemModifyDate',
'OrderItemCreateDate', 'OrderItemDescription', 'OrderInsuredValue',
'OrderInternalNotes', 'OrderItemExtendedPrice', 'OrderItemISBN',
'OrderItemItemURL', 'OrderItemExternalID', 'OrderItemID', 'TaxAmount',
'OrderCustomField1', 'OrderCustomField2', 'OrderCustomField3', 'Zone']

# Removal of unused columns
df.drop(unused_variables, axis = 1, inplace = True)

# Removing rows with cancelled order status
df = df[df.OrderStatus == 'Shipped']
df.OrderID.count

# Removing duplicates based on 'OrderID'
df.drop_duplicates(subset=['OrderID'])

# Checking the dimensions of the dataframe
df.shape

# Checking new column information
df.columns

# Creating copies of the dataframe
df_vol = df.copy()
df_time = df.copy()

# Volume calculation based on order length, width, and height
df_vol['OrderVolume'] = df_vol['OrderLength']*df_vol['OrderWidth']*df_vol['OrderHeight']

```

```

# Removal of missing values
df_vol = df_vol.dropna()
df_nozero = df_vol.loc[~(df==0).any(axis=1)]

# Declaring unused variables from time order dataframe
unused_variables2 = ['OrderStatus', 'OrderLength', 'OrderItemWeightOz', 'OrderWidth', 'OrderHeight', 'OrderID']

# Removal of unused columns
df_time.drop(unused_variables2, axis = 1, inplace = True)
df_time.dropna()
df_time.head(5)

# Conversion to datetime index
a = pd.to_datetime(df_time.OrderShipDate, infer_datetime_format=True)
b = pd.to_datetime(df_time.OrderDate, infer_datetime_format=True)
c = (a - b).dt.days

print("Statistics for Order Lead Times")
c.describe()

# Plotting the order data
bins_list = range(0,21)
plt.figure(figsize=(16,8))
plt.hist(c, bins=bins_list, color="lightblue", edgecolor="black")
plt.xlabel("Order Lead Times")
plt.ylabel("Time (in days)")
plt.title('Histogram of Order Lead Times')
plt.xlim(0,21)
plt.show()

# Convert to datetime index
df_vol.OrderDate = pd.to_datetime(df.OrderDate).dt.floor('d')

# Grouping by datetime
df_vol.groupby('OrderDate').mean()

# Program coded by Nicolai Sison as part of the Optimized Brain E-Spaces.

```

# Appendix X: Project Gantt Chart

