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Applying Lean Manufacturing Principles at VIP Cinema: Standardizing Hardware Assembly Workstations

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Applying Lean Manufacturing Principles at VIP Cinema Seating:

Standardizing Hardware Assembly Workstations

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Dedication

This work is dedicated to the memory of Reverend Earl Black and Ronald Koch. I would not be who I am today were it not for these two incredible men. My father's many lectures on hard work, grit, and determination were not lost on me, and those lessons made this project and my impending graduation possible. He was there for my very first visit to Ole Miss and the CME and told me then that the CME would be an incredible opportunity for a student like myself. He was absolutely correct.

Abstract

This paper will explore the benefits of standardization and consistency in a manufacturing setting by demonstrating the value of improved tooling and organization. “Lean Manufacturing” is the broad term used to describe key principles that can be applied to most businesses to reduce waste and increase efficiency. This ideology’s theme is to maximize customer value while minimizing waste. The purpose of its adoption is to transform managers and operators into experts of identifying the deficiencies in many manufacturing and assembly processes and implementing changes that can lead to enormous improvements in takt time, production output, and ultimately, profitability. At VIP Cinema Seating in New Albany, MS, these lean manufacturing principles are set to be implemented without disturbing current work or output. In this paper I will focus on how the standardization of a hardware assembly station can impact the output, efficiency, and operator well-being at VIP Cinema Plant #6. Our project had a narrow focus on redesigning the hardware assembly process, so that it can be used as an example of the benefits of lean manufacturing principles which shall be revered throughout the VIP campus in the near future.

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Introduction

This project to design and build a standardized workstation spanned over two semesters and about 9 months. We worked very hard and were excited to deliver a great hardware assembly station prototype to the operators and managers at VIP Cinema. Unfortunately, this project was upended during the second semester before we were able to begin building our second prototype, due to the threat of COVID-19. Worst of all, VIP permanently shut down on March 30th, after the demand for their products dried up due to the pandemic shutting down theaters across the globe. In light of these developments, the focus of this paper has shifted to a broader scope and theoretical gains that VIP was not able to realize because of these tragic events. This paper is written chronologically and follows the real time process and thinking of our team. In the first half of the paper, written before the spread of this novel coronavirus and ignorant of the consequences, I refer to the future of VIP with optimism. This section is largely devoted to the problem-solving procedure and construction of our first prototype. Beginning on page 18 with the Recent Development heading, the paper changes in tone and acknowledges the closing of our subject company, VIP Cinema Seating. The reader should note this strategy and be aware of when the perspective of the paper changes.

Background on VIP Cinema Seating

VIP Cinema Seating is the leader in the luxury cinema seating industry. Founded in 2008 in humble New Albany, MS, they have shaken up the cinema seating industry by proving that theaters could increase revenue by installing fewer, more luxurious and feature-laden seating rather than traditional cinema seating. This trend setting company sold over 500,000 units in their first 10 years, and recently opened their first international offices to coordinate sales across the globe. VIP's seats are made entirely in Mississippi with six different assembly plants in New Albany that house operations ranging from cutting and sewing vinyl to hardware assembly and finishing work. The wood structures of the seats are built in Pontotoc, MS.

If you have ever been to a movie theater such as AMC, Cinemark, or MALCO and found yourself in a vinyl, power-reclining chair, there's a good chance that seat came from VIP Cinema Seating as they have captured more than 70% of the domestic market [1]. That chair may have even included features such as a seat-warmer, power-tilt and power lumbar, USB outlets, and a swing-away table for your snacks. These are types of luxurious upgrades offered by VIP Cinema Seating, and they continue to innovate to meet customer demands. They are now offering modular, high-backed, white vinyl models that were designed for Saudi Arabian theaters where consumers prefer premium experiences and a high level of privacy.

VIP Cinema Seating has done a great job disrupting a market that had largely remained unchanged for decades, and they continue to do so. This dynamic company is the embodiment of entrepreneurial spirit and their workforce is proud of the top-notch products they produce. Maintaining their position as a market leader will depend upon their ability to continue to meet customer demands regarding both quantity and quality. Because a large part of their manufacturing is performed manually, their efficiency is dependent upon the tools and

methodologies in place that dictate processes and utilize workers' time and movements. When those tools and methodologies are not optimized, it leads to waste.

Problem Description

The rapid growth VIP Cinema Seating has experienced caused some priorities to be ignored in order to keep up with demand. One of the most glaring issues is the lack of application of lean manufacturing techniques. The results of this are assembly plants that waste space, effort, time, and materials. Their workflow is not aligned, their processes are inconsistent, and their quality control is outside of lean manufacturing tolerances. These issues are not simply because of laziness or mismanagement, but rather the symptoms of a flourishing manufacturer that has grown faster than its engineering and quality departments. To begin the process of reigning in VIP's production, we are tasked with redesigning a hardware assembly station at which operators build the frames of reclining seats. If we can succeed in creating workstations that are favorable to the operators and the process, VIP will be positioned to continue introducing lean principles by standardizing the process that is performed at these stations.

When first arriving at VIP, it was overwhelming to try to find one problem that we could focus on for the duration of this project because of all the waste that is immediately apparent to a student trained in lean manufacturing. After seeing the jigs used at the hardware assemblers' workstations, we knew this subassembly process offered a great opportunity to improve upon their current tooling. This precise focus would keep us from tackling too large of an issue, while also not limiting their ability to work. There are two types of jigs currently used at these workstations, and different operators prefer different contraptions. Two of the operators we observed (CJ and Ray) prefer a table-top jig with a circular rotating platform that the base of a

recliner sits on while the rest of the hardware is attached to it. Another operator we talked to (Bubba) prefers a small metal framed stand that allows him to easily move in and around the hardware. Bubba's jig also rotated and had two flat metal bars that acted as a platform for the bases and could be interchanged to fit the different sizes and styles as needed. Both types of jigs offered some material storage but the table-tops were especially limited in this capacity.

While observing these three operators, it was obvious that they each had their own procedure and sequence of operations. Individual operators may even vary in their own process sometimes. This means that the process cannot be taught to others or replicated because there is no standard or "right" way of completing the task. These types of inconsistencies are at odds with the principles of lean manufacturing, teachings of Taiichi Ohno, and good manufacturing procedures. In order to be able to standardize the process, however, we needed to first standardize the equipment the operators were working with.

Problem Solving Process

Identifying the Advantages and Disadvantages of Current Models

As briefly mentioned above, VIP Cinema operators currently use two different types of hardware assembly jigs, one table-top model that has a rotating platform for the chassis to rest on, and one metal frame with a rotating head that includes a hardware platform and material storage (Photos 1 & 2). The biggest advantages to the table are its stability and versatility (it can be used to make all the models VIP currently produces). However, the table-top has very limited storage, with only a few holes drilled that allow for cups of bolts and nuts to be placed in them. Most operators we saw simply laid other materials they needed directly on the table, without much organization or separation of the material (Photo 1). CJ mentioned that he preferred his

nuts and bolts to be separate from his jig, storing them on a workstation table behind him, but this forces him to turn around multiple times during the assembly process. Another downside to the table model was how much space it physically takes up (48” x 42”). This is a waste of space and forces operators to walk farther to obtain the materials stored on the edge of their workspace, embodying one of the seven deadly wastes, motion. The table model also only allows for operators to access the chassis from above. One operator stated that he preferred “working from the top, especially when installing motors” – motors that give the seats their ability to power-recline. While this is a preference for this particular operator, and presumably the others that use this model, it would impede all of the operators who use the metal frame and like to be able to reach up and under parts of the chassis when installing motors and other internal hardware.

The most cited disadvantage for the metal frame jig was its instability. The base of this jig is one-inch square tubing welded in an X pattern. Metal strapping had been welded from the central column of the jig to these base tubes in an effort to diminish the wobbliness experienced, but it was only somewhat successful. The jig offers lots of material storage that is fashioned from sectioned aluminum. This allows for many of the small nuts, bolts, pins, and keys to be held in a compact, accessible space. Many operators also kept some of their tools such as hammers and screwdrivers in this space. The easy rotation of the head of the frame allows operators to reorient the chassis many times during assembly. Its small footprint left lots of room for material storage and operator movement in their workstation, especially for the larger-framed operators.

Photo 1: Table-top model with material

Photo 2: Metal Framed Jig, top view

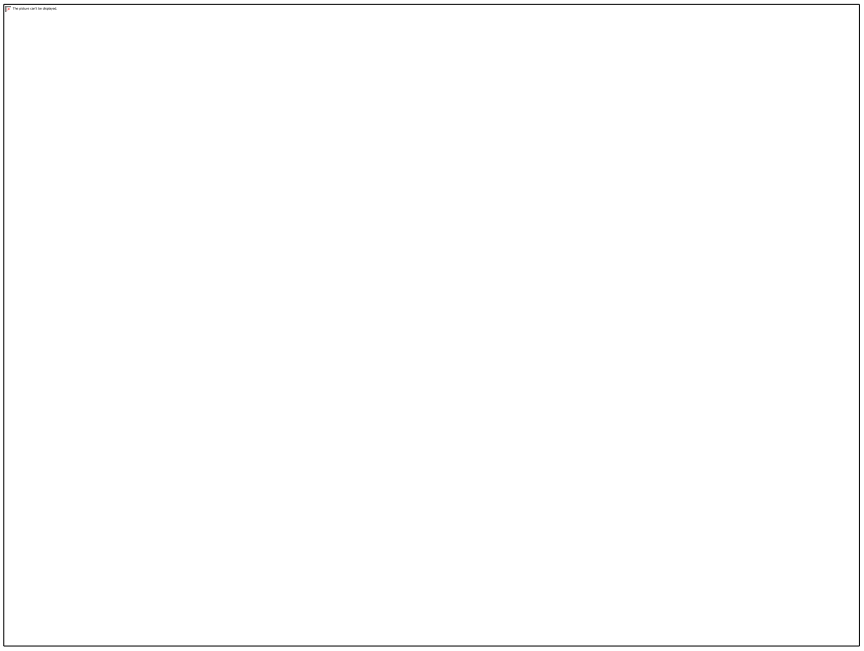
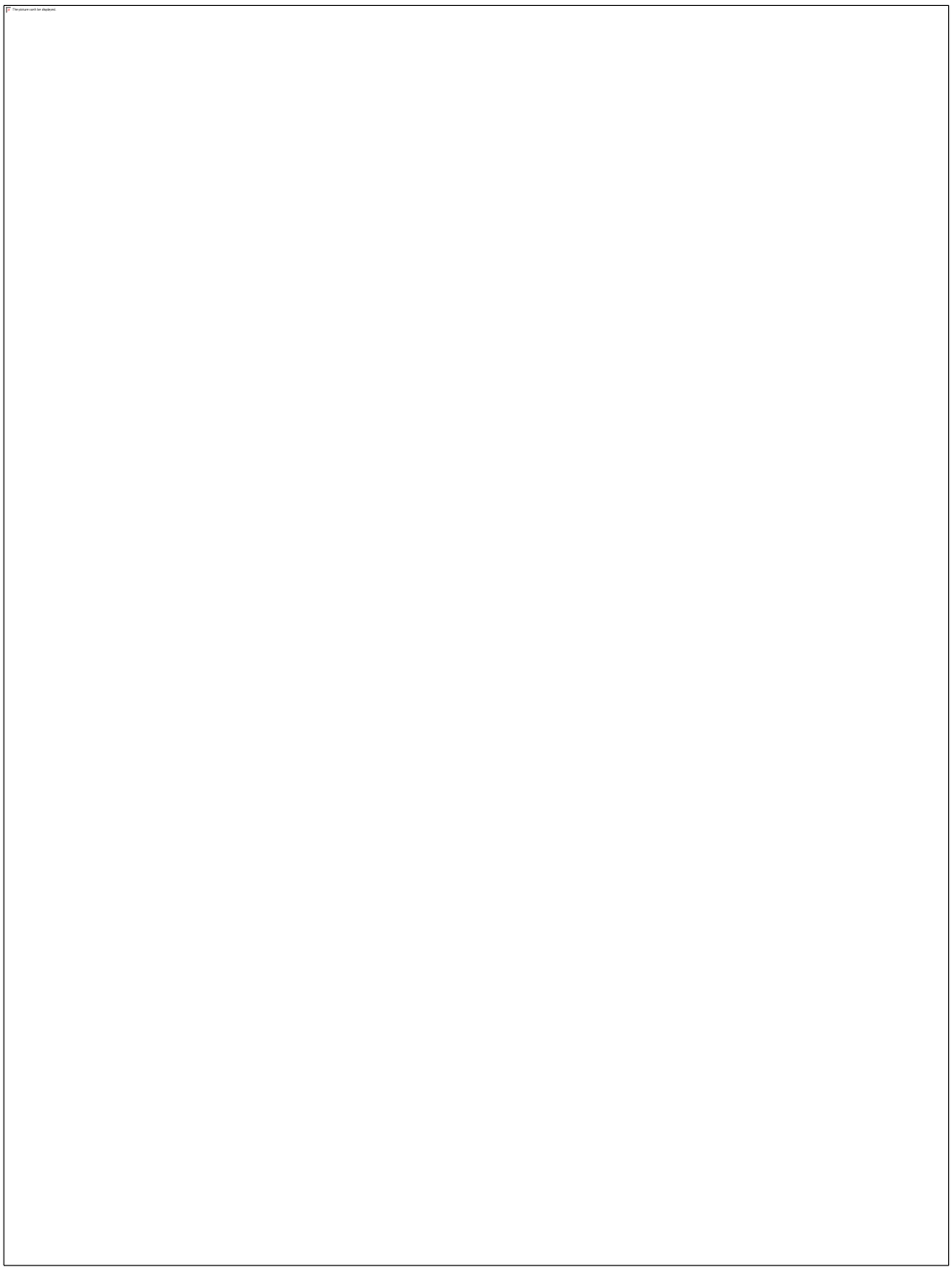


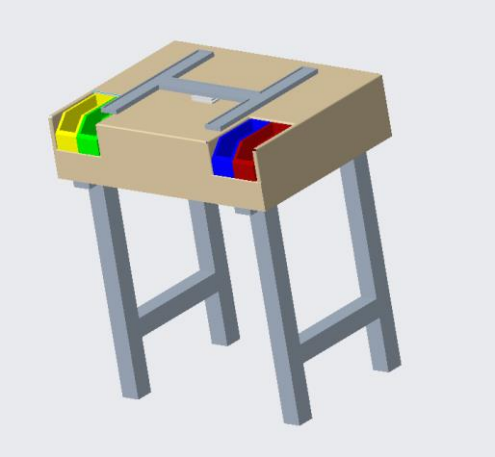
Photo 3: Metal Framed Jig, side view



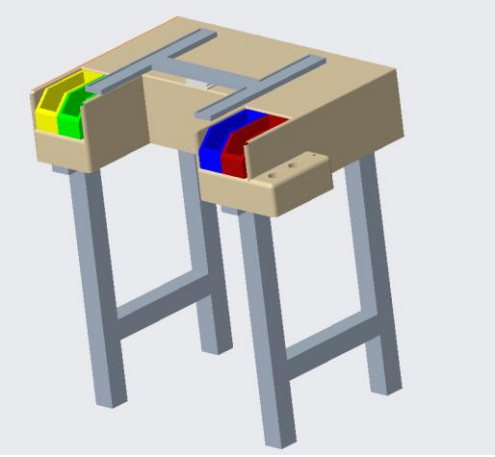
Brainstorming and Choosing Initial Design

On the drive back from our first visit to VIP Cinema Seating in September 2019, the team discussed what we had seen and heard from operators, and what the best path forward would be. It was decided that each member would make a rough sketch of their proposal for a new hardware assembly station and we would choose the best one at our next meeting. There were a few objectives we all agreed needed to be kept in mind. We wanted a new jig that would combine the elements of the two current models, maintained rotating ability, was very operator friendly, and could increase storage and efficiency - leading to decreased takt times. Most members had proposed a design similar to the table-top, but with a smaller, square footprint and more material storage (CAD 1). My sketch deviated slightly from this, because I had proposed a U-shaped table-top, that allowed for operators to still work up and under the chassis if they would rather. It also included legs that could be adjusted to the height each operator preferred. Ultimately, we moved forward with the U-shaped proposal and drew the best parts of the others into this initial design. With a consensus on what direction we would take this first jig, we could make new CAD drawings and begin the prototyping process (CAD 2).

CAD 1: First proposal



CAD 2: Proposal after team meeting



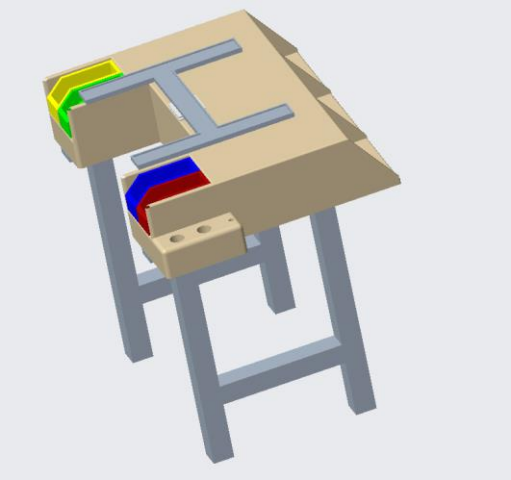
Building the First Prototype

Having agreed upon the design to move forward with, our team then ordered materials to start the building process. The "body" of our prototype would be made out of standard plywood, approximately two eight foot sheets, and the hardware platform would be made from two inch square tubing, attached to a pre-made rotating square, with ¼" iron plates on top cut in the exact same shape and dimensions of the current metal frame. Adjustable legs were found online that could be moved up or down and bolted into place. We also made an addition on the right side for tools such as impact drivers, hammers, and screw drivers to be kept within reach at all times (CAD 2).

These materials would allow us to accomplish all of the objectives we laid out after our initial visit. The wood body would incorporate the table-top model and hopefully appease those who liked to work on that surface. The shelves on both sides of the hardware platform increased storage, were designed to fit two small hardware bins of standard size and could be interchanged depending on different models' material needs. The spinning base and H-shaped platform would all be bolted together and could be changed to accommodate different models' dimensions. The adjustable legs would make it possible to adjust the height and would be more stable than the current metal frame model. We performed some finishing work such as beveling all the edges of the plywood with a sander so that they would not catch operators clothing or hands and adding stain and polyurethane for aesthetic and durability purposes.

As our first prototype began to come together, one team member suggested that we add a "tail" on the back end of the body to further increase material storage. This rear platform of shelves could be used to house the bins of materials not needed for the current models or keep materials that were too large for the front bins (CAD 3).

CAD 3: Final design with added “tail”



This design came to fruition in November of 2019, and we unveiled it to our class and professors in early December (Photo 3). We were very pleased with our work and thought that we had put a good initial prototype together, however, it is the opinions of the operators who work with it every day that truly matters. The prototype was delivered to VIP Cinema Seating in January 2020, and we would travel to VIP in early February to meet with the operators and managers for feedback on the first prototype.

Photo 4: Finished prototype

Delivery and Feedback

During any type of change or transition in a manufacturing facility, the most important element that determines success or failure is the level of buy-in from the operators on the production floor. Similar to a team sport, everyone has to be willing to do their part and believe in the goals they are trying to achieve to be successful. That is why the feedback from the hardware assembly operators is one of the most important aspects of this project. They know more about this process than anyone else, so their input and insights are absolutely critical.

Our team kept these facts at the forefront of our approach to receiving feedback from the operators on our first assembly station prototype. When we arrived at VIP Cinema Seating for the first time in Spring 2020 our prototype was set off to the side collecting dust and appeared as though it had not been used at all. This was a blow to our team's confidence and personal egos. During the time that we had been away, VIP had consolidated two of their plants that were serving similar production objectives. This meant there were now six operators performing the hardware assembly at this location, and none of them were impressed by our first prototype. The larger workforce now present gave us a great opportunity to discuss the jigs with operators who all offered unique perspectives and critiques.

While the first prototype was not as well received as we'd hoped, it gave the operators a chance to be more precise about their criticisms of their own jigs and our prototype. Richard, a user of the metal frame, was one of the most vocal critics and gave us lots of feedback. He had found a way to fix the stability issues common to this model by drilling holes in the concrete floor of his workstation and securing his jig to the floor with bolts and nuts. This was the sturdiest metal jig we found, but managers expressed discontent with creating more holes in the concrete, and the lack of mobility for this jig. He also said he "didn't know if there was anything

he would change" about his current model, foreshadowing some of the difficulties we will likely experience when trying to convince operators to buy into a new workstation and standardized process. Richard had also fashioned a U-shaped piece of wood that he could attach to the top of his platform that allowed him to use the metal frame for different models and still access some of the material stored in the center of his jig. Richard's creativity and ability to implement his own solutions is a common theme among these operators who have enjoyed the freedom to customize their own workstations. I believe this is a strength of the VIP Cinema Seating culture, and there should be an effort to maintain this type of continuous improvement within the new lean manufacturing guidelines.

Another operator, Francisco, cited the bulkiness of the table as the reason he preferred the jig. He explained that his compact metal frame allowed him to limit movements that wasted time and energy. Francisco, short in stature, also pointed out that he preferred his jig to be higher relative to other operators, because he could maintain good posture while working above waist level, and this kept his back from hurting at the end of the day. He had standard locations for his different nuts and bolts (at his right side and left side, respectively) so that he could grab one of each without ever looking at the materials. Francisco also expressed his frustration that in order to produce some of the models, he had to use a table-top workstation because his current metal frame did not accommodate the dimensions of all models. His observations were right in line with lean manufacturing objectives, and his arguments for the metal framed model were compelling. This highlighted our need to ensure that our next prototype was highly flexible, able to accommodate all models, and maintained the ability to adjust the height to each operator's preference. The last operator we interviewed was Bubba, who we were most familiar with from conversations last fall. Bubba is a big proponent of the metal framed model, having fashioned

platforms so that he can use it for every model, and stating the he “loves it.” His only recommendation for improvement was to make it less wobbly, emphasizing that a strong base would be key to the success of any new prototype. Production managers we talked to were very interested making sure a new prototype could have the height adjusted easily, requiring only one operator to adjust it. They also suggested using spring-loaded T-handles on the head of the metal stand to make the width of the hardware platform easily adjustable.

New Prototypes

With all of this insightful feedback, the team felt that we had to “go back to the drawing board.” Our original objectives would still guide us, but there were more requirements that we would have to fulfill to please the operators and their managers. After hearing lots of the operators express their contentment with the current models, we brought an unused metal frame jig home to reverse engineer and potentially repurpose for our next prototype. As is common in solving a complex problem, we had to take a few steps back in our process and begin again at making new design sketches. Our last prototype resembled the table-top model, and incorporated parts of the metal frame jig. We now believed that a better prototype would resemble the metal frame jig and incorporate parts of the table-top model. More precisely, we wanted to offer the operators flexibility in how they assembled their own personal workstation, so that it could more accurately represent their current preferences. During our most recent conversations, there was a tension between the operators that preferred the table-top model and those that preferred the metal framed jig, due to the belief that our team was going to select one of these as the basis of our new model. Our challenge was going to be to build enough flexibility into our new prototype that neither group felt like we had ignored their requests.

To begin this process, we first decided that we needed to rethink what “adjustable height” meant to our prototype. The first model we made was adjustable, but it was a very labor-intensive process that required removing bolts, readjusting the height, and then holding the jig at that height while the bolts were reinstalled. This would undoubtedly require two operators and could be cumbersome. Therefore, we were looking to include a hydraulic system that would make this process simpler and faster. We determined the best way to achieve this would be to use a hydraulic system like is found on barber’s chairs. The wide, circular, and moveable base of a barber chair would also achieve our stability goals without having to weld any extra supports or drill into the floor. The height of most bases available online was too low for our purposes, so we would have to add an extension to the top of the rod in order to bring our jig head up to waist height.

The more tedious part of a new prototype would be deciding what the jig head needed to look like, and what attachments we may need to provide to operators along with it. We decided we would repurpose most of the jig head that we brought home from VIP, using the same structure for the hardware platform and material storage. However, we would implement the manager’s suggestion of spring-loaded T-handles to make adjusting the width easier, and fashion better storage locations for tools. We would also borrow from Richard’s design of a platform that could be attached to the top of the metal jig that still allowed for the material underneath to be accessed. This platform design was also intended to appease the operators who preferred the table-top model. If done correctly, hopefully they would have the same experience using the new prototype with a flat, plywood platform installed as they do with their current table-tops.

Optimization and Future Objectives

This project, and the prototype of a hardware assembly station that is popular and can be replicated, is only the beginning for VIP Cinema Seating. With a standardized workstation, they can start the process of writing standardized work instructions and make their way towards standardizing the entire process and positioning of this hardware assembly operation. Making a new jig for hardware assembly is just one small part of a larger effort to implement lean manufacturing in the VIP Cinema Seating plants. During conversations with operators, it was obvious that at this point they were not enthused about the idea of change. Many of the operators are experienced, with more than 5 years at VIP. They have all developed processes that work best for them and have rhythms and muscle memory associated with those processes. It is understandable then, that a lot of them are reluctant to change and will likely push back on the implementation of these principles that will require standardized work processes. Even little things like the way their hardware is positioned in their workstation is very unique to each operator and during the first round of 5S implementation many voiced their unhappiness with the new standardized material positions. Our project that pushes yet another change on these operators was not initially well received and is an embodiment of the difficulties these types of transitions face. However, if a sincere effort is made to involve those same operators in the design and decisions that surround lean implementation, there is real hope that they will see that there are potential benefits for them and their work in lean manufacturing. Properly including the operators was therefore a main goal of ours, because if they are not fond of the new jig that we present them, the theoretical production efficiency gains will never be realized.

VIP Cinema's managers and engineering department are starting their implementation of lean in this hardware assembly area, but these lean principles could radically change the

environment at their plants. In order to fall in line with lean manufacturing principles, they need to completely redesign their plant layout. They must do away with batch and queue production, instead creating a continuous workflow that does not depend on material being trafficked around the plant many different times. They must introduce the idea of in-line quality control, where each subassembly is checked before it moves into the next stage of the process.

If VIP can successfully implement these practices, they could see incredible improvements to their production metrics and a boost to their bottom line. Many companies have experienced the turbulence VIP is now only just starting to feel, but time and again it has been proven that these guiding principles lead to a better performing manufacturer. It is crucial that management and employees alike do not become content with the status quo, simply because they have been successful in the past. They must realize that they have not been successful *because* of their processes and lack of discipline, but *despite* those cultural norms. This is not meant as a criticism of VIP Cinema's process, as these issues are common with smaller, younger companies. But if they plan to continue to be a market leader, they will have to bring their manufacturing facilities up to speed with top manufacturers all over the world. If they don't, they could be pushed out by a competitor who will. This is the nature of big-time manufacturing and capitalism. If you aren't consistently improving your products and processes, you're falling behind. This will determine whether this company is successful for many decades to come and a real powerhouse on a global scale, or if they become a case study for future generations to study when looking at how a company's growth can expand at first but plateau and fade. VIP Cinema Seating is in a position right now to take their operations to the next level, and all indicators are that this is the intention of their management. However, they must retrain some of their workforce to think in this way and emphasize the benefits that everyone can obtain if they prove

to be successful in this campaign. I am excited to see where VIP goes from here and was honored to be a part of their transition into a top-notch manufacturer.

Recent Developments

Unfortunately for VIP Cinema Seating, their efforts to implement these cost-saving and streamlining measures never came to fruition, as they permanently suspended operations and closed their doors on March 30th, 2020 [2]. VIP had previously filed for a Chapter 11 bankruptcy that included debt settlement and a restructuring on February 18th, citing saturation of the market, and a longer than expected life cycle for chairs they had previously installed [3]. At that time, management hoped to put the bankruptcy behind them by mid-April without interrupting production or laying off any employees [3]. However, as the effects of the COVID-19 pandemic became more widespread and movie theaters across the globe were shut down, VIP could no longer see a viable path forward. They were in a vulnerable position because the plateau of "big screens" in the United States did not leave many opportunities to grow, and this global health crisis came at just the wrong time for a company struggling to keep its head above water. It is a travesty for the employees and the New Albany community that this large employer was not able to pull through. However, for the purposes of this paper I will continue with a high-level analyzation their business structure, where they may have gone wrong, and what implementing lean manufacturing principles could have meant to VIP Cinema Seating's present and future.

Lean Manufacturing Principles and Their Potential at VIP

Brief History and Introduction to Lean Manufacturing

Lean manufacturing has become the standard in almost all major industries today. These principles were not developed overnight, or by one individual, but are the result of years of advancements in manufacturing settings. Henry Ford, Kiichiro Toyoda, and Taiichi Ohno are credited with having the largest impacts on these principles, even though they may not have referred to it as "lean manufacturing." The term "lean" was first used by Jim Womack of MIT to describe the way Toyota was doing business and producing vehicles in the late 1980's [4]. Henry Ford's installation of assembly lines, interchangeable parts, and go/no-go constant quality checks in the early 20th century can be seen as the beginning of the modern development of lean principles. By the end of World War II, Kiichiro Toyoda and his loyal manager Taiichi Ohno began focusing once again on some of Ford's procedures and what they could mean to their own car manufacturer [5]. Out of this management team came the Toyota Production System, now lauded as the premier example of lean implementation.

While lean principles can be used in almost any business setting to improve performance, the most demonstrative cases are seen in manufacturing and assembly settings. Companies throughout the world have realized the benefits of applying these simple ideals and have created an environment where everyone must adhere to them in order to compete. If a company has not implemented them by now, or does not have a plan to, their business could be in severe trouble. By 2011, 72% of machine shops had adopted lean techniques [6]. VIP finds itself on the wrong side of this statistic, as they've only just begun to introduce lean ideas in their workplace and are struggling to obtain buy-in from their employees. It must also be noted that lean principles are not exclusive to the assembly process, and they have also been applied to supply chains to reduce

inventory and capital requirements. As Taiichi Ohno puts it, manufacturers should "Produce what you need, only what you need, and when you need it" [7]. This mantra led to the development of a strategy now referred to as "just-in-time manufacturing." The idea is to streamline a supply chain with such precision that you can use a "pull" system where customer orders directly drive production rather than a "push" system where production is set and then the sales team is tasked with selling this inventory. The traditional "push" model can lead to huge inventory costs when finished goods pile up, and while raw materials are being stored to supply a production output predetermined by sales forecasts. VIP Cinema has a long way to go before they could attain these objectives. Their approach to inventory right now could be hugely improved and lead to a profound impact on their bottom line and return on capital invested.

Lean Principles

Lean Manufacturing can be used to describe a number of different strategies all aimed at increasing efficiency and delivering value to the customer. The steps needed in order to achieve a lean business model are:

1) Identifying value – from the standpoint of the end customer
2) Identifying all steps in the value stream – entire process of delivering a product
3) Creating flow – organizing the value stream in order to eliminate waste
4) Establishing pull – customers "pulling" value from upstream
5) Seeking perfection – continually working through this process to find and eliminate waste

[8]

The steps that are most relevant to this project are identifying the steps in the value stream and creating flow. This where you get into the details of the manufacturing process and what it takes

to streamline these processes. These two steps are all about identifying and eliminating wastes that are usually described as the "seven deadly wastes." These are as follows:

1) Waiting – time spent waiting on someone else to complete a task
2) Motion – the unnecessary movement of people during a process
3) Over-processing – using more energy or activity than is necessary to produce a product
4) Inventories and queues – excess product waiting to be processed
5) Transportation – unnecessary movement of goods from one process to the next
6) Overproduction – making more parts than is required
7) Defects – time spent repairing or reworking material

[6]

These seven deadly wastes can be found in most manufacturing processes, and almost all were present at VIP's plants. They provide the clearest picture of the deficiencies of their processes and lack of organizational discipline.

One of the wastes not as prevalent was waiting, as most operators had plenty of material to work on near their workstations. But this was not because flow had been achieved and takt times had been leveled for each operation, but because they are operating on a batch and queue system where each operation is performed on a batch of product before moving into the next operation's queue. This type of production strategy is very inefficient, causing a lot more material to be in Work in Process at any point in time, requiring space to store such inventory and laborers to move it from one process to the next.

The next deadly waste, motion, was also present and partly derived from the batch and queue process. Because work cells did not flow into each other, operators routinely have to fetch

hardware from the edge of their workstations and place it on jigs to begin their work. Once their process is complete, they would have to stack the finished assembly on dollies that would be picked up by a material handler once full. Most of that motion could be eliminated if work cells were created and organized in a manner that allowed each operator to complete their task in a similar amount of time and pass the work in process inventory from one operation to the next without much space between workstations. The pieces of hardware that are larger than bolts and nuts were stored behind the operator, strewn about on tables and shelves. This led to the operator turning around many times during each assembly process.

Over-processing is a waste that is harder to detect and requires a more in-depth investigation to hone in on. However, I think the best example of over-processing at VIP was the complexity of all their models. They built incredibly nice seats, all of them reclined, a good number with motorized recline, and many more with a ton of features. But for cinemas that were not looking to tailor to a luxury requiring audience and wanted to retain their larger number of seats per theater, they did not offer many options. VIP had likely become aware of this and had plans to unveil a non-reclining seat at CinemaCon this year, another goal that was also never realized [9].

The largest and most consequential waste found at VIP was inventories and queues. In the massive, metal framed buildings of VIP Plants #1 and #6, approximately 10-15% of the total space was used for the manufacturing process. The rest of these buildings were packed full of inventory of all kinds: raw materials, work in process, and finished goods. My first reaction to walking into plant #6 was astonishment at how much inventory they had. In course lectures ranging from Manufacturing, to Supply Chain, to Accounting and Financial Statement Analysis, I've heard many times how costly inventory can be, as it ties up precious capital and chokes cash

flows. This was a red flag, but also presented an opportunity for serious improvement if they could successfully implement new inventory strategies and replace their batch and queue process with a flowing design of cellular manufacturing. This waste was also one that I believed we could have an impact on by designing a standardized hardware assembly station and eventually standardizing the entire workstation or "work cell." Our project could have been the catalyst for a new era in VIP's manufacturing process that could greatly reduce inventories, lead times, and inefficiency. Sadly, we weren't able to complete our task and give way to the larger goals.

Their poor inventory strategy leads into the next deadly waste, transportation. The batch and queue process and lack of workflow design necessitates an enormous amount of transportation throughout the plant. There were forklifts and manual material handlers going in all directions all the time to deliver raw materials, pick up work in process, and move batches from one process the next or to a staging area in between. Almost every movement of this material that requires someone other than the operator to handle it should have been eliminated. Material handlers having to move material in and out of each work area added an extra step in between every single value adding operation. This design was a lean nightmare, slowing down the entire process and requiring many more labor hours than should be necessary. One specific example of the lack of awareness that stuck out was the omnipresence of white boards near the manufacturing lines that had each operator's output for the morning and afternoon. These were meant to motivate the operators and keep them accountable. But where were the material handlers' output numbers? No one questioned the fact that all of these laborers whose sole purpose was to move work-in-process inventory from one station to the next added zero value or output to the manufacturing process.

During VIP Cinema's initial high growth period while they gained market traction and expanded their client list, overproduction was probably not an issue they had because of the growing demand. They also traditionally only build lots of seats to fulfill contracts that are already in place. However, while working there for a week preceding the Fall 2019 semester, some management mentioned that they had some inventory that had not been sold because of changes to orders or cancelled contracts and the plan was to auction off those pieces to individuals looking for home theater seating, likely at prices much lower than originally planned. The recent closure of theaters due to the COVID-19 threat has likely also left VIP "holding the bag" with finished goods that cannot be delivered and contracts that will not be fulfilled. These issues are exacerbated by the large inventories common at VIP and lines that are not quickly responsive to changing models because of large work in process queues.

The data on defects and mistakes is hard to retrieve now that the plants are shut down, and I did not want to be intrusive to managers who recently lost their jobs and access to this information. Anecdotally, defects and mistakes seemed common because of the lack of standardized work. During our Manufacturing 450 class that worked at VIP for a week, my team was tasked with figuring out why cupholders were able to be removed from some of their models. This had become a problem because some bad actors at theaters across the nation were stealing them, leaving seats without cupholders. This could expose electrical components that were vulnerable to moisture and could fail. We found that the root causes of this problem lie in two different processes. One in which the framing of the chair arm was stapled together and one where the vinyl upholstery was added, a hole cut, material removed, and cupholder installed. If the frame was stapled so that there was too much room for the cupholder, there would not be a tight fit when it was installed. This process was not standardized and did not use any poka-yoke

tools that would have ensured each frame was stapled correctly. The process of cutting a hole and removing padding material was also not standardized, allowing some operators to cut large holes and remove sizable amounts of padding, while others made many small incisions and removed no material. If this process was standardized so that each frame left just enough room for the cupholder, and each operator only made small cuts and did not remove any padding, I believe most of the issues theaters were having with loose cupholders could have been alleviated. This is just one example of mistakes and defects that were costing VIP Cinema valuable goodwill and reputation among their customers, and likely could have been avoided if better manufacturing techniques and quality assurances were in place.

Potential Solutions Not Implemented

Our proposed jig for VIP Cinema's hardware assembly operators could have made a real difference for their efficiency and output. If operators were willing and able to use our prototype during their process, we estimated that it could improve output by 30% because of the decreased takt time needed to complete the assembly.

	Pre-implementation	Post-Implementation*
Weekly Production	1,720 units	2,240 units
Hourly Production	43 units/hour	56 units/hour
Total Wages/Hour	$74.00/hour	$74.00/hour
Wage Cost/Output Unit	$1.72/unit	$1.32/unit

* estimated

- Increase of $0.40 of profit per unit due to 23% reduction in cost per unit

FIGURE 1: Analysis of Financial Effects of Proposed Jig

As shown here, the improved output due to our jig could have led to a 23% reduction in cost per unit. That is a substantial difference that could have likely been replicated throughout VIP's manufacturing line. These estimates are also in line with research conducted to measure the impacts of lean principles on a medium-sized furniture manufacturer in Brazil.

Indicator	Initial measurement	Objectives	Final measurement	Results
Productivity	1330 pieces/day	20%	1686 pieces/day	27%
Movement	276 meters	30%	184 meters	33%
			Monthly cost reduction	1,322.29 BRL
			Return on investment	13.61 months

FIGURE 2: Impact of Lean Manufacturing on Output [10]

This research, along with our estimates, indicates that the adoption of lean principles, and in particular furnishing operators with our prototypes, could have had major implications for the costs VIP Cinema incurred during manufacturing and ultimately their bottom line.

These are not the only benefits VIP could have achieved through lean manufacturing, however. Another area with enormous potential to improve efficiency was their approach to inventory. Before implementing their bankruptcy settlement, VIP expected their inventory to be more than 40% of their Current Assets at the end of Q1 2020. This is one reason that implementing lean manufacturing principles not only on their manufacturing line but throughout VIP Cinema could have been extremely beneficial. Because previous years' financial information is not available, I believe this iteration to be the most accurate representation of their most recent financial statements.

($ in Millions)	Pre-Emergence 3/31/2020
Cash	4,246
Net A/R	11,080
Inventories	12,628
Other Current Assets	2,589
Total Current Assets	**$30,543**
Property Plant & Equipment, net	12,870
Other Non Current Assets	197,176
Total Assets	**$240,588**

FIGURE 3: VIP Q1 2020 Assets [11]

Furthermore, a paper that analyzed and summarized findings from research on lean principles found that inventory could be reduced by over 40% if these principles were enacted throughout a firm's business.

Table 1: Impact of Lean Principles on Inventory Turnover [12]

Inventory Days	Traditional	Lean
Raw Material Inventory Days of Production	38.6	24.8
Work In Process Days of Production	22.8	15.1
Finished Product Inventory Days of Production	25.4	13.5

In each category of inventory shown here, companies that had implemented lean practices significantly reduced their amount of inventory. Inventory levels were reduced by 36% for raw material, 34% for WIP, and 47% for finished goods. These types of reductions would have had major implications for VIP Cinema's inventory metrics and subsequently their balance sheet.

FIGURE 5: VIP Inventory Breakdown 12/31/2019 [11]

($000's)		Net Book Value	Projected with Lean
Inventory:			
Raw Materials			
Raw Materials - Electronics	$	1,962	
Raw Materials - Hardware		2,772	
Raw Materials - Filing		77	
Raw Materials - Frames		33	
Raw Materials - Kit		348	
Raw Materials - Packaging		171	
Raw Materials - Other		1,737	
Raw Materials, sub-total	**$**	**7,100**	**4,544**
Finished Goods		3,454	1,831
WIP		-	
Total	**$**	**10,554**	**6,375**

The calculations above are simply estimates and should be criticized with that in mind. However, they are included to provide some context to the potential impacts on VIP's operations that lean manufacturing could have provided. In practice, it is extremely hard to know what improvements VIP Cinema could have precisely realized. But I think they undoubtedly could have seen some very serious improvements on all business ratios had they implemented these waste eliminating measures.

Summary

In 2019 and early 2020 VIP Cinema Seating was going through a transition to lean manufacturing. They planned to implement principles such as “5S” which included the standardization of workstations and processes. As a part of this process, our team from the CME was tasked with improving and standardizing the hardware assembly stations operators used to construct the chassis of reclining theater seats. We were able to deliver a first prototype that attempted to combine the two jigs currently used, while adding space for hardware and tool storage. This first prototype was not favored by operators but gave them a chance to more precisely criticize our design and their own current jigs. After we received this feedback, we began the initial steps of designing and building a second prototype that we hoped would receive better reviews. Our objective was to improve and standardize this one process so that this project could be an example of the gains that lean principles could deliver and could be replicated throughout the VIP Cinema Seating manufacturing campus.

If this implementation of lean manufacturing were to be successful, it was going to radically change VIP’s approach to most of their manufacturing processes. One strategy that I believe needed to be harshly criticized was their approach to inventory. From our observations it appeared that they were carrying high levels of inventory of all kinds, requiring lots of space to store it and capital to maintain it. If their manufacturing lines could be streamlined in a cellular manufacturing design, this could reduce work in process inventory greatly. If they could organize their supply chain so that they never had more than about a month of inventory at a time, it could drastically reduce the capital tied up in inventory and potentially allow for a downsizing of the physical space needed to supply their manufacturing line.

This project was challenging but exciting. It provided our team with the opportunity to make a difference in a real-world application and I am proud of the work that we did and prototype we developed. With the feedback we received during our visit in 2020, and with a new strategy to repurpose parts of their current model, I'm confident we could have delivered a great hardware assembly station to the operators of VIP. To study takt times and production output when our new prototype was used and contrast this with the current data would have been very interesting and rewarding for our team. Unfortunately, we were not afforded this opportunity, and the potential gains from a new jig and process must be estimated. However, I hope this paper provides some clarity about the problem solving and design procedures followed and can be used a guide to future teams who may be involved in similar projects.

The implications of adopting lean principles at VIP Cinema Seating go far beyond this individual process and new jig. From what I observed during many visits to VIP, I am certain they could have made major improvements to their manufacturing processes and inventory strategies using lean principles to guide them. If all, or even some, of those improvements had been made and potential gains captured perhaps their fate would have been different. Of course all of that is speculation, and we cannot access any information needed to further demonstrate the realities they were facing. Nonetheless, VIP Cinema Seating had the right idea when they decided to introduce lean manufacturing to their processes and would have benefitted had they succeeded. Our team was delighted to be included in this quest for a more efficient manufacturer and appreciated the hospitality we received. Sadly, these initiatives may have been "too little too late" for VIP Cinema Seating, and they were unable to realize the potential lean manufacturing principles have to offer.

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