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Optimization of a Manufacturing Work Cell Design and Layout

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Abstract

This project intends to use engineering analysis and lean manufacturing principles to re-design an assembly line layout at the Fisher Dynamics company in Evansville, Indiana. Fisher Dynamics has a long history in the automotive parts business and continues to supply many well-known car manufacturers with seat structures and mechanisms. Fisher Dynamics has been facing issues with warranty claims, inefficient part flow, and increased cycle times on one of their assembly lines. This project focuses on implementing a new machine design as well as a new layout into this assembly line. This report will give a brief history of the Fisher Dynamics company as well as introduce the objective and deliverables for this project. The motivation and need for this project come from wanting to eliminate warranty claims, decrease cycle times, and increase production rates of the assembly line to deliver more products with higher quality to our customers. Similar projects that have solved problems like the ones faced at Fisher Dynamics are discussed and show that implementing lean principles can address these issues. Three conceptual designs are looked at and pros and cons of each are discussed. Of these designs, one was selected and taken into the design stage and discussed in further detail to show how the engineering designs were justified. Concluding remarks discuss how new engineering knowledge was gained and used to complete the final design of the work cell. An analysis of the work cell was conducted to evaluate its performance after the new design was implemented. The results of the analysis showed that the new layout and design were able to decrease part warranty claims, decrease cycle times, and increase production.

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1. Introduction

Manufacturing facilities are always searching for ways to improve their processes. This report discusses the engineering principles used in order to re-design a work cell and improve its layout so that it is more efficient in the assembly process at Fisher Dynamics located in Evansville, Indiana.

1.1 Objective

The objective of this project is:

Design a new layout for an assembly line at the Fisher Dynamics Evansville Plant to optimize efficiency by increasing production rate, decreasing cycle time, and decreasing part warranty claims.

1.2 Deliverables

The deliverables for this project are the following:

- Re-design of assembly line layout using AutoCAD software
- AutoCAD models of assembly line flow racks
- Warranty analysis of re-designed assembly line layout

The stakeholders of this project include but are not limited to:

- Production Operators
- Engineering Team
- Quality Team
- Management
- Customers

By increasing the efficiency and improving the flow of materials throughout the system we expect to see production rates increase, part quality increase, and better ergonomics for workers throughout the work cell assembly process.

2. Background

Fisher Dynamics was founded in 1980, but this was not where the company initially began its history. The Fisher Body Corporation began in the early 1900s when they were producing automobile bodies for major automotive manufacturers such as Ford, Cadillac, Oldsmobile, and Studebaker. By the time World War II rolled around, the Fisher Body Corporation had produced over 21,000,000 automobile bodies before they were forced to focus on production of planes and tanks for the war effort. After the war had ended, the company had returned its focus to the manufacturing of automobile bodies [1].

With the massive growth of the automotive industry, safety concerns also began to grow, and manufacturers were being pressured to improve the safety components incorporated in their vehicle designs. New laws were being set in place that required seat belts to be installed in all vehicles. To accommodate these new requirements, the Fisher Body Corporation elected to create a new company focusing solely on safety features in vehicles. In 1980 Fisher Dynamics was established and began producing automotive seating components for major automotive manufacturers such as it did when it began in the early 1900's [1].

Today, Fisher Dynamics is the automotive industry's premier supplier of seat structures and internal mechanisms. Fisher Dynamics has manufacturing facilities across the globe including multiple facilities in North America, Europe, and Asia. This project will specifically focus on an assembly work center that is located at the Evansville, Indiana manufacturing facility. At the Evansville facility internal seat structures are manufactured and assembled to then be packaged and sent to customers. An example of a completed seat structure can be seen in Figure 1.



Figure 1: Completed Seat Structure

Later in this report we will discuss the statement of the problem as well as what motivated and drove the need for this project. We will discuss similar projects from a literature review that have solved or aimed to solve the same problem that we are exploring in this project. We will then summarize what we have learned from analyzing these previous projects and discuss the positive and negative results that were demonstrated in each piece of literature. Since each project is unique to its own characteristics, we will also discuss how we anticipate the project to be different from the previous projects discussed in the literature review.

Three conceptual designs that were considered over the course of this project will be discussed along with the pros and cons of each design. An in-depth analysis of our preliminary engineering design will be discussed where engineering tables, graphs, and analogies will be used to support a completed design for this project. Justification of tradeoffs based on engineering design and analysis will also be discussed. Lastly, we will look at the decision of this design project indicating which design concept was chosen to be taken into the critical design stage. An analysis will take place to evaluate the performance of the work cell and concluding remarks will be made on lessons learned as well as how teamwork played a role in this project.

2.1 Statement of the Problem

The work cell that is being re-designed for this project is an assembly cell that specializes in assembling powered seat cushions. Seat cushion does not refer to the soft, foam material that you may think of, rather the internal metal structure that the foam material would surround. An example of a part that this cell would assemble is circled in Figure 2.



Figure 2: Powered Cushion Assembly [2]

The motivation and need for this project come from Fisher Dynamics implementing a new machine into their current assembly line to address part warranty issues. Previously, a component of the cushion assembly was assembled using processes that had to be manually completed by an operator. This process caused Fisher Dynamics to consistently receive several warranties claims for bad parts month after month. Fisher is also facing issues with the current layout of this assembly work center in the forms of unnecessary operator movement, poor part presentation, waiting times, and inefficient material flow. Taking all of these factors into account Fisher Dynamics was motivated to find a solution to these problems.

2.2 Similar Projects

2.2.1 Telecommunication Company

The first piece of literature researched was a project done by a company that manufactured telecommunication parts. This company was faced with issues in their manufacturing process that promoted high cycle times and costs. The reason behind these issues was because of wasted motion and inefficient material flow [3]. The company conducted research to fully understand the manufacturing process and then implemented lean (more efficient) processes to solve the problem. Creating more ergonomic workstations, implementing material flow racks/conveyors, and re-designing a better flowing layout allowed the company to decrease the amount of time it took to assemble one product by 90%.

This piece of literature is very useful when compared to my senior design because it focuses on a work cell similar to my project. It implements engineering principles and ideas that will be helpful and need to be considered when working on my project's critical design.

2.2.2 Lean Production Assembly Stations

The second piece of literature researched discusses using principles of lean production to design assembly stations. The project focuses on key components that should be addressed when designing an assembly station. These components include continuous flow, workplace organization, parts presentation, reconfigurability, product quality, maintainability, ease of access, and ergonomics [4]. An in-depth discussion of each of these components gives me a better understanding of how I will need to focus on the specific areas pertaining to my project. It is stated in this literature that these concepts provide the framework for an efficient and competitive production environment. Relating to my Senior Design project, these will be important concepts to use when my critical design is being developed.

2.2.3 California Polytechnic State University

The third literature review is a project completed by an Industrial Engineering student at California Polytechnic State University. This project focuses on redesigning a plant floor layout in order to maximize the productivity of a company that tests and ships electrical products [5]. As a whole this project looks at an entire facility, however in order to create an efficient floor layout, work cells need to be redesigned to be efficient as well. The project focuses on different types of work cells, their importance, and how they should be designed. A large part of this

involves understanding a pattern that production processes follow so process maps were created. Knowing where products were coming and going allowed this project to successfully increase overall productivity for the company. Understanding the flow of materials is critical in the grand scheme of things, so the creation of a process map for my Senior Design project may prove to be useful.

2.3 Factors that Impact Design

Public Health, Safety, and Welfare

When re-designing the assembly line, public health, safety, and welfare factors were considered since operators will be continuously interacting with machines that pose risk of danger. Safety features were put in place to assure that Fisher Dynamics employees were safe from any potential dangers. Light curtains were implemented on the new machine to ensure that operators could not be injured by any moving parts during certain assembly processes. The light curtains communicated to the process through a programmable logic controller. The logic controller was programmed to stop the process if an operator were to break the beam of the light curtain. Another safety factor that was considered includes adequate aisleway space for operators and equipment according to OSHA Standard 29 CFR 1910.22(b). Lastly, ergonomics of material racks and equipment were considered when analyzing the system so that operator movement is limited to prevent any work injuries.

Global, Economic, and Environmental

In this assembly line, components to build finished goods are sourced from all around the world. By sourcing these components from distributors located in different countries, it is easy to see how this assembly line plays a role in global impact.

Fisher Dynamics sells parts that they produce on this assembly line to customers all across the United States. They play a key role in the automotive industry by manufacturing parts needed by General Motors. They have a substantial economic impact on things from purchasing parts from other manufacturers to selling their own finished goods to their customers.

From an environmental perspective, Fisher Dynamics does its best to decrease their environmental footprint. Throughout the design of this assembly line, many considerations were made to deal with waste that may come from it. The work cell was designed so that scrap may be minimized. Any scrap material that does come from the assembly line is taken care of accordingly by recycling or appropriate disposal.

2.4 Applicable Standards

The Occupational Safety and Health Administration (OSHA) has standards pertaining to industrial worker safety. Through literature review, there were several standards that needed to be considered when re-designing the layout of the assembly line to act in accordance with OSHA. The standards being considered over the course of this project are the following:

- OSHA Standard: 29 CFR 1910.303(g) which states for equipment operating at 600 volts, nominal or less to ground, electrical panels must have a minimum of three feet of clearance in front of the panel and a minimum clearance width of 2.5 feet or the width of the equipment, whichever is greater.
- OSHA Standard: 29 CFR 1910.176(a) which states employers are directed to ensure that all aisles, passageways, and walkways are appropriately marked.
- OSHA Standard 29 CFR 1910.22(b) which states that the recommended width of aisles is at least 3 feet wider than the largest equipment to be utilized, or a minimum of 4 feet – whichever is greater.

These OSHA guidelines as well as the requirements described below play a large role in the design and analysis of the overall layout of the work cell.

2.5 Requirements

Based on requirements set by Fisher Dynamics, as well as in accordance with OSHA guidelines, the following requirements were determined and can be seen in Table 1 below.

Table 1: Table of Requirements

The assembly line re-design shall:

Fit inside of its current layout dimensions.
Maintain all processes necessary for part assembly in the layout.
Act in accordance with Occupational Safety and Health Administration (OSHA) guidelines. <ul style="list-style-type: none">– OSHA Standard: 29 CFR 1910.303(g)– OSHA Standard: 29 CFR 1910.176(a)– OSHA Standard 29 CFR 1910.22(b)

3. Conceptual Designs

3.1 Design Concept 1: “L” Shaped Conveyor

Over the course of the semester, three design concepts for the layout of the work cell were considered. The first design concept is shown in Figure 3. This initial design concept implemented an “L” shaped conveyor to transport parts from the newly installed assembly station further downstream in the assembly process. This is one benefit of this design due to the fact that “L” shaped conveyors tend to be cheaper than curved conveyors which are discussed in a later design. This design also positioned the operators at Station #40 closer together in order to decrease the distances traveled when transporting work in process (WIP) parts, which is another pro of the design.

Unfortunately, the lack of space of the work cell makes it difficult to efficiently present parts to the operators, so a drawback of this design is the movement needed by operators to grab parts. In order to grab the appropriate parts, operators at times will need to turn about 180 degrees every time they need to grab a new part. This does not promote ergonomics or operator safety. This layout also is very crowded around Station #40 which can be an issue anytime maintenance is needed to work on a machine or may cause issues where operators are interfering with each other when moving work in process parts.

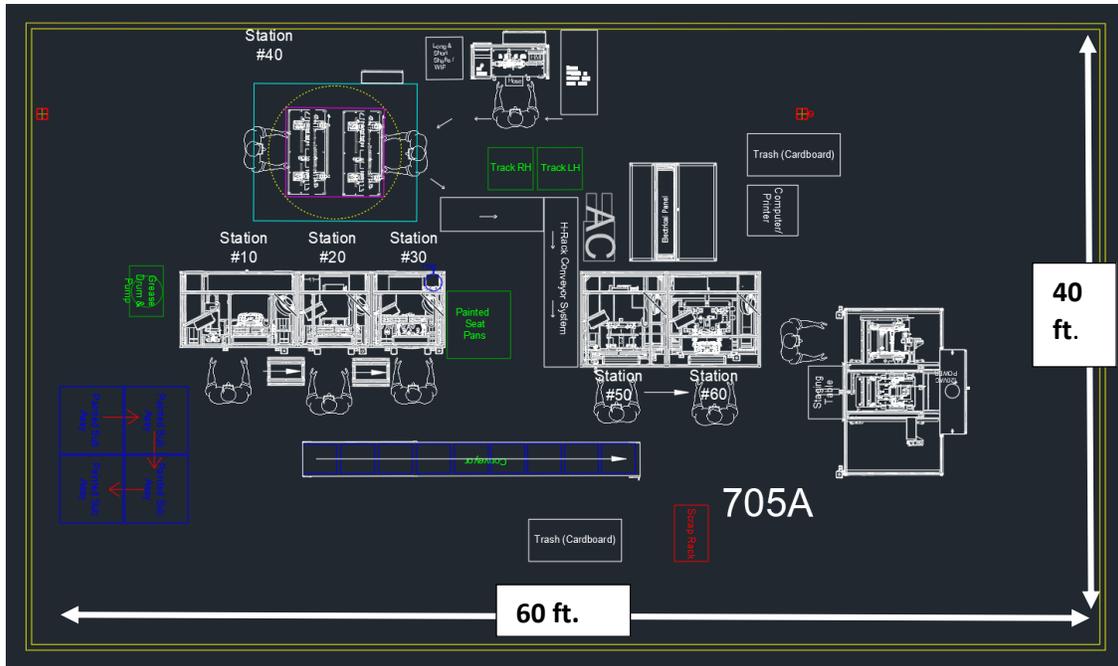


Figure 3: Layout Design Concept #1

3.2 Design Concept 2: Straight Conveyor

The second considered design concept can be seen in Figure 4. This design concept incorporates a more operator friendly part presentation where the least amount of turning and walking is needed to be done for operators to access part components. This design layout also features a single, straight conveyor to transport WIP to other operators on the assembly line. This type of conveyor is much cheaper than any style curved conveyor and also doesn't require a power source if using a gravity style conveyor. Minimal maintenance would also be an advantage of incorporating this style of conveyor in the layout.

The main drawback of this design is that the operators would need to travel a longer distance to transport parts across Station #40. The diagonal configuration of the conveyor system also limits operators from being able to move across the assembly line if needed. Maintenance would also be a cumbersome task when working on machines. Lastly, refilling parts at stations may be more difficult with paths being blocked by the conveyor.

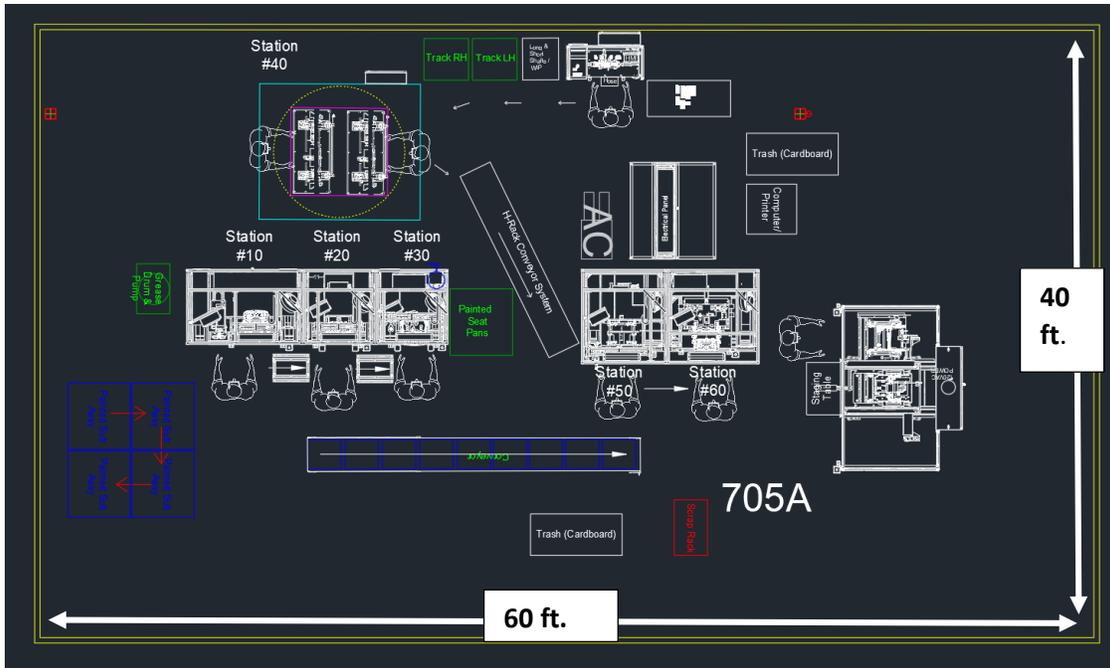


Figure 4: Layout Design Concept #2

3.3 Design Concept 3: Curved Power Conveyor

The third and final conceptual design that was considered is shown in Figure 5. This concept is similar to the previously discussed concept, but it incorporates a curved, powered conveyor in order to transport parts across the assembly line. This style conveyor system allows for more accessibility to machines inside of the work cell. Part presentation to the operators is also optimized in this design so there is increased safety and better ergonomics.

The biggest downfall of this design is the cost of implementing the curved, powered conveyor. The price of this style conveyor is nearly five times the cost of a traditional straight style conveyor. We also still face the issue that the operators are traveling further distances between Station #40 to transport WIP.

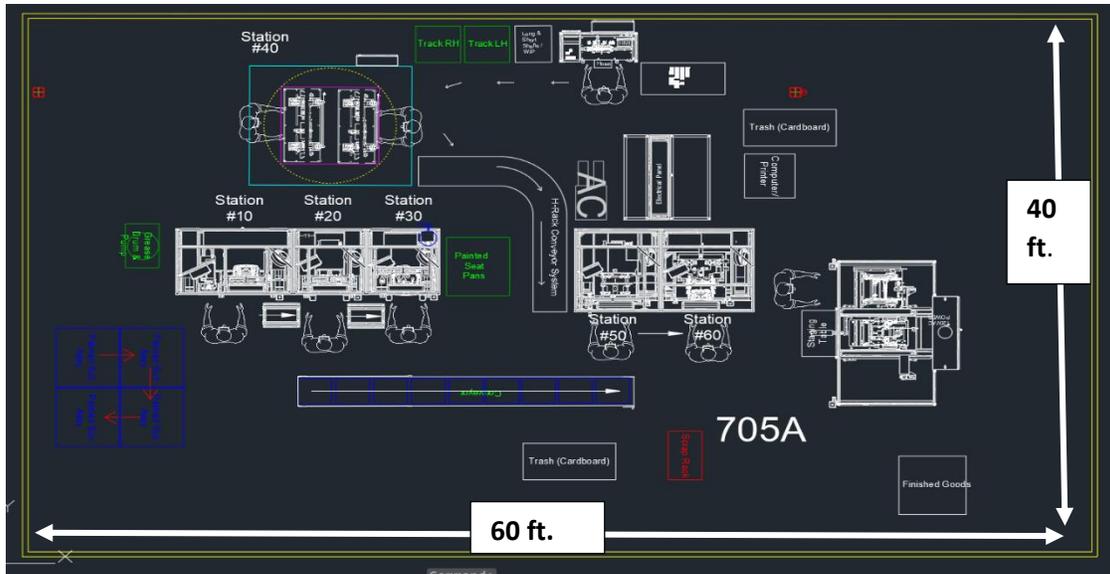


Figure 5: Layout Design Concept #3

3.4 Justification of Chosen Design

The preliminary engineering design that was chosen is layout design concept #3 shown in Figure 5. To gain a better understanding of the process flow that is occurring in this work cell, refer to the Mechanical Block Diagram in Appendix F. The engineering approach that was taken to justify this design comes from the research of lean manufacturing practices used by many manufacturing companies. The five main principles of lean manufacturing include value, value stream, flow, pull, and perfection [6]. Value defines the customer’s needs in a product, the value stream defines steps to create the product, flow is the smooth transition of products, pull defines the customers “pulling” for product as needed, and perfection defines perfecting all the previous steps. By implementing these principles into the layout design of the work cell it ensures that more steps will be value adding as opposed to wasted motion.

4. Final Design and Analysis

4.1 Final Assembly Line Layout

After presenting the initially selected design to operators, maintenance, and material handlers, suggestions were taken into consideration and the design was continuously improved upon. The flow of parts that were incoming as well as outgoing from the cell were re-evaluated, the layout of surrounding fixtures and machines re-arranged multiple times, and the design was

finally adjusted into the assembly line layout which is in place at the Fisher Dynamics facility today.

The final assembly line layout that was configured is shown in Figure 6. The red arrows on the drawing indicate the final flow of parts between each station throughout the work cell. Each station contains an operator that will perform a task on the sub-assembled part received from the previous station. At the last station the part is placed in an end-of-line function tester where the part is tested for proper function before being packed and shipped to the customers.

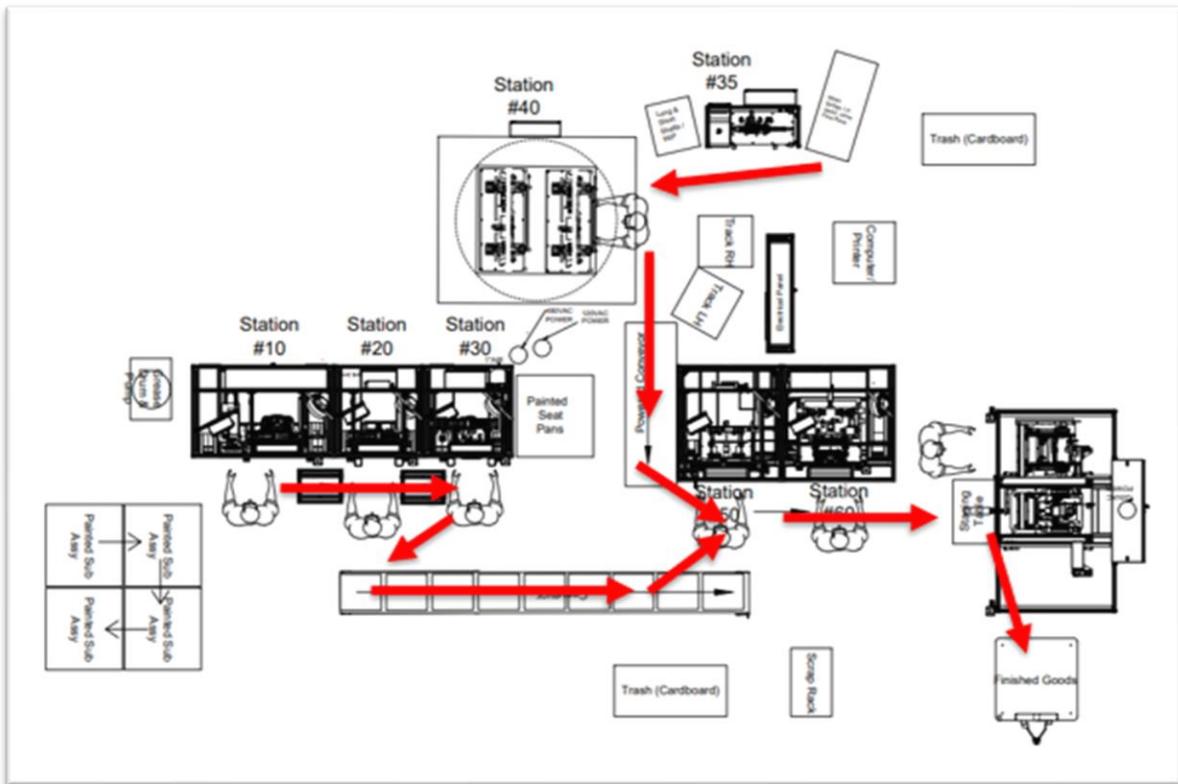


Figure 6: Final Layout Design

The configuration of part fixtures and part containers changed drastically after receiving feedback from the operators. The original idea of a powered, curved conveyor was dismissed, and a normal straight conveyor was decided on. This helped to decrease the overall cost of the project and opened more space in the work area for maintenance and part replenishment by material handlers. This layout was the most efficient and cost-effective solution after analyzing

the improvement in cycle times and production rates. Figure 7 gives an overview of the implemented layout inside the Fisher Dynamics facility.



Figure 7: Implemented Final Layout

Figure 8 gives an overview of the re-designed build area where the new machines were implemented. This layout design promoted efficient flow of parts throughout the work cell and decreased travel distances of parts between workstations. This ensured that the shortest amount of time was taken to complete parts. An analysis showed us that production rates increased, better ergonomics were promoted for operators, and the quality of parts improved for the customers.



Figure 8: Re-Designed Build Area

4.2 Design Improvements

4.2.1 Material Flow Racks

Along with the physical layout of the work cell, material flow racks were designed to encompass all necessary components needed when operators are building parts on the assembly line. Fisher Dynamics uses an outside company to build their flow racks, so these designs will only be used for dimensional references. A bill of materials (BOM) for parts being assembled on this line was studied to understand all necessary components that needed to be encompassed on the material flow racks. Then, using standard production rates and standard packing quantities of parts, calculations were done to determine the number of boxes needed over an 8-hour shift. The table of results from these calculations can be seen in Appendix G. Research on ergonomics for operators was done in order to justify the flow rack design. A design of a flow rack for the Station #40 WIP is shown in Figure 9 below.

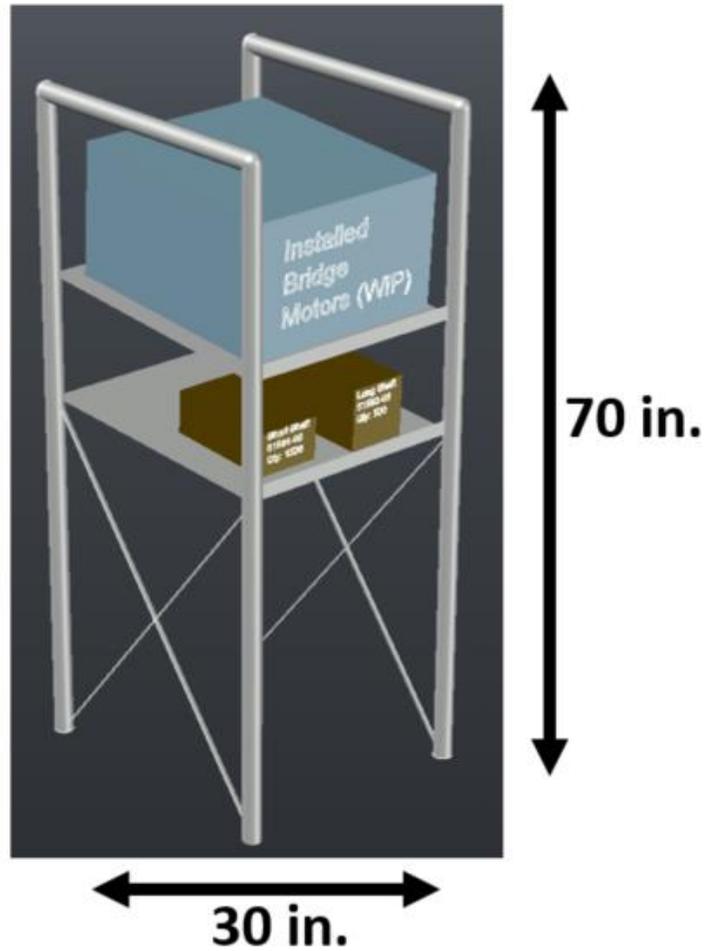


Figure 9: Flow Rack Design

An overview of how the flow racks will be set up can be seen in Figure 10 below. The setup of these flow racks in the work cell intends to decrease the amount of operator movement needed to assemble parts. By decreasing operator movement, operators are engaging in less non-value-added tasks and decreasing the cycle time of building sub-assembly parts.

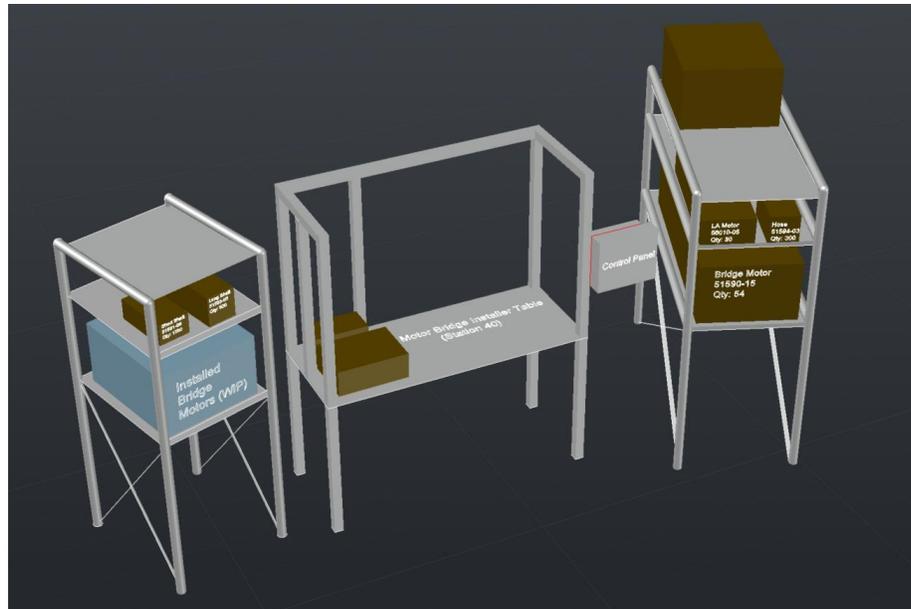


Figure 10: Flow Racks Layout

4.2.2 Part Transfer Racks

In addition to material flow racks, spinning part transfer racks were also designed to increase the part flow through the assembly line. The spinning rack can be seen in Figure 11 below. Inefficient part flow was seen between stations on the front side of the assembly line and often stations further down the line would be waiting on parts. The previous racks used were referred to as “slide racks” and only allowed space for a few sub-assembled parts. The newly implemented spinning racks allowed for placement of up to eight sub-assembled parts. Allowing more parts to be placed on these racks meant that a buffer was created so these stations further down the line would not be left waiting. This helped to balance the overall part flow of the build process.

Another added benefit of the spinning racks was that they were designed with operators in mind. Their design decreased the effort needed by operators to move parts between stations. The rack can spin 360 degrees, so operators can easily gather the next part when they are ready to begin building. Parts are presented to the operator such that the least amount of effort is needed to place or gather parts. Overall, this design was safer for operators and helped improve overall part flow through the assembly cell.



Figure 11: Spinning Part Transfer Rack

4.2.3 Part Transfer Conveyor

As previously mentioned, a curved, powered conveyor was initially considered for implementation into the work cell. However, a straight, powered conveyor was selected instead. The conveyor inside the assembly cell can be seen in Figure 12. One of the largest problems faced in this project dealt with the transport of parts from the back side of the line to the front side. Often, operators were required to transport the parts by hand across the work cell if too few operators were present. By implementing this conveyor, it not only eliminated the need to move parts by hand, but it also created a buffer of parts for the next station in the assembly process. Much like the spinning racks previously mentioned, this helped to increase overall part flow and eliminated stations further down the line running out of parts to build with.



Figure 12: Powered Part Transfer Conveyor

4.2.4 Machine Light Curtains

The next design idea involved adding safety light curtains to some of the present machines to decrease cycle times and increase operator safety. Using programmable logic controllers, light curtains were put in place to allow machines to run while operators are not present. This allows operators to perform other tasks on the line while the machine works so no time is wasted. It also adds another level of safety to ensure operators cannot get hurt by machines. Light curtains operate using infrared beams and when the beam is broken the machine will stop running. The light curtain that was installed on the machine can be seen in Figure 13.

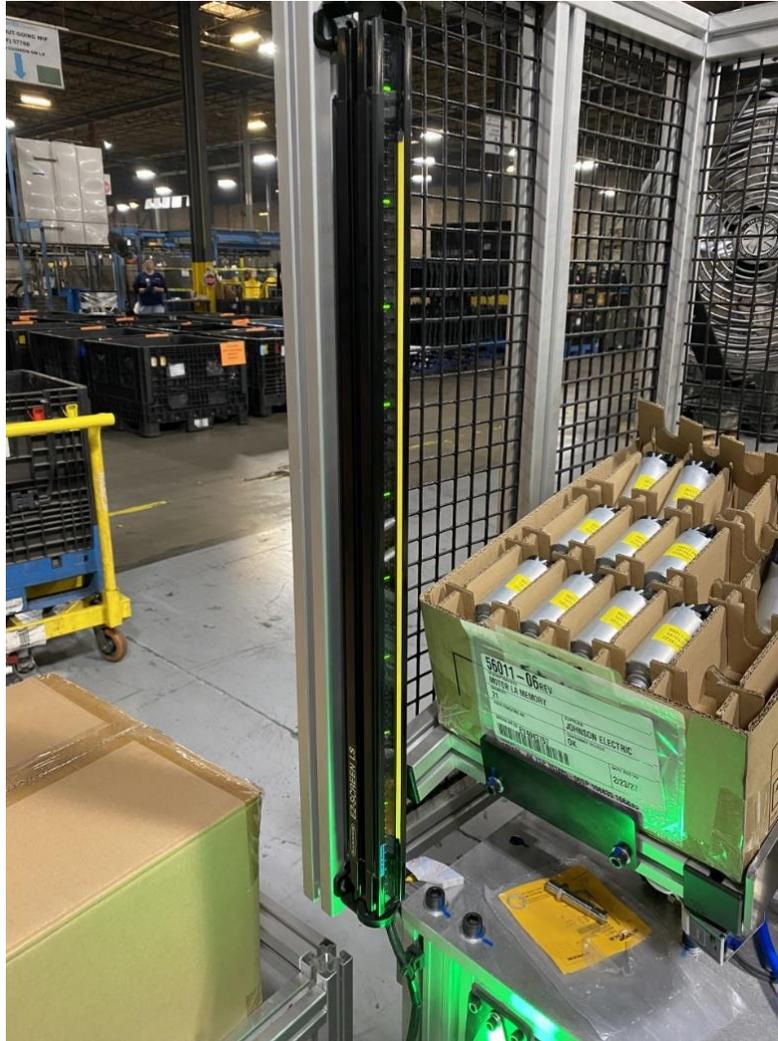


Figure 13: Machine with Light Curtain Installed

4.2.5 Other Machine Design Improvements

Further improvements were made to the machines located inside of the work cell. The two improvements to be discussed were specifically made based on concerns from the quality engineers as well as issues that were experienced by operators while building parts. A set of indicator lights were placed inside of one of the machines in the viewing area of the operators which can be seen in Figure 14. Before this change was made, operators experienced issues with the machine being unable to cycle since parts were not in the correct position. Using a programmable logic controller and proximity sensors, these lights were programmed to light up green when parts were placed correctly in their fixture.

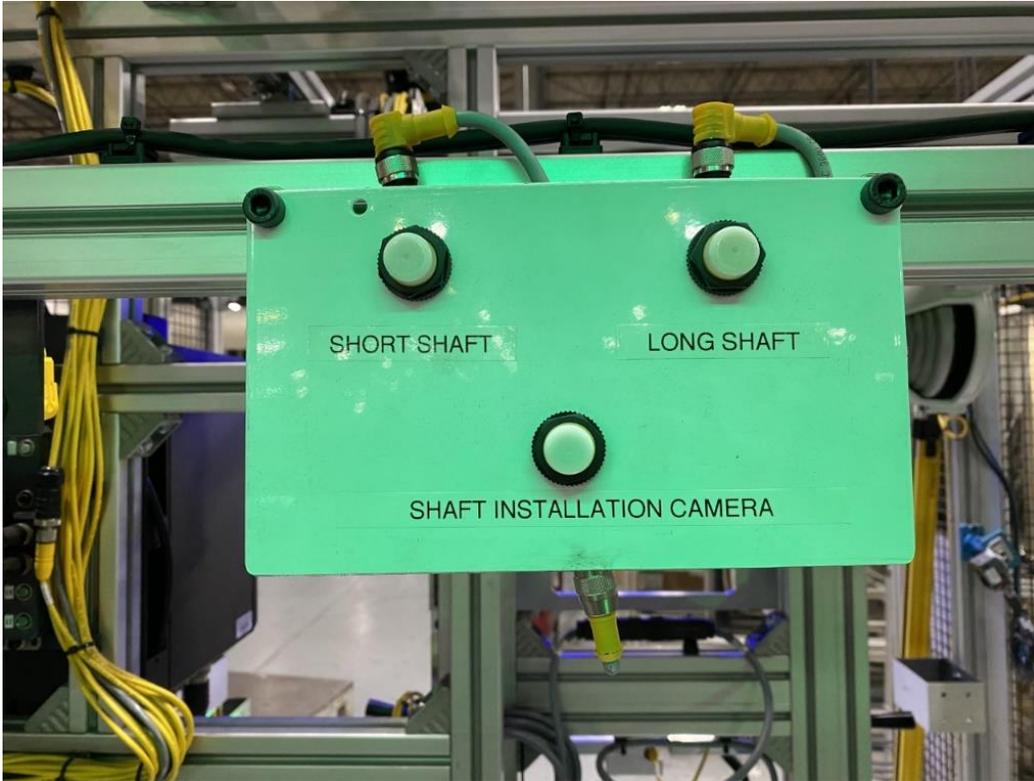


Figure 14: Operator Indicator Lights

Periodically, serial numbers will be scanned on part components for traceability purposes. One station in the work cell requires the serial number to be scanned on one of the seat's driver motors. To aid in quickly placing the motor for scanning, a fixture was designed and placed so that the camera used for scanning could quickly complete this task. Figure 15 shows the motor scanning fixture that was designed and implemented into the machine. Operators originally struggled with orienting the motor correctly to scan the barcode on the part. This fixture helped operators orient parts quickly which led to a decrease in cycle times for this part building process.

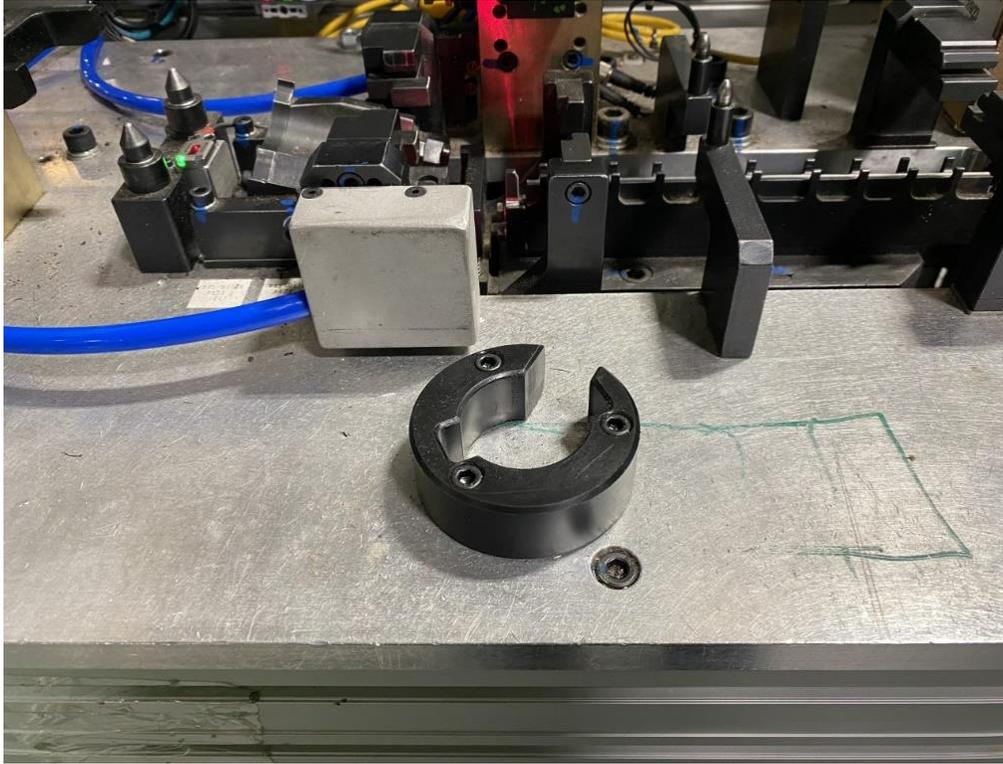


Figure 15: Motor Scanning Fixture

5. Disposal Plan

When the machines and components of this assembly line reach the end of their useful life, Fisher Dynamics will look to either re-use them or properly dispose of them. The disposal plan for the assembly line's major components is shown in Table 2.

Table 2: Disposal Plan for Work Cell

Component	If in good condition	If unusable	Recycle as
Assembly Machines	Sell for scrap	Sell for scrap	N/A
Human Machine Interfaces (HMI)	Re-use within facility or resell	Sell for scrap or recycle	Electronics
Control Panels (Power Supplies, PLCs, etc.)	Re-use within facility or resell	Sell for scrap or recycle	Electronics
Computers, Sensors, Light Curtains	Re-use within facility or resell	Sell for scrap or recycle	Electronics
Conveyors	Re-use within facility or resell	Sell for scrap or recycle	Metal
Part Racks	Re-use within facility	Sell for scrap	N/A
Part Containers	Re-use within facility	Recycle	Plastic

6. Budget

A budget was developed for the project which included all necessary components that were implemented into this work cell along with any software used or labor costs associated. No spending limit was set for this project. Table 3 shows the budget which is found in Appendix B. In the table, an approximate price was set for each item along with its quantity (if applicable) and description of the item. The largest cost associated with this project was the new machine tooling designed to address the warranty issues. Note that the machine tooling cost includes the engineering design of the machines, the fabrication, and installation into the work cell.

7. Economic Analysis

When considering implementing a project of this size, it is always a necessity to conduct an economic analysis to determine if it is feasible for the company. The decision to design and implement this new machine was made at a corporate level, so information based on return on investment or cost savings was unavailable to be provided for this project. Fisher Dynamics typically uses a two year payback period for projects of this size.

Since this assembly line is one of the most run lines in the plant, it was apparent that the warranty issues being faced had a substantial impact on relationships with the customers. Although there was a large initial investment made for this machine design change, Fisher does plan to recover the costs associated with this project in the future from increased sales to customers and decreased warranty claims.

8. Warranty Analysis

The graph for the cushion frame warranty analysis can be seen in Figure 16. This graph depicts the total number of warranty claims by the month that a part was produced on the assembly line being re-designed for this project. Before the new design was implemented, the total number of warranty claims was 83 since January of 2020. This amount of warranty claims resulted in a total loss of around \$54,000. Not only does this have a significant cost impact on the company, but it also plays an important role in maintaining good relationships with the company's customers.

Of all the assembly processes that take place at Fisher Dynamics, the parts produced on this assembly line account for about 30% of the total. This is a considerably large amount of the company's revenue, especially since these parts are one of the most profitable being sold. If the company were to continue having on-going warranty claim issues, then this may cause buyer issues and eventually loss of business. It is crucial that the company addressed these warranty issues in order to continuing selling parts.

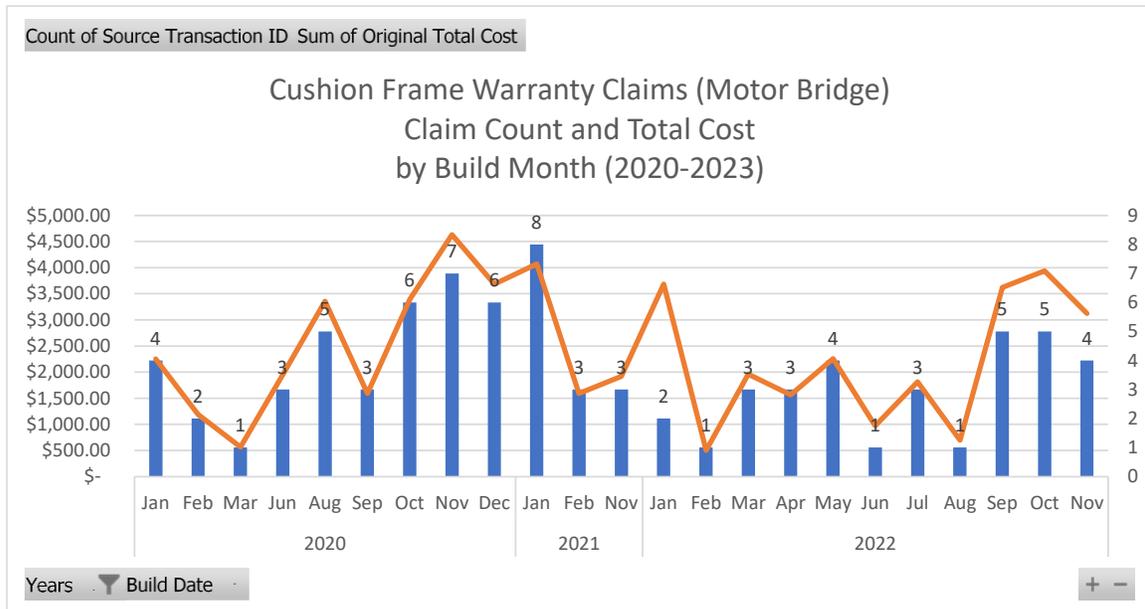


Figure 16: Cushion Frame Warranty Analysis

Figure 17 is a graph that shows the total number of warranty claims by the years the parts were produced. This graph shows that as of January 2023, no warranty claims have been filed on parts that were produced on the re-designed assembly line. Since the implementation of this new machine design and layout was made in late November of 2022, the evidence is only able to be supported by a few months data. However, the opportunity to receive warranty claims is still very present. Parts that are produced on this assembly line have the potential to be installed in a vehicle as early as a week time period. Seeing as the warranty claims have gone from several per month previously to zero over the past 5 months shows substantial improvement.

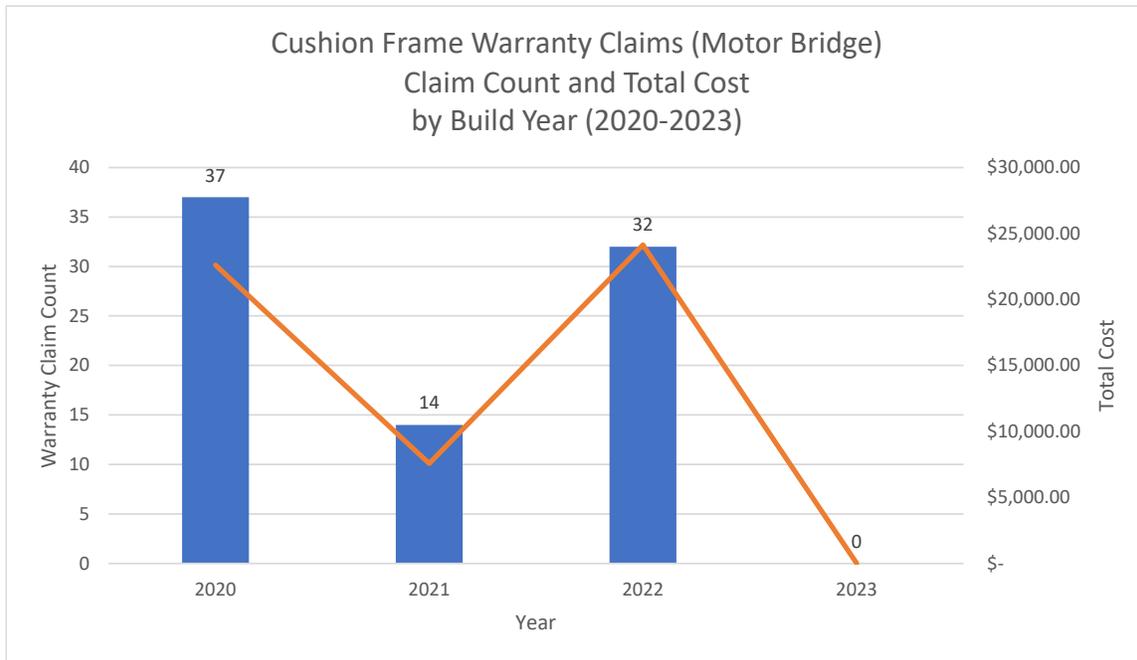


Figure 17: Cushion Frame Warranty Analysis Year-to-Date

9. Results

In Figure 18, the graph shows a comparison of the average cycle times that were recorded between the old machine design versus the new machine design implemented into the work cell. To gather data that was an accurate representation of how cycle times could change across a shift, the cycle times were recorded over a period of weeks at different time intervals throughout the day. The old design is represented by the orange line on the graph and typically demonstrated higher cycle times that were less consistent. The new design represented by the blue line on the graph was more consistent and produced lower cycle times on average.

After analyzing the data gathered, there is evidence that indicates cycle times were decreased using the new machine design and final layout compared to the previous design. When we compare the averages of the cycle times from each machine design, we see that the new design has cycle time which is nearly two seconds faster than before. Taking into consideration that on average 60 parts are produced an hour, two seconds can add up quickly over time when the plant is running for 24 hours a day, five days a week.

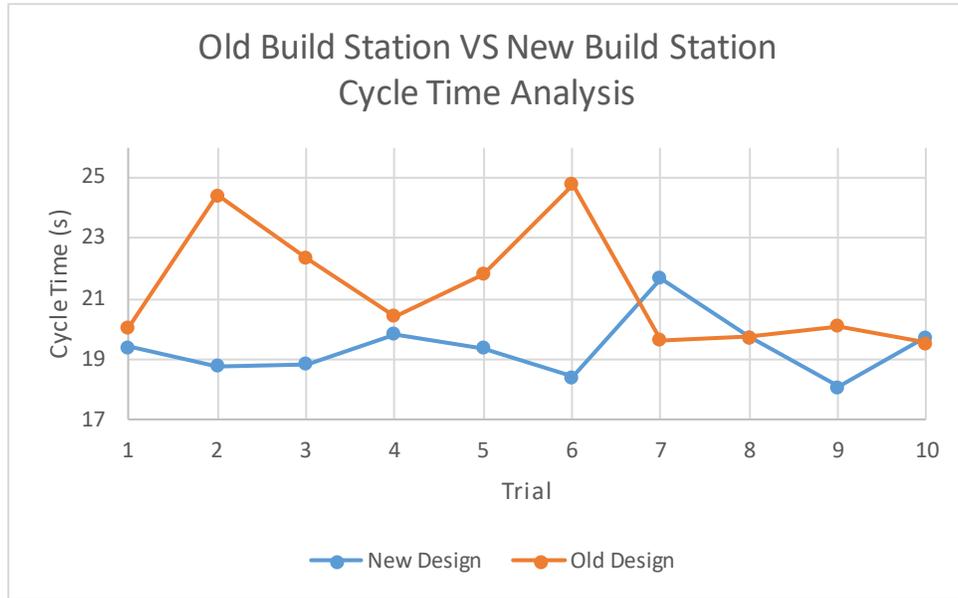


Figure 18: Cycle Time Analysis

Figure 19 shows a comparison of the recorded production numbers for the assembly line from the months of the previous year to the months when the new design was implemented. The blue line on this graph represents the production numbers before the design changes and the orange line represents the numbers after the design change. When we look at the previous year's production numbers and compare them when the new layout and design was implemented, we can clearly see that the rate of production has increased.

Analyzing the data for the five months the design has been in place shows that production increased by 36% compared to the same five months of the previous year. Overall, we can confidently say that the final layout along with the new machine design were able to create a safer work environment and more efficient layout for use by operators to produce high quality parts.

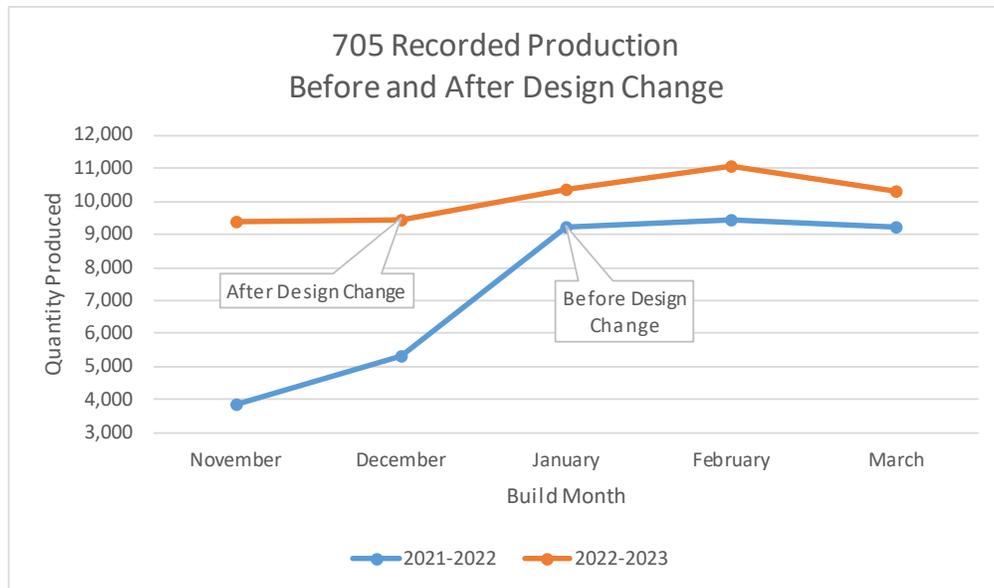


Figure 19: Assembly Line Recorded Production

10. Future Work

Fisher Dynamics has several more assembly lines in their facility that have the same machines and part building processes that could utilize the same machine design, design improvements, and layout that were developed within this project. Seeing the success of this project in decreased cycle times, increased production rates, and lower warranty claims, there is great motivation for these designs to be replicated across the facility.

Since the design of this work cell is still relatively new, the processes will be monitored, and information will be continually gathered so that continuous improvement can be made within the cell. Other design improvements have been suggested that were not able to be discussed within this project. One design improvement to be made later includes moving machines closer together by relocating HMIs inside of several machines. The current design has HMIs located outside of machines which requires machines to be spaced further apart than desired. With HMIs located inside of machines, operator movement can be decreased which ideally will result in even further decreased cycle times.

The addition of more work-in-process racks was discussed in order to increase part availability to operators inside of the work cell. The parts would need to be evaluated and the

racks would need to be designed specifically for these parts for optimal part presentation. Lastly, small components used by operators such as nuts and bolts will be positioned in containers closer to operators for ease of access inside the machines. Some of these smaller components are currently located outside of machines, so getting these components closer to operators will help speed up the part building process.

11. Lessons Learned

11.1 Engineering Design

Over the course of this project, there were many important aspects of engineering design that were learned. Several design options were first considered to solve the problems that were being faced. By researching projects that had been completed by others previously, this helped to lay the foundation for where to start when trying to solve the problem at the Fisher Dynamics facility. The lesson learned here is that it is important to do preliminary research prior to starting a project in order to gain a greater understanding of how to approach the problem needing to be solved.

Another important aspect of engineering design learned was that the engineering design process is an iterative process. When looking at this project, there were several iterations made to the layout of the work cell as well as to equipment that was being used inside of it. As the project progressed, new information was gathered from research, trial and error, and input from the team at Fisher Dynamics. Changes were continually made to the ideas and designs for the work cell until it was developed into its final iteration.

11.2 Teamwork

Teamwork played a tremendous role in the development of this project. The experience of teamwork in this project involved working with multiple departments at Fisher Dynamics in order to understand all the different aspects that went into the part building process. Communication was done mainly in person, but also included emails, texts, and video calls. Any problems that I experienced during this project required me to report directly the manager of the department in which the problem dealt with.

As this was a solo project, I did not have any team members from USI. However, there were many non-student team members from Fisher Dynamics that served to help with this project. My

first point of contact was my boss Mark Payne who is the Maintenance and Engineering Manager. Mark familiarized me with the machines and process flow that was taking place inside the work cell. Adam Riggs is the Production Manager and helped me understand production requirements as well as helped me gather production data for this project. Luis Tovar is the Quality Manager and assisted me with the quality side of this project, specifically the warranty analysis portion. Aida Rodriguez is the Materials Manager and helped me understand different aspects of the supply chain needed for the project along with material handling methods taking place in the facility. Lastly, Jessica Heathman is the Plant Manager and helped me with gathering data needed for aspects of this project. All these individuals served as team members and played important roles in the successful outcome of this project.

12. Conclusion

It is an important part of manufacturing for the processes that are taking place within a facility to operate smoothly and efficiently. It is also important in manufacturing to ensure that the parts produced are of good quality and to ensure customers are happy with the products they are receiving. At Fisher Dynamics, the assembly line being analyzed by this project faces issues with both aspects. The assembly line faces issues with part warranty claims, high cycle times, and low production rates.

The goal of this project was to re-design the layout of a work cell in order to improve part quality, increase the efficiency of the line, and improve the flow of parts. A literature review was conducted to find solutions to problems like the ones being faced at Fisher Dynamics. This research helped to allow the development of three preliminary designs for the work cell. Of the three designs considered, one was selected and developed into the final design that is currently in place at the facility.

Multiple analyses were conducted to evaluate the performance of the work cell. The results of these analyses show that this project accomplished what it intended to. Even though the project successfully met its requirements, there is always room for improvement. At Fisher Dynamics we will continue to monitor this work cell and improve its processes over time. All in all, the project was successful in optimizing the layout and design of a work cell at the Fisher Dynamics Evansville facility.

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Appendices

Appendix A: System Hierarchy

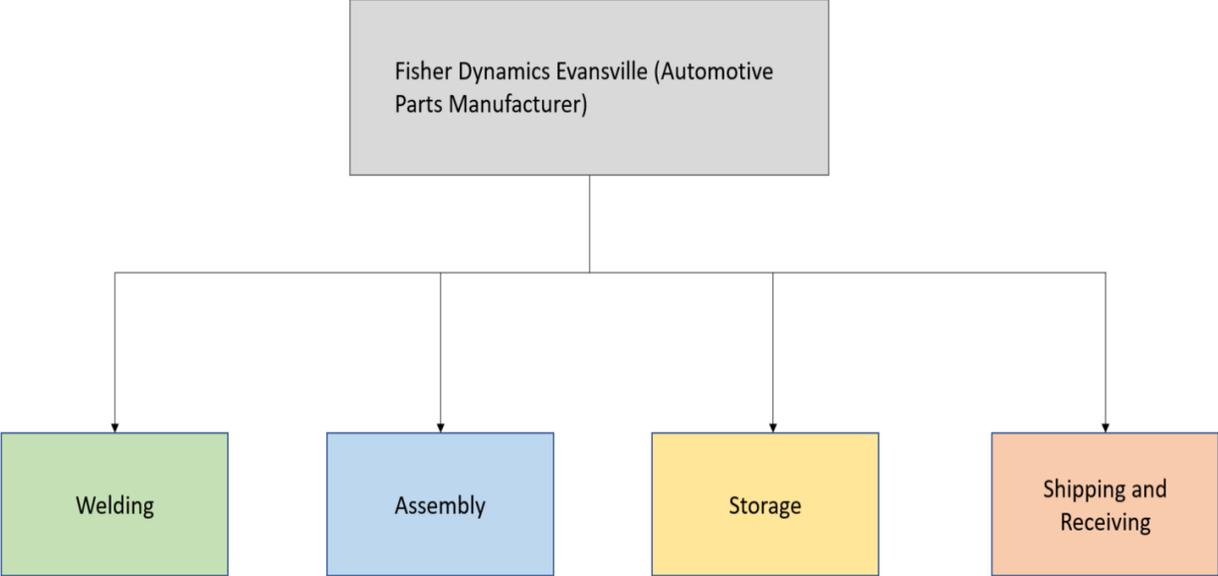


Figure 20: Overall System Hierarchy

A.1 Assembly

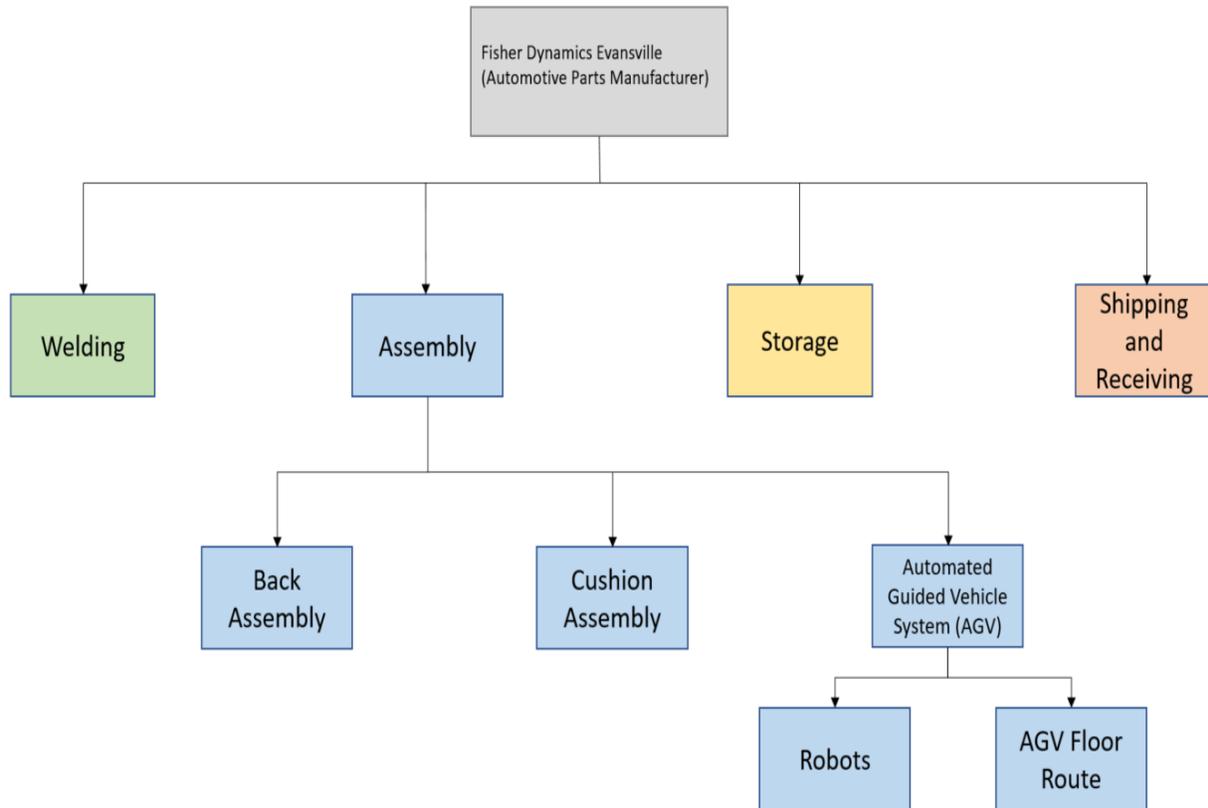


Figure 21: Assembly System Hierarchy

Appendix B: Budget

Table 3: Budget for Assembly Line Re-design

Budget for Assembly Line Re-design			
Item #	Quantity	Description	Price
S-23890	3	Vinyl Safety/Marking Tape	\$34.50
N/A	1	10' Powered Parts Conveyor	\$7,790.00
SG4-30-30-OO-E	2	Safety Light Curtain	\$1,427.00
N/A	1	Gravity Flow Racking (Custom) 24" x 60"	\$500.00
N/A	1	Gravity Flow Racking (Custom) 24" x 40"	\$400.00
AutoDesk 2023	1	Autodesk AutoCAD Software	\$1,586.00
N/A	N/A	Machine Tooling	\$500,000
Total Cost:			\$511,737.50

Appendix D: Concept of Operations

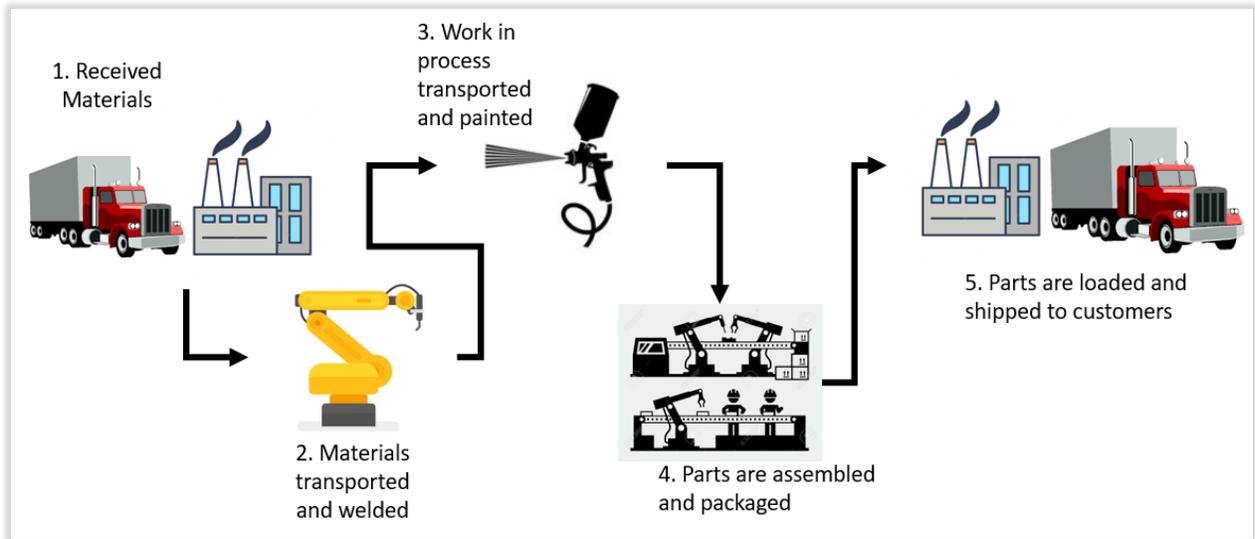


Figure 22: Concept of Operations

Appendix E: Failure Mode and Effects Analysis

Table 4: FMEA Analysis

Item	Failure Modes	Cause of Failure	Possible Effects	Probability	Possible action to reduce failure rate or effects
Layout Design	Design decreases production rate	Inadequate planning, Failure to account for all machines, Incorrect calculations, Inaccurate simulations, miscommunications	Overall plant efficiency decreases (production rates decrease, longer travel times, etc.)	Medium	Close analysis on all processes in the plant. Create spreadsheets to account for machines and production rates. Communicate ideas with management. Have a good understanding of material flow.
Flow of Materials	Machine goes down	Preventive maintenance not done on machines, operator incorrectly uses a machine, machine overheats	Material flow is inefficient (operators have to wait on parts, higher down time)	Low	Perform preventive maintenance, train operators to properly use machines, do not overrun machines.
Work Cell Requirements	Required work cell components are not all accounted for	Analysis of work cell was not carefully completed. Failure to account for all components and required material handling methods. Operator needs were not taken into consideration.	Cell does not operate efficiently and parts can not be made.	Medium	Carefully analyze work cell processes. Discuss processes with management and operators. Create checklists to account for all necessary work cell components.
Proposed Layout Size	Proposed layout design will not fit in the designated space	Measurements were taken incorrectly	All machines and necessary components will be unable to fit in the work cell	Medium	Carefully take measurements, ensure measuring instruments are in good working condition, double check measurements with another team member.
Operator Ergonomics	Material handling and machine designs are inefficient for operators	Various operator characteristics not taken into account (height, size, lifting capabilities, etc.)	Operators are unable to use work cell machines or material handling components efficiently	High	Study operator work habits and characteristics, talk with operators, conduct background research on operator ergonomics for effective work cell design, discuss ideas with management before design.

Appendix F: Mechanical Block Diagram

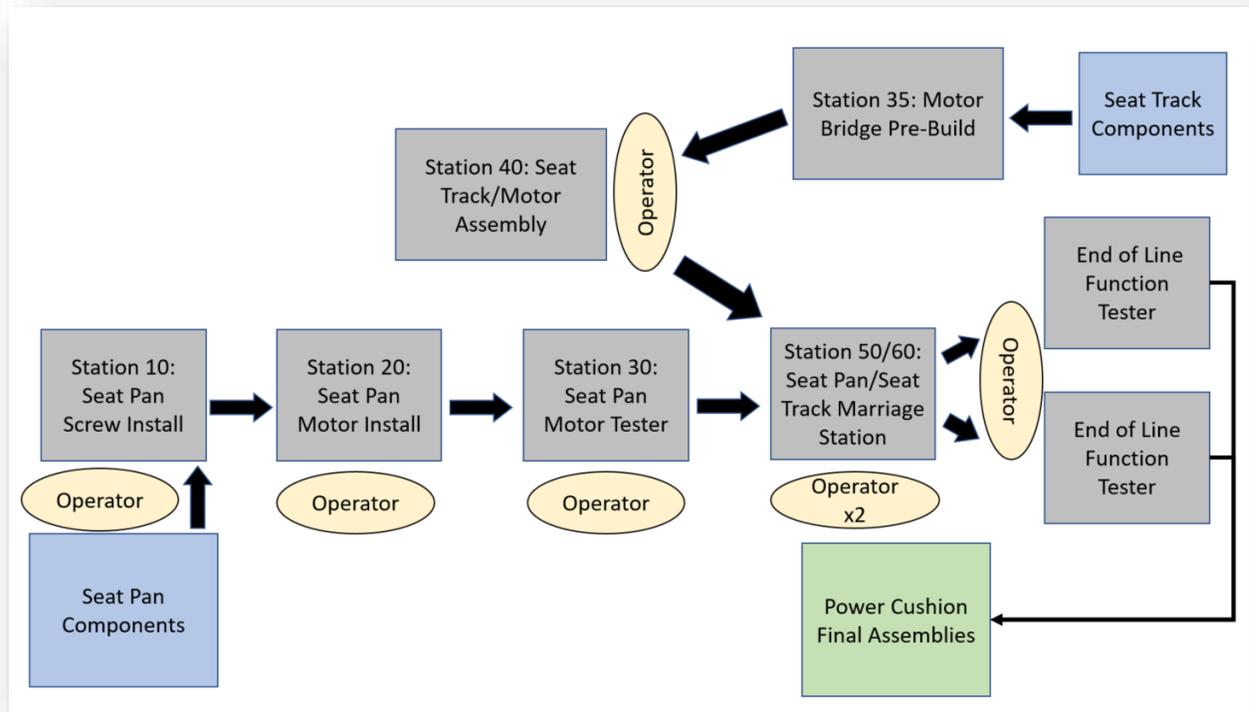


Figure 23: Mechanical Block Diagram of Assembly Line

Appendix G: Table of Flow Rack Components

Table 5: Material Flow Rack Component Characteristics

705 Dial Table for Motor Bridge

Modular Flow Racks

Components Needed:		Length	Width	Height	Qty./Box	Boxes needed per 8hr Shift
Short Shaft	51591-06	12.25"	6.75"	4.5"	1500	0.267
Long Shaft	51593-05	14.5"	6.25"	6.5"	500	0.8
LH Track Assembly	130515-03	32"	30"	-----	60	6.666666667
RH Track Assembly	130516-03	32"	30"	-----	60	6.666666667
Motor Bridge	51590-15	25.5"	22"	14"	54	7.407407407
Hose	51594-03	12.25"	6.5"	6.5"	300	1.333333333
Motor LA	56010-05	15.75"	11.5"	6"	30	13.33333333

Standard Production Rate:	50
Parts Required Per 8hr Shift:	400

Appendix H: ABET Outcome 2, Design Factor Considerations

ABET Outcome 2 states *"An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health safety, and welfare, as well as global, cultural, social, environmental, and economic factors."*

Table 6: Design Factors Considered

Design Factor	Page number, or reason not applicable
Public health safety, and welfare	Section 2.3, pg. 6
Global	Section 2.3, pg. 6
Cultural	N/A due to the assembly line having no cultural impacts.
Social	N/A due to the assembly line having no social impacts.
Environmental	Section 2.3, pg. 6
Economic	Section 2.3, pg. 6
Ethical & Professional	N/A due to the assembly line having no ethical impact.
Reference for Standards	Section 2.4, pg. 7