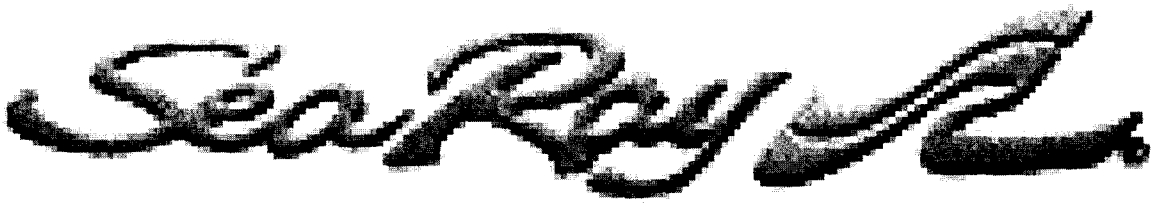
Senior Honors Capstone Project Spring 2005



Vinyl Cushion Department:

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Senior Project Objective:

Completing the Senior Design Project has provided two outcomes. The first being it provided the company beneficial feedback to an unsolved problem. Secondly, it provided an opportunity to experience and solved a work situation out in industry. A successful project will be the end result after the concepts from the University's curricula has been applied and analyzed. In order to successfully complete the assignment, consideration was to be given to the current problem, a feasible solution, and an evaluation of the benefits after the proposed solution has been established.

Executive Summary:

This project was driven by the fact that there was a need for the Upholstery Department of Sea Ray to reduce the non-value added steps from the manufacturing process. There was a goal to reduce this by at least 30%. This mark was set by the production manager Bryan Robertson because there are a large amount unnecessary steps in the process such as storage and rework that were limiting the process's effectiveness. In order to reach this target, a Kaizen activity was be executed and the DMAIC methodology was utilized. This methodology included defining the problem, measuring the performance, analyzing the data and methods, improving the system, and controlling the system after the improvements have been implemented.

The process was defined thoroughly across a functional team made up of employees at Sea Ray Boats. This team of shop floor workers, a quality manager and a production manager, communicated to the group the scope and define overall problem. The details came only after studying and observing the system in all areas. Possible improvement opportunities can be found in transport, excess handling, and excess inventory and work in process. The employees also have to be considered when looking at the repetitive work elements of process. The repetition could lead to possible injuries because some of the setup tasks require awkward movements. The motions also required a certain amount restructuring of the working area, which was accomplished by redesigning the work cell layout.

There the improvement and progress was evaluated according to a system. The current performance was only evaluated after the initial measurements were taken. Improvement in the system was measured in the areas of work in progress, inventory, and lead times (the time it takes for a product to go from start to finish.)

The analysis phase was completed after developing the current state and after the identification of non-value-added and value-added activities. After analyzing this data the proposed future state was developed. Part of this was the completion of the new layout which later was evaluated using a simulation model. The final part of the project is to control the new process. Controlling the system involves setting standards,

maintaining standards, and keeping the new system running in an ideal manner.

Project Scope:

The duration of the project was approximately four months. Upon meeting with the Sea Ray Manager, it was stated that a preliminary system was going to be put in place by the end of February. By having a system up and running so early in the timeline, there was time to make evaluations and improvements in areas that are were meeting the requirements. This project was successfully completed in the allotted time frame by defining the problem and equally evaluating the continuous improvement efforts.

Problem Statement:

Sea Ray is a world-class manufacturer boats. The boats range from smaller boats to larger boats that are referred to as cruisers. They plan on reducing their producing strictly to cruisers sometime this year. No matter the type of boat, the fundamental steps in manufacturing the boats are similar. The area of concern for the project lies in the Upholstery Department. The Upholstery Department has an excessive amount of inventory and work in process. Alternatives in the areas of cell layout, product flow, and worker capacity are needed to adjust the current state of operation.

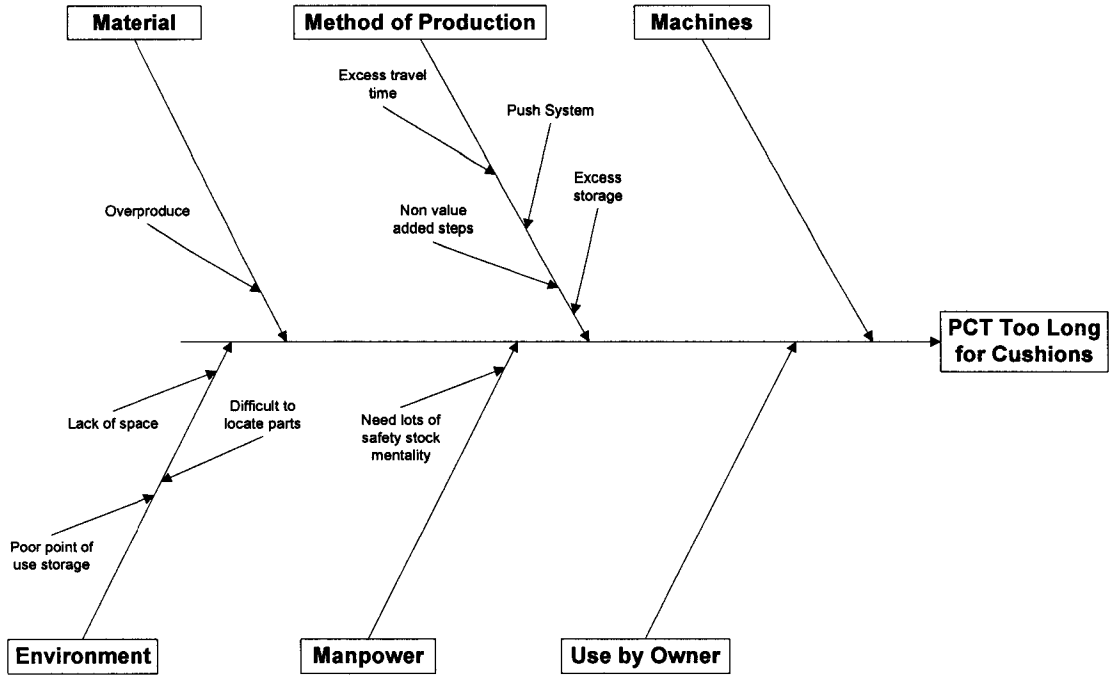


Figure 1. Cause and Effect Diagram

The problems facing the current state of the process are shown above in figure 1. The main problems are the lack of space, the amount of non-value added steps and the excess storage that arises from running a push system. Our goal is to implement lean techniques that we have learned to address the issues and make the vinyl cushion production more efficient in terms of product lead time, work in progress and employee safety.

Why Become Lean?

Lean manufacturing is the process of analyzing the flow of information and materials in a manufacturing environment and improving them by cutting out all activities and resources that are unnecessary and do not ultimately add value to the customer. Another central concept in lean manufacturing is that the system

can always be improved upon because processes that have undergone change are still critiqued to find other possible improvements.

Lean manufacturing focuses on eliminating the waste in a system, which is an often time referred to as non-value added time or activities. These tasks are simply steps in a process that a customer or client would be unwilling to pay for. Examples of non-value added activities include unnecessary transportation and spending time searching or looking for needed components. Adjusting production flow of a certain product to the demand of the customer is one aspect of lean manufacturing that will help reduce and eventually result in the elimination of waste.

Lean manufacturing uses the building blocks of standardized work, effective plant layout, quality at the source, batch reduction, cross functional teams, customer demand-based manufacturing, quick changeover, cellular manufacturing, and takt time.

The benefits of lean manufacturing can affect the overall sales and customer service as well as your internal operations in any particular company. Market impacts include better lead-time, more product flexibility and increased sales. Internal impacts are reduced space and work-in-progress, quality improvements, and minimal expediting.

Initial Evaluation Procedure:

In order to develop a proposed solution to the design project, an evaluation of the current environment had to be done.

There were several steps that were completed to ensure proper evaluation and recommendation of the proposed future state. The first step was to become familiar with the manufacturing process in the Upholstery Department. It is important to fully understand how the current system is working before evaluating and proposing a future system. The layout and flow of the current system is shown below.

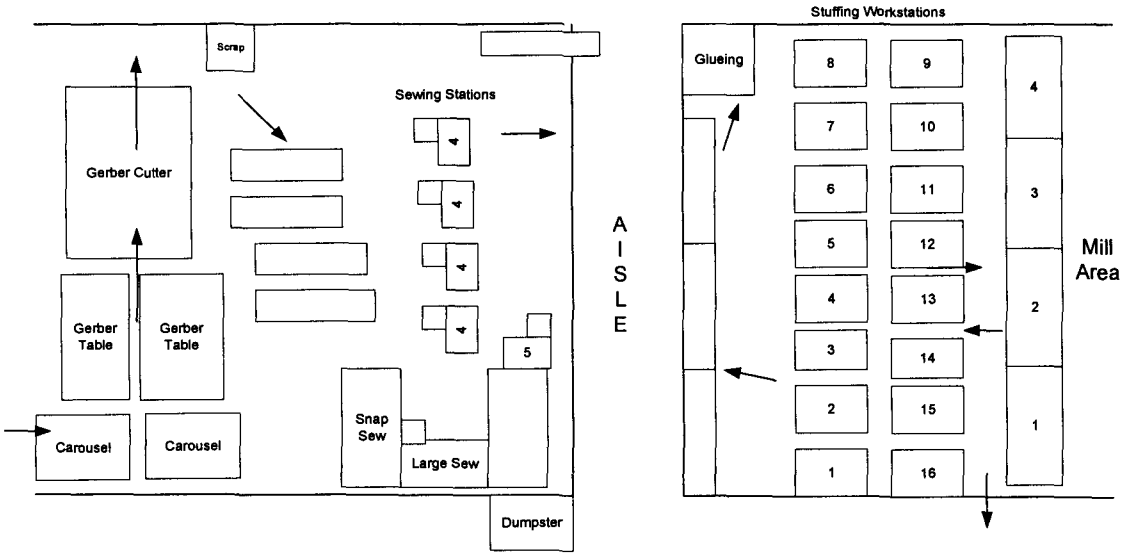


Figure 2. Current Layout of Upholstery Area

The process starts out with the Gerber cutter that cuts the fabric for the skins and the wood cutter that cuts the pieces for the substrates. The skins are taken an storage rack until one of the sewers is ready to turn it into the seat's skins. The wood is also taken to a wood shelf until the workers at the stuffing workstations (setup) are ready to assemble them with the plastic substrates. The skins are stored on a rack. Once the plastic and the wood are combined, they are taken to the gluing station where

foam is glued onto them. This assembly is then covered by the skins from the fore mentioned storage rack. The finished assembly is then placed on a storage rack until an assembly line worker pulls it. Consideration has to be given not only to the Upholstery Department directly, but also to the indirect effects that changes in that department may show in the overall production of Sea Ray boats.

As shown in Figure 2 above, it is clear that the flow of parts through this department included wasteful transportation movements, and often repetitive visits to storage racks and other common areas. While on the shop floor, workers in the department were interviewed to fully assess the different functions of the department and to better understand how each function is related or dependent on another process. Worker input and compliance is very instrumental in implementing new techniques and new layout designs. Topics that were covered with the workers include typical work flow, inventory counts, process times, variation in the different parts, and any concerns or problems they were personally facing. This feedback was beneficial to identifying the current state and problem as well as in the reconfiguration of the work cell. It is also beneficial to have operator and worker input to an implementation process because they will ultimately be the individuals who will have to adapt to the new system and make it a success.

Data collection for time studies was also an important step in analyzing the system. The Sea Ray Company had old files of

times recorded, however, additional studies were conducted to compare the new times with the older times on file. Inaccurate data would yield inaccurate results and would make the proposed future state invalid.

Operation	File Time (min)	Our Time (min)
Gerber		
Cutting		3
Sewing	10.87	13.62
Wood		
Cutting		3.88
Setup		14.26
Foaming	2	5.22
Upholstery	19.31	18.44

Table 1. Comparison of Sea Ray Times and Group Time

Another step that was taken to fully evaluate the current condition was to sit in and talk with the different managers that were involved in the Upholstery Department redesign. Talking at least once a week provided a foundation of information to go forth and analyze and suggest changes. During the meetings brainstorming took place in order to develop the best possible designs for the new work cell. Ideas were challenged and questions were raised in order to distinguish the practical possibilities from the unpractical.

After documenting the information we gathered from our time studies and meeting with the Sea Ray team, the next step was to develop a value stream map of the current process and of the future state. The current state value stream map was useful because it showed the different values regarding processing times, inventories, waits, and moves. This format made it easier

to identify areas that needed to be modified or completely changed. This current state value stream map also provided a list of measures by which improvement would be measured from. These core measurements would be in the area of inventory, work in process, and process time.

Current State of Vinyl Cushion Process:

The current state is a traditional processing layout (see Figure 3). It is traditional in the sense that once the skins and wood are made, one individual or employee will build the single seat from start to finish. The worker will begin and end the same process and have covered every aspect with that particular part. There are pros and cons to this scenario. It is good in the sense that the worker is competent is every processing step to make the part, however, since there are several workers making the exact same part it is not easy to identify which workers are the most effective and what makes them more effective than others. Standardization of operations and movements are necessary to obtain a standard working level that can be attained by all workers involved in the work cell. The current state also has marginal cross training. Several works are very skilled in an array of parts, however, a problem arises when a part needs to be manufactured and there is a short in manpower and the worker who are present are not performing at an optimal level. Crossing training throughout the whole department is necessary in order to ensure a consistent constant flow of the product.

By developing the map of the current state it is also apparent that there is a problem with excess work in process and there are too many storage racks. The storage is located in various locations throughout the plant and many times it is not efficient to go through the transportation to retrieve the supplies. Also, by having several different storage locations it is more difficult to account for every piece of product that is being stored.

Sea Ray 260 DA Boat Lounge Seat Cushion Current Value Stream Mapping

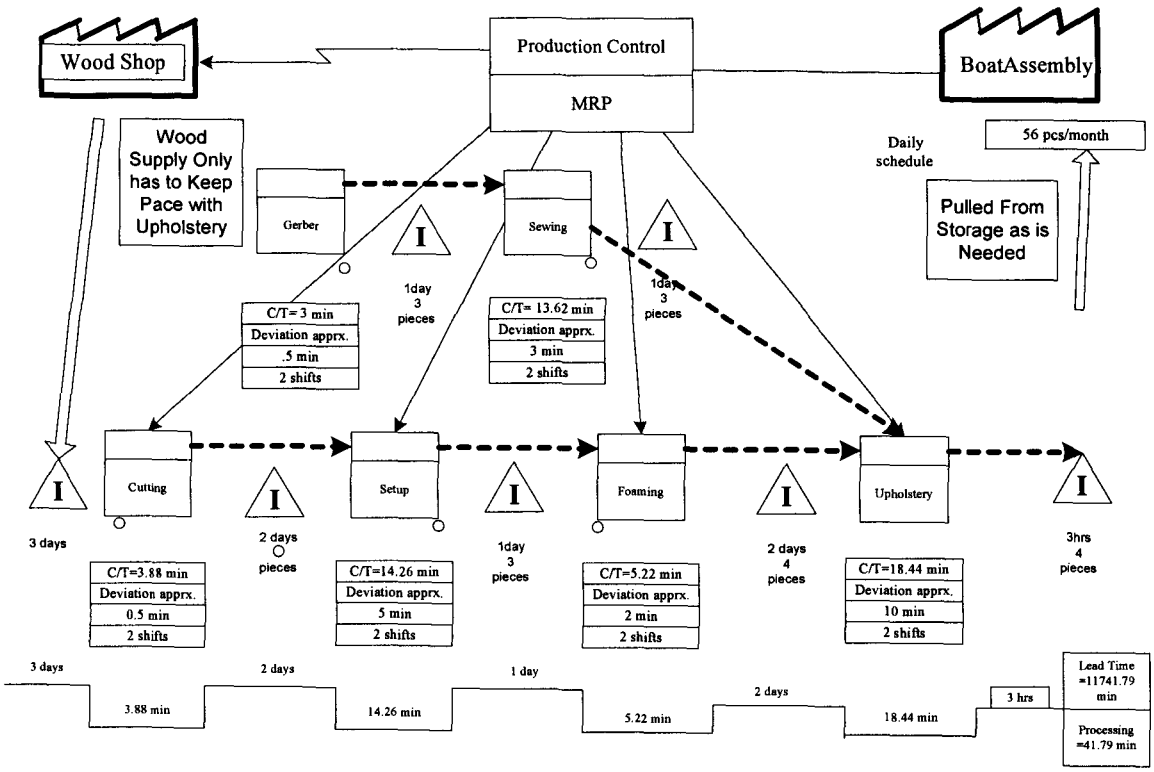


Figure 3. Value Stream Map of Current State

The Design Phase:

The design phase will involve reconfiguring the entire layout of the work cell as well as redesigning the tools and individual work areas of the operators. One of the changes to the individual work area was a new design work bench. These were added by Sea Ray about three quarters of the way through our project. The older work benches were table top work areas that were primarily there to complete the work on the table. The tools needed to produce the parts were located in individual work boxes and on different shelves. The newly designed work benches include several storage areas. The benches would now have two areas for storage and an area to load the material that can be pulled off of spools. The benches will now have table tops that are lids as well. These lids open to a compartment inside of the work bench. There will also be shelves under the work bench where tools and other needed items can be stored. The cords that come on spools will be located at the ends of the tables and will be easier to use due to the fact the material will now be able to be pulled in the necessary quantity as needed.

The design phase will also involve the layout of the different work benches in relationship to each other. The work benches will be located in groups of four which will create an optimal work area that will support one piece flow because the workers will not have to move through process. As soon as they receive the wood from the wood cutter, they can start to combine it with the plastic substrates, glue the foam onto them and finally cover them with the skins. This setup creates an

environment with less confusion because the workers will not have as many transportation movements. The new work cells will also be developed considering the ergonomic factors that concern the welfare of the workers. The benches will be at the proper height to eliminate poor posture and strains on various muscles for long periods of times. Other factors such as the reach and the rotation of the worker are also considered when placing items in their new locations.

The main change in the layout, however, is the combination of the gluing operations with the standard work benches. If the proper equipment can be installed and the workers can be trained to perform the gluing operation by themselves, then it would greatly benefit the process. A rough estimate for the necessary equipment would be around two hundred dollars per setup station.

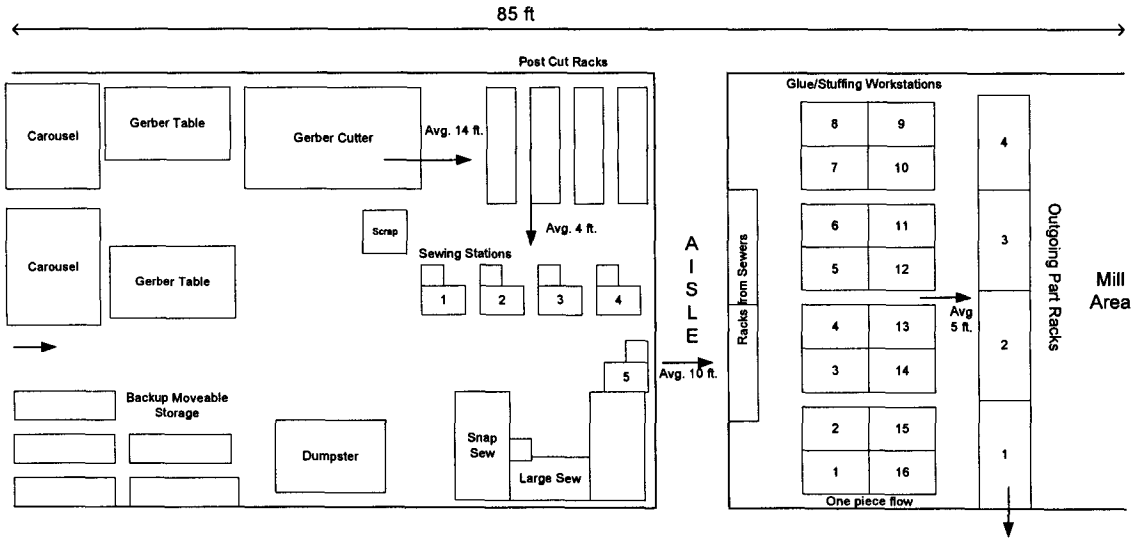


Figure 4. New Upholstery Layout for Upholstery Area

As shown above in Figure 4, the proposed work area layout, which was designed by our team, has a clear left to right flow. It involves creating one-piece flow workstations for the stuffing and gluing phase and repositioning the Gerber cutter so that material may flow directly out of the warehouse, into the cutter, and to the racks for the sewers without any wasted transportation. Another important piece of the new design is the removal of approximately 50% of the storage racks from within the "flow area" to a location more out of the way. Once the process becomes Leaner, there will inherently be less of a need for all these racks taking up space.

Along with the new design layout, there will also have to be a new design in the scheduling and performance evaluation levels. This new layout will support implementing new processing standards that can be replicated from part to part, from worker to worker, and from shift to shift. This consistency will help control the inventory problem.

Future State:

The future state value stream map incorporated all of the changes to the system that were needed to reach the goal of becoming leaner in the manufacturing processes. The much simplified value stream map is shown below.

Sea Ray 260 DA Boat Lounge Seat Cushion Future State
Value Stream Mapping

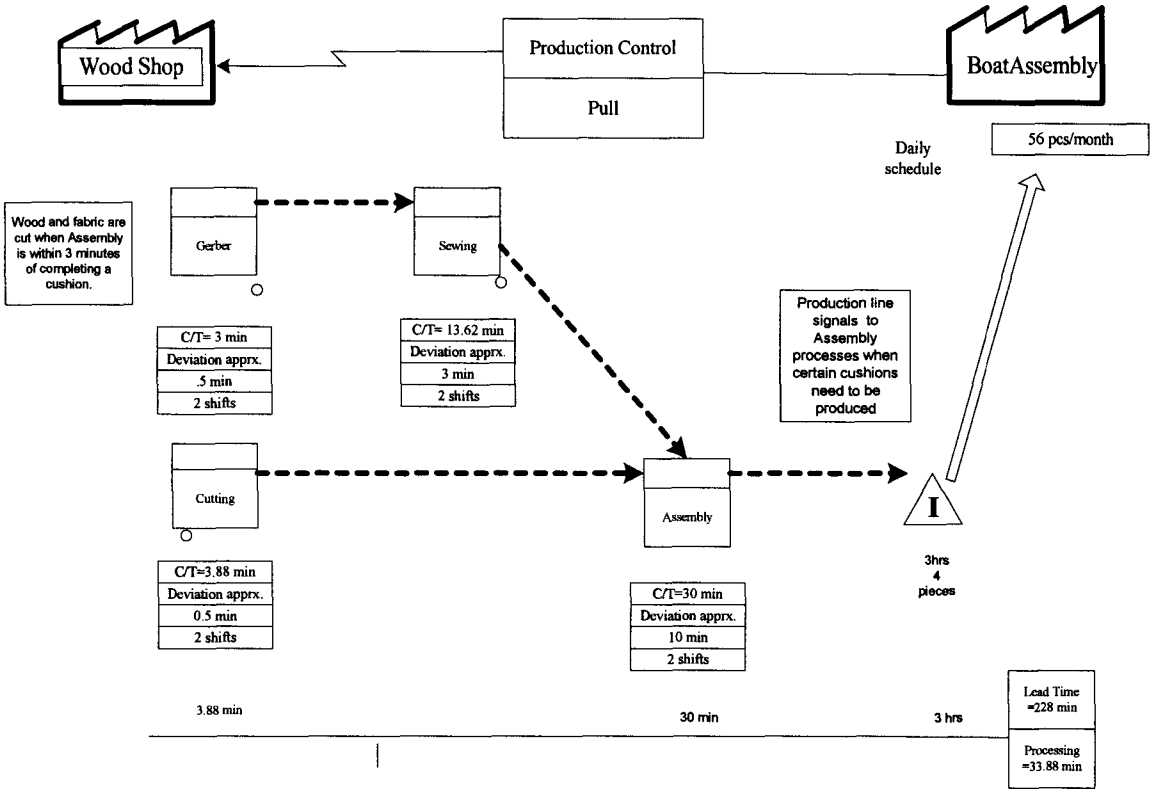


Figure 5. Value Stream Map of Future State

The future state for the Upholstery Department included several concepts. The first area of change was with the physical flow of the product. The flow should be converted from a push system to a pull system. This can be done by combining the setup, foaming and upholstery processes into one large process called "Assembly." This process will be the bottleneck because its processing time is by far the longest. It will initiate the pull from upstream process. The Assembly workers will signal the fabric and wood cutters to start when they are within four minutes of finishing their part. Four minutes was chosen because the fabric cutting

and wood cutting operations takes a little less than four minutes. This will enable the assembly worker and the sewer to pick up their respective pieces with out the part going into storage and without them having to wait on what they need. The fabric will then be sent to the sewers to make the skins, which will take place as the Assembly workers are attaching the wood to plastic substrates and then gluing foam onto them. Running the process this way will eliminate the massive inventory that currently exists because parts will only be produced when they are immediately needed. Also, when the Assembly workers become proficient in gluing the foam onto the assembly, the cycle time should be reduced. This will take out the wait times that historically arose while traveling to and waiting for the glue booth.

Each worker will be responsible for completing a certain task which will be one component of the whole process. By breaking the steps down into different individual components, these components can be analyzed to find the optimal (from a time and quality standpoint) way to perform each. Once the optimal way is established the task can be documented to become standard procedure. This will become the standard working rate. The future state will also involve a layout that is sensitive to the fact the employees will become cross-trained in the different manufacturing processes. By having all workers on the same skill level the production will be constant and will not be dependent on the particular workers that are present on a given day. The

cross-training will be reinforced by having regular rotation of job functions. By doing this, the workers will have a continual exposure to the different manufacturing functions and will not lose the skills needed to complete various tasks. The ultimate goal of the future state is to move toward one piece flow and be able to replicate the production rate across the different workers and the different shifts. This will cut down on the work in process and inventory levels significantly.

Standard Processing Times:

Processing times or cycle times are critical to any function. This is the rate or pace at which product is produced and available to the client. Before implementation of the new work cell, many workers completed finished products at different times. This was due to the fact the worker were working at their own pace and with their own working style. Attempting to standardize the operations and movements of the workers should help stabilize the processing times. There are five different styles of cushions that are manufactured in the Upholstery Department. These categories are Sundancer, Amberjack 270, Sundeck, Amberjack 290, and Select Cushions. By analyzing the current and future states, standard operating times were suggested. The suggested times served as a basis for beginning to evaluate the new process and layout.

In each category of cushions are certain components of each with the amount per day, time in minutes, the total time for the

day, and the count. There are different quantities that need to be produced. There needs to be 14 Sundancer Cushions, 6 Amberjack 270, Sundeck Cushions, and Select Cushions. There also needs to be 3 Amberjack 290 Cushions. The times to complete the cushions are sent in minutes and are used to measure the progress of the workers.

Simulation:

Simulation was used because this analysis and report will show if the ideas concerning the new work cell and standard working techniques and times are going to improve the system. Initially observations will be drawn to identify potential bottlenecks and excess inventory waits in the future state. After the initial observation, the output from the program will be analyzed for utilization and processing times vs. wait times. All of this information will be important and relevant for evaluating the future state and making changes if necessary. It is easier and more cost effective to make changes in a computer program than to waste manpower and money to fix and keep fixing layout errors.

The model's blocks mirrored that of the future value stream map shown in Figure 5. The process times shown in that map were put into the simulation program, Arena's basic blocks. Transportation times in between the stations were also input based on the estimated travel distances in the new layout. The

station route station sequence of blocks was used to simulate the transportation.

The results from the simulation are as follows:

Replication ended at time : 600.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
lead time	356.23	(Insuf)	40.564	587.95	16
Entity 3.VATime	60.375	(Insuf)	51.021	71.599	16
Entity 3.NVATime	.00000	(Insuf)	.00000	.00000	16
Entity 3.WaitTime	26.566	(Insuf)	1.0118	80.142	16
Entity 3.TranTime	.90144	(Insuf)	.83400	1.0000	16
Entity 3.OtherTime	.00000	(Insuf)	.00000	.00000	16
Entity 3.TotalTime	64.128	(Insuf)	41.564	127.82	16
Cutter.Queue.WaitingTi	.06413	(Insuf)	.00000	1.0261	16
Upholstry.Queue.Waitin	2.0978	(Insuf)	.00000	10.383	17
Sewing.Queue.WaitingTi	3.5975	(Insuf)	.00000	18.255	21
Setup.Queue.WaitingTim	3.5467	(Insuf)	.00000	19.185	15
Gerber.Queue.WaitingTi	.23269	(Insuf)	.00000	3.3058	21
Foaming.Queue.WaitingT	.00000	(Insuf)	.00000	.00000	14
Batch 1.Queue.WaitingT	8.8933	(Insuf)	.00000	80.142	34

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Entity 3.WIP	3.8350	(Insuf)	.00000	10.000	6.0000
substrates.NumberBusy	.38387	(Insuf)	.00000	1.0000	1.0000
substrates.NumberSched	1.0000	(Insuf)	1.0000	1.0000	1.0000
substrates.Utilization	.38387	(Insuf)	.00000	1.0000	1.0000
sewingmachines.NumberB	.45865	(Insuf)	.00000	1.0000	.00000
sewingmachines.NumberS	1.0000	(Insuf)	1.0000	1.0000	1.0000
sewingmachines.Utiliza	.45865	(Insuf)	.00000	1.0000	.00000
woodcutter.NumberBusy	.10384	(Insuf)	.00000	1.0000	.00000
woodcutter.NumberSched	1.0000	(Insuf)	1.0000	1.0000	1.0000
woodcutter.Utilization	.10384	(Insuf)	.00000	1.0000	.00000
gerbercutter.NumberBus	.12048	(Insuf)	.00000	1.0000	.00000
gerbercutter.NumberSch	1.0000	(Insuf)	1.0000	1.0000	1.0000
gerbercutter.Utilizati	.12048	(Insuf)	.00000	1.0000	.00000
upholstering.NumberBus	.56350	(Insuf)	.00000	1.0000	1.0000
upholstering.NumberSch	1.0000	(Insuf)	1.0000	1.0000	1.0000
upholstering.Utilizati	.56350	(Insuf)	.00000	1.0000	1.0000
gluing.NumberBusy	.12597	(Insuf)	.00000	1.0000	.00000
gluing.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
gluing.Utilization	.12597	(Insuf)	.00000	1.0000	.00000
Cutter.Queue.NumberInQ	.00171	(Insuf)	.00000	1.0000	.00000
Upholstry.Queue.Number	.05944	(Insuf)	.00000	1.0000	.00000
Sewing.Queue.NumberInQ	.12591	(Insuf)	.00000	2.0000	.00000
Setup.Queue.NumberInQu	.09469	(Insuf)	.00000	2.0000	1.0000
Gerber.Queue.NumberInQ	.00814	(Insuf)	.00000	1.0000	.00000
Foaming.Queue.NumberIn	.00000	(Insuf)	.00000	.00000	.00000
Batch 1.Queue.NumberIn	.51506	(Insuf)	.00000	2.0000	1.0000

OUTPUTS

Identifier	Value
Entity 3.NumberIn	54.000
Entity 3.NumberOut	48.000
substrates.TimesUsed	15.000
substrates.ScheduledUti	.38387

sewingmachines.TimesUse	21.000
sewingmachines.Schedule	.45865
woodcutter.TimesUsed	16.000
woodcutter.ScheduledUti	.10384
gerbercutter.TimesUsed	21.000
gerbercutter.ScheduledU	.12048
upholstering.TimesUsed	17.000
upholstering.ScheduledU	.56350
gluing.TimesUsed	14.000
gluing.ScheduledUtiliza	.12597
System.NumberOut	16.000

Figure 6. Results from the Simulated Future State Model

The replication was run for ten hours. The creation time, which controls how often an entity is sent through the process, that was used was based on the largest processing time (Upholstery) to simulate a pull system. The reason that there are products in the queues before each process is that there is a built in variation in the processing time for the Upholstery station and the arrival times are exponentially distributed.

Initial observations are that the average lead time for each part will be 356 minutes which is down from 11741 minutes in the current state. The reason for such a dramatic change is the elimination of the inventories between each process. The lowest lead time is 40 minutes which is closer to how the process will actually be. The lowest lead time always belongs to the first entity sent throughout the system because it is able to avoid the log jam that arises as time goes on. The WIP was decreased to an average of 3.84 parts going through the process at a given time.

A summary of the most important information can be found in the Outputs section of the report. The Times Used tells how many times that each of the different resources was seized by the

entity. The Scheduled Utilization shows what percentage of time that the resource is in use. This is a perfect scenario, however, that does not take into account any breaks, worker socializing, etc.

Cost Benefit Analysis:

From our suggestions the main costs will be to implement the gluing equipment at the different stations. By eliminating the storage and adjusting the production rate to a streamlined number of boats/ week, the addition of the glue equipment should pay itself off very quickly. It will also cost money to train the employees to use the equipment but this cost should be insignificant. The workers that sew and cut wood could also be cross trained to perform other tasks while waiting on the assembly operation to signal them.

Recommendations:

After completing the senior design project there are several observations that can be concluded and suggestions made. It was found that a fundamental component of change would be the involvement of the persons who will have to make the change within the system. In this project it was important for the workers to understand that change was being made to improve not only the flow of the parts but to also improve the environment and conditions the workers were previously working in. Ergonomics was a key component in redesigning the work cell.

The best approach was to be open and up front with the workers. By genuinely identifying with a worker, getting that particular worker to be open to change was that much simpler. The opinions from the workers are valid and should always be considered to some degree to ensure the individuals that the best possible solutions will be the end result of the project.

Another recommendation would be to strive to think lean on a continuous basis. Lean manufacturing is a way of thinking that will shape the culture of a company and will serve as a continuous improvement process. There are always ways to improve and to keep improving upon different processes. One objective of lean manufacturing is the development of one piece flow and a pull or con-wip system. The ultimate solution would be a complete pull system. This system would only introduce raw materials and require manufacturing upon request from a signal in the process. This would eliminate vast amounts of inventory and work in process.

A con-wip system would be a preliminary system to the pull system or it could become the system under which the manufacturing processes of the upholstery department parts are completed. This system will make parts and then at a certain point a signal will have to identify the need for a certain cushion or material. This system is easier to implement and analyze, as well as more cost and time effective.