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Lean Implementation Through Process Automation

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“LEAN IMPLEMENTATION THROUGH PROCESS AUTOMATION”

A thesis submitted to satisfy requirements for the

Master of Manufacturing Engineering program

By

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TABLE OF CONTENTS

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ABSTRACT

As lean manufacturing is increasingly becoming a common practice today in an effort to keep companies competitive, new and innovative processes are becoming the norm. Part of that innovation includes the development of automated machinery that can help alleviate some struggles with lead times and reduce overall labor. It is all in keeping with the trend of building products cheaper and faster to gain that edge.

Company X has been focusing their efforts on lean manufacturing for years now. This paper covers an important project that involves the implementation of a complex mechanical system in an effort to build products faster, smarter, and simpler while keeping lean manufacturing in mind.

Some of the lean tools used are Value-Stream Maps, Spaghetti Diagrams, Time Studies, and understanding the 5S+1 principle in order to understand the product flow, identify both value added and non-value added work, all to eliminate waste during the product build.

DEFINITION OF MAJOR TERMS

WIP

Work-in-progress, also called work in process. It is inventory that has begun the manufacturing process and is no longer included in raw materials inventory, but is not yet a completed product

(TechTarget.com)

JIT

Just-In-Time. It is an inventory strategy companies employ to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs.

(Investopedia)

Batch Processing

Manufacturing process in which components or goods are produced in groups and not in a continuous stream

(Business Dictionary)

One Piece Flow

Concept of moving one workpiece at a time between operations within a work cell – Opposite of “Batch Processing”

(Strategosinc.com)

Kanban

Materials requirement planning technique developed by Toyota Corporation (as a part of just-in-time inventory system) in which work-centers signal with a card when they wish to withdraw parts from feeding operations or the supply bins

(Business Dictionary)

Kaizen

Also known as continuous improvement, is a long-term approach to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality

(SearchManufacturingERP.com)

Value Added Work

Activities that further the purpose of an organization by generating output that is considered more valuable by its internal and/or external customers than the inputs consumed in producing it

(Business Dictionary)

Non-Value Added Work

Activities that generate a zero or negative return on the investment of resources and usually can be eliminated without impairing a process

(Business Dictionary)

Time Study

Method for establishing employee productivity standards in which (1) a complex task is broken into small, simple steps, (2) the sequence of movements taken by the employee in performing those steps is carefully observed to detect and eliminate redundant or wasteful motion, and (3) precise time taken for each correct movement is measured

(Business Dictionary)

Spaghetti Diagram

A spaghetti diagram (sometimes called a physical process flow or a point-to-point workflow diagram) is a line-based representation of the continuous flow of some entity, such as a person, a product or a piece of information, as it goes through some process

(TechTarget.com)

Value Stream Map

A Toyota lean manufacturing visualization tool for documenting all the processes that are required to bring a product to market

(SearchManufacturingERP.com)

Chapter 1

INTRODUCTION

1.1 Background

This project was completed at Company X in Minneapolis, Minnesota. The company produces industrial Heating, Ventilation, and Air-Conditioning (HVAC) units. The company has several assembly stations for the unit builds and a fabrication area to manufacture the unit components.

The fabrication shop consists of three turret-style punch presses, four hydraulic press brakes, and two foam injection press machines. The parts that come out of the fabrication area are critical to the timeline of the unit build as the base parts, exterior panels, ceiling, and several interior components are fabricated onsite.

Sheet metal is taken to a punch press where flat parts, or blanks, are punched out and set on a table as a kit. This kit is then sent to one of the press brakes where the operator forms them to the specifications provided from an inventory of programs stored on the controller. Once all the parts in the kit have been formed, panels that need a foam injection get sent to the foam press and the rest get sent to the assembly station. This process within the fabrication area can take up to three days depending on the volume of work coming to the shop.

Through this process, Company X was experiencing large amounts of wok-in-process (WIP) after every operation since batch manufacturing and push system were part of the process used to produce parts. This led to several bottleneck problem areas in the fabrication process.

To become lean in their manufacturing, new methods were sought ought and that is where the automation and pull system were employed. The company recognized the benefits of a one-piece flow to improve the overall process and eliminate a lot of non-value added time.

1.2 Statement of the Problem

Disorganized flow of production through batch processing and push method results in bottleneck areas and more jobs being worked on more than is necessary, creating extra WIP.

To combat this, Company X decided to move from batch processing to a one-piece flow and implement some automation through lean manufacturing principles.

1.3 Purpose of the Study

The current state of the fabrication shop was in dire need of improvement. The principles of lean manufacturing were implemented and results were analyzed to see how much improvement in productivity was gained through the new machinery and lean practices.

1.4 Thesis Outline

This paper was developed using the “IMRAD” method:

(Esperado, 2016)

Introduction – What is the problem?

- Explaining the problem and why it was necessary by explaining the current state

Methodology – What was done?

- What was done as part of the research and solution to the problem

Research – What was found?

- What the findings and outcomes of the research were using data

Analysis – What does it mean?

- Interpreting the data

Discussion – What are the tangible conclusions?

- Resulting conclusions from the analysis

Chapter 2

LITERATURE REVIEW

2.1 Lean Manufacturing

From the very many definitions of Lean Manufacturing, it can best be described as a manufacturing philosophy that focuses on continuous improvement in a production process. A huge part of continuous improvement is the elimination of waste (McLaughlin, 2011).

Anything that does not add value to the end product is waste (Pride, Hughes & Kapoor, 2012) and the principle of lean encourages a smooth flow throughout the manufacturing process. This leads to a faster and more efficient method of producing a product.

Womack and Jones (Lean Thinking) stress the importance of creating value for the customer where value is what the customer is willing to pay for. Many companies today are beginning to see the value in leaning out manufacturing processes by taking out the non-value added and unnecessary work that takes up time to build the product being paid for.

As an example, in a process to build a box; the customer pays for the finished product which means a flat part bent on four sides. What is being paid for is the flat part, then bending the sides that form the box and a quality finish. Extras such as transporting the part, storing the part, polishing the part, rework if the part was defective, etc. This is illustrated with the following diagram.

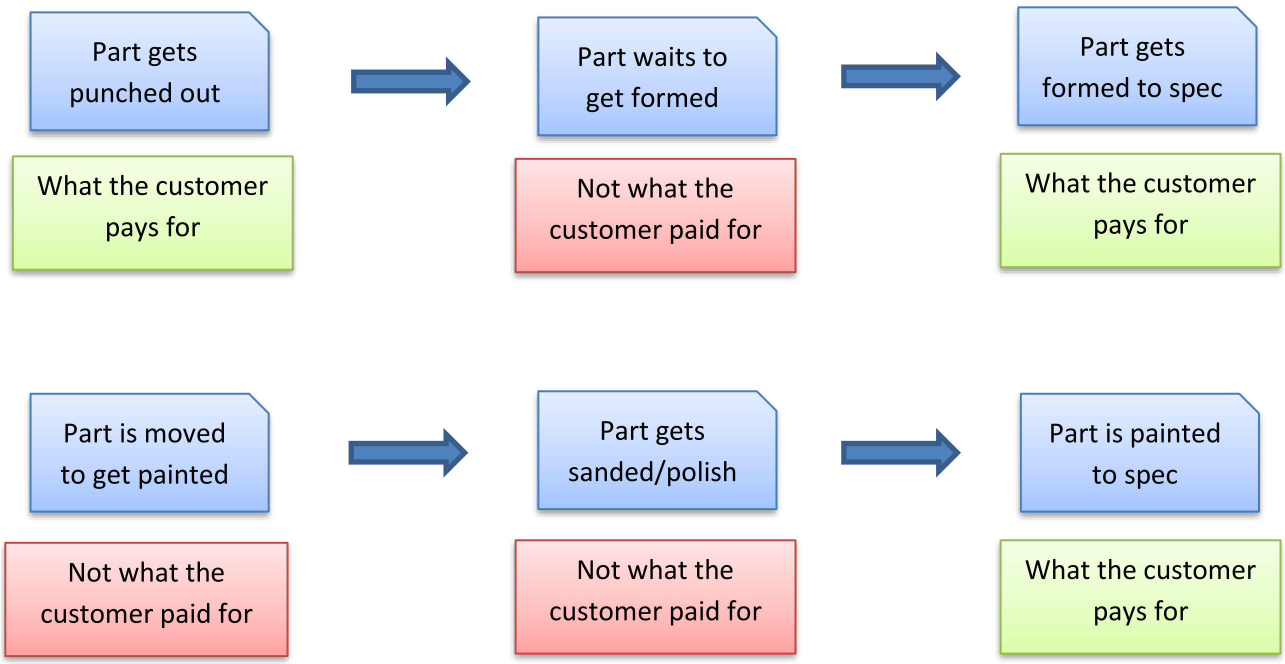

Figure 1; Part Process

Even though polishing or sanding would make for an excellent finish, it is not what the customer required. Some non-value added work is required by the company to distinguish them from the competition by producing better quality but it is all done at the company's expense.

Companies today try to maintain lean practices through daily processes, or Kaizen, where the operation is briefly reviewed to eliminate waste and improve process reliability (Manzouri, 2014). In the example above, a cost reduction in the process would be an elimination of the sanding/polishing process. Another would be an implementation of Just-In-Time where parts are produced when needed to eliminate wait times. Some steps are unavoidable such as transportation between machines to have the part punched out, formed, and painted. That is where creativity is encouraged and some automated machinery could be implemented. An example would be moving all the machines or work areas together and having a conveyor system between them to keep the workers working while the machines transport the product.

2.2 The 8 Wastes in a Manufacturing Process

Muda, or waste, is the main cause of inefficiency in production. In order to become more efficient, companies will need to identify waste not just from the production side, but also from the perspective of the customer and eliminate it (Domingo).

One way to think of waste is to see it as the leading cause of downtime. Hence, the acronym D.O.W.N.T.I.M.E. can help identify the eight wastes in every process (Stack, 2010).

DEFECTS

OVER-PROCESSING

WAITING

NON-UTILIZED TALENT

TRANSPORTATION

INVENTORY

MOTION

EXTRA-PROCESSING

DEFECTS

Non-Conformance or shortcoming that prevents an item from being complete, desirable, effective, safe, or of merit, or makes it to malfunction or fail in its purpose (Business Dictionary).

In other words, results that are not acceptable to customers and require rework; caused by incorrect information, expiration of materials, bad quality materials, etc.

In a manual forming process at a press brake, the operator is responsible for reading the bend prints provided by the engineers and programming the controller to form the parts.

This presents some challenges as there have been issues with the prints themselves, human error coming from the operator not understanding how to form the parts, and many others…

With the new system, this becomes an automated process where bend programs have been installed into the system and tested. Any part delivered to the new forming machine will be bent to specifications repeatedly without errors. This eliminates the rework process and defects by having a quality part without the human factor.

OVERPRODUCTION

Making products in too great a quantity before it is actually needed leading to excessive inventory (Lean Manufacturing Tools).

The process of punching parts and storing them until an operator is ready to form them leads to the over-processing of parts to create a WIP of jobs.

With the new system, parts are processed much faster and an estimated finish time is easier to determine so a JIT production style can be implemented in order to avoid storing unnecessary jobs, leaving parts vulnerable to damages and getting lost.

WAITING

The act of doing nothing or working slowly whilst waiting for a previous step in the process (Lean Manufacturing Tools).

In the new system, the parts are punched out and immediately transferred to an automated press brake where they are formed. This eliminates the waiting period where some parts would sit on carts for up to two days until an operator gets to form them.

This process also changes the batch processing of jobs in the sense that a part is formed within a minute after it has been punched out. Labor is saved in this process and so is the risk of losing parts between the punch and forming process.

NON-UTILIZED TALENT

Failure to make good use of employees; all of them (Lean Manufacturing Tools).

The operators have years of experience and some have a skill set that may not be tied to their production jobs. The introduction of new technology gives an opportunity to some individuals to shine with their technological knowledge or mechanical aptitude.

As an example, an operator with knowledge on how to work out computer issues will save the company money by reducing the downtime compared to an employee who sits and waits for a technician or engineer to resolve the issue. This would be a valuable employee and an asset to the company.

TRANSPORTATION

The movement of products from one location to another (Lean Manufacturing Tools). This movement of products or materials is unnecessary and disrupts manufacturing production processes.

The unnecessary moving of parts to store or transfer them in the production process is eliminated to reduce waste. Parts are taken directly from the punch press to the press brake with the assistance of a material transfer conveyor system.

This is a non-value added process that the customer does not pay for. Hence, the more automated a process like this can become, it turns into more profit for the company by reducing labor from operators taking the time to transfer parts from one machine to the other.

INVENTORY

Raw materials, work in progress (WIP) and finished goods stock that is held; we often hold far more than is required to produce goods and services when the customer wants them using Just in Time (JIT) principles (Lean Manufacturing Tools).

Tied to over-production, since a JIT methodology will be replacing the current process, inventory drastically reduces to what is needed which in turn gets delivered to the assembly side when it is needed.

Through this, we are eliminating the storage of parts that may get lost in storage or get damaged while waiting to be used in the assembly process.

MOTION

Waste due to motion is a process step that is not value added where moving is not necessarily working (Lean Manufacturing Tools). Basically, the movement of people that is unnecessary consumes energy and time that could be put into something else that is valuable to the production.

Having an automated system takes care of the time and energy spent by the operators in moving parts from one place to the other.

The machine itself is designed to bring some ease to the operator; the sheet metal is placed on a loading table and the machine takes care of the rest. A loader picks up the sheet and places it in the punch and from there, the parts get sent to the press brake where a robotic manipulating arm grabs the part and forms it in the machine. That is a lot of saved energy for the operator.

EXTRA-PROCESSING

Adding more value to a product than the customer actually requires (Lean Manufacturing Tools). An example is putting more work and effort than is necessary for the job such as painting areas that will never be seen or exposed to corrosion.

The extra work and labor that goes into additional processing when parts are reworked is eliminated in this process. The elimination of this ensures that quality time and effort is spent on value-added processes for the final product.

2.3 Eliminating waste

To tackle the issue of waste, the current process must be examined. The flow of parts from one operation to the next should be observed with how it affects the process. Batch processing of jobs is an excellent way to observe a disrupted flow. A good place for a company to begin the journey to lean is to create continuous flow wherever applicable in its core manufacturing and service processes (Liker, 2004).

The current state can be laid out using a value stream map where value added services are easily identified along with waste. Through the map, the circuitous path can be followed to determine what the future state should look like.

Step one is to realize that there are wastes in the system to be removed. This first step is done by an analysis of the organization, often conducted by outside sources in order to provide a new set of eyes on what are normal day-to-day operations by all the permanent employees who might not realize areas that can be reduced or removed. Once this is complete, you can move on to the second step.

In the second step, you will identify the different forms of that waste and then identify the cause of that waste.

The third step in the process is finding the cause of the waste. To do this the organization must adhere "to the basic lean manufacturing principle of seeing the total picture and the bid effect the solution will have on the entire system.

The last step is the implementation process and making sure things are going in the intended way. Here the solutions will be tested and implemented. Then these solutions will be tweaked to accommodate practical difficulties occur in the implementation process.

The lean process steps coupled with the tools implemented through the process if the median used for development of efficiency. The diagram below shows the four-step process and implementation of the lean tools. It will be the same tools we will see as we transition to the review of case studies from real business fields.

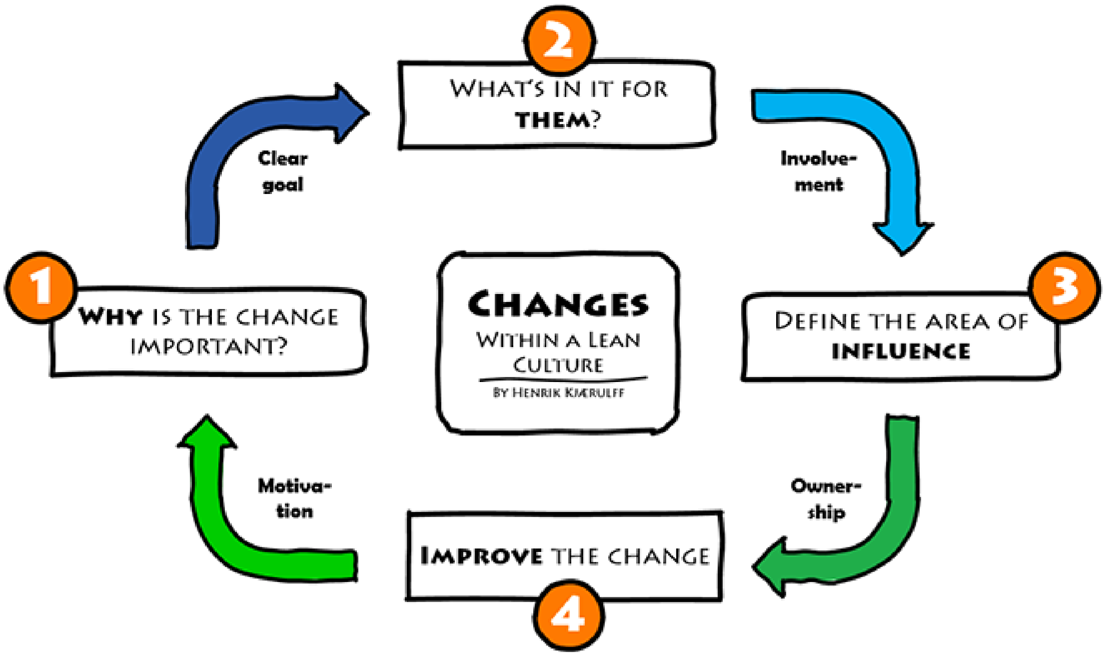

Figure 2; Four Steps to Change Management (www.LinkedIn.com)

Lean implementation is a journey that takes many years (Pearce & Pons, 2013) and requires a cultural change. Companies with this understanding are willing to accept that change takes time and in the case of lean, it is never ending. Company X has been implementing lean since 2003 and one constant is the fact that there is always going to be a better way of doing things; One change in a process today can be improved a day, week, month, or year from now.

Chapter 3

METHODOLOGY

3.1 Methodology Flow Chart

The flow chart below shows the steps used in the methodology of this project. It shows a high level overview of the engineering methodology.

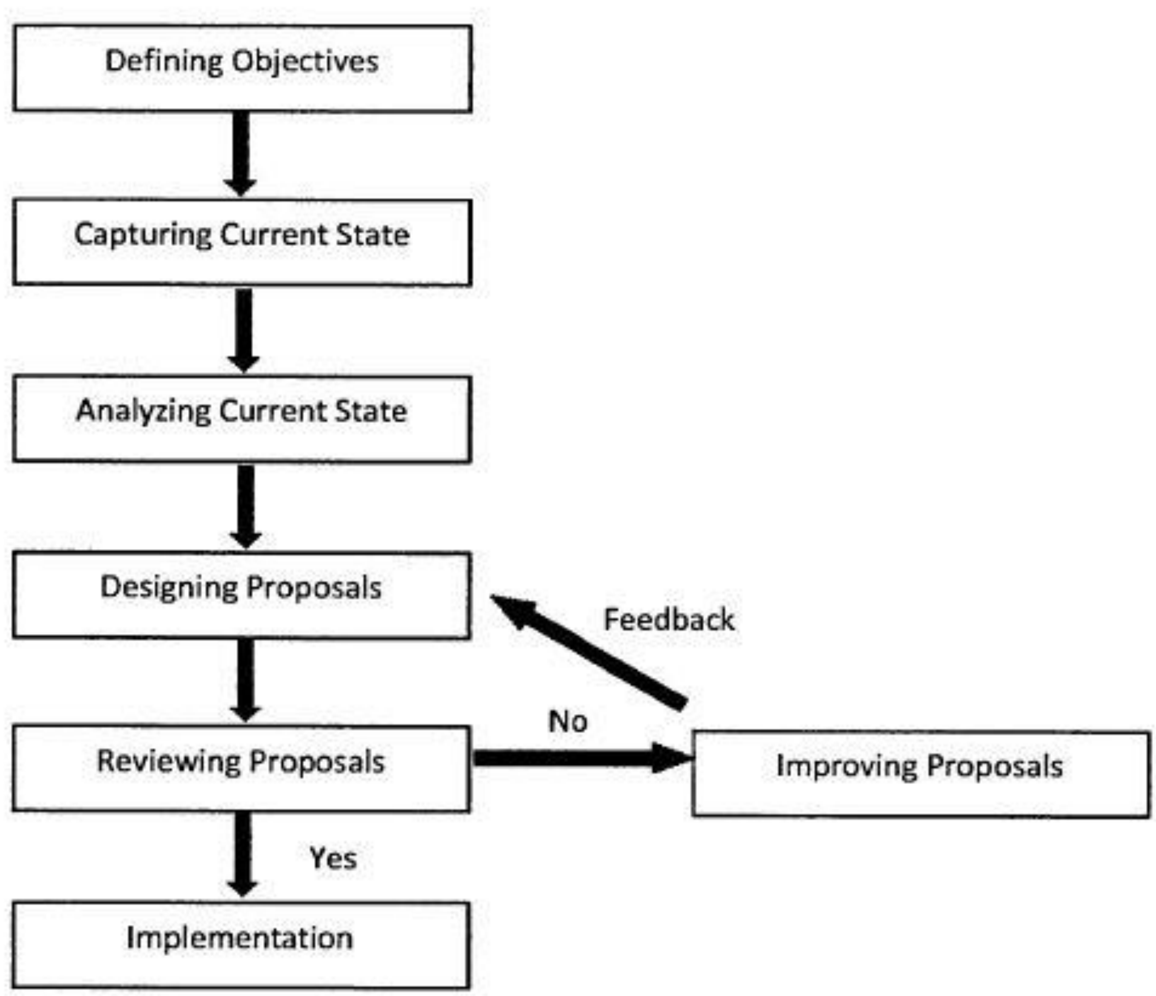

Figure 3; Methodology Flow Chart

3.2 Defining Objectives

The goals, objectives, and scope for this project were defined in the preliminary stages with the involvement and ultimately, the buy-in of upper management. They in turn, communicated the information down to the supervisors and operators to start a culture change. The operators were informed of what to expect and assurances were made that jobs would not be lost as a result since it came up as the number one concern over the purchase of automated machinery.

Subsequent meetings were had with team members to iron out the goals in order to remain consistent in our project. An action plan and timeline was drawn up in order to achieve the goals with some contingencies put in place. An example of one such plan was having an outsourcing vendor to handle our punch/form capacity as we would have a couple of machines out of commission during the take-down of the obsolete machinery and set-up of the automated system.

3.3 Current State

To get a sense of how the manufacturing process was operating to identify opportunities for improvements, the current state was observed and mapped out. Time studies were done and opportunities for improvements through lean were identified.

Due to our batch processing or kitting of parts for jobs, the issues were quite obvious. The start of the process involves punching sheet metal where the operators would punch out blanks, or flat parts. The problems here were:

- Punch machines were old and to get parts out of the sheet metal after punching, the operators would have to shake the parts out of the sheets. These sheets were as light as 22 gage (0.031” thin) and went up to 10 gage (0.135” thick) which posed an ergonomic and safety issue as parts would sometimes fly out or operators would complain of wrist discomfort from lifting.

- Parts were stacked in carts until they were ready to be moved to the next operation which led to a buildup of work-in-progress (WIP).

The next process was forming the parts where a traditional press brake would be used. Here, some more red flags were raised:

- Some parts were up to 12 feet long, some 5 feet wide, and some were a mix of both which made handling them awkward, leading to some damaged parts from operator handling.
- Programming time at the press brake made it a huge bottleneck area as the press brake times were slower than the punches.

The next part of the process is the foam preparation and foam injection process which was not in the scope of the project but the issues seen there dealt with waiting on parts from the press brakes so the focus remained on the first two stages of punching and forming.

Current State Flow Map

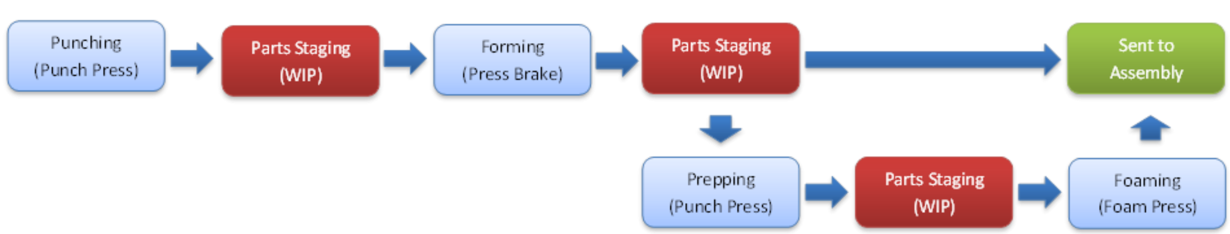

Figure 4; Current State Parts Flow Map

Value Stream Map

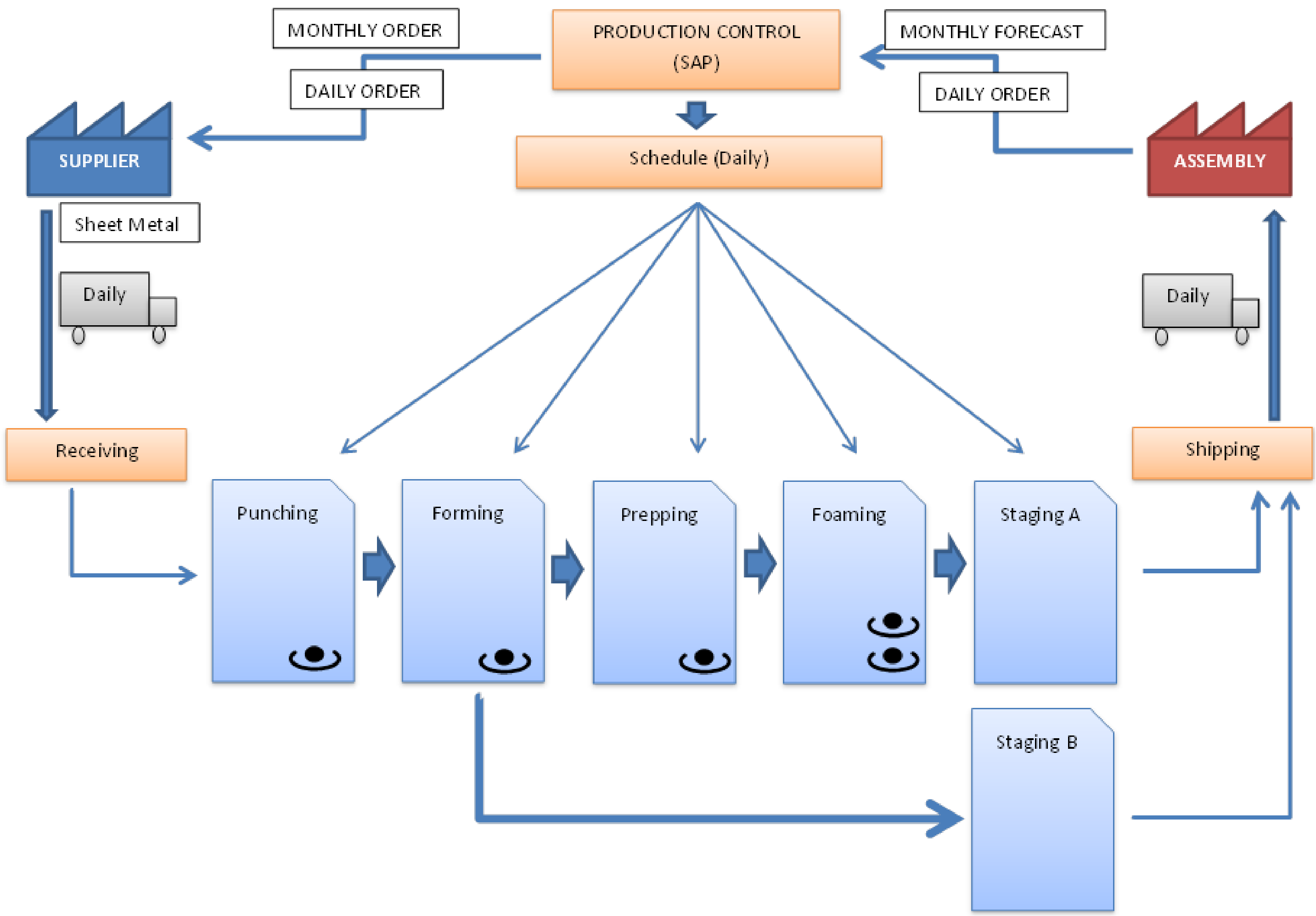

Figure 5; Current State VSM

The Value Stream Map and Flow Map show an overview of the manufacturing process where parts flow from the punch down to our staging before being carried off to the assembly work area when needed. The problem with the push system is the creation of a lot of WIP. One major problem area is the forming at the press brakes; with punched parts coming in from the punch machines, the press brake operator has to separate the parts for the appropriate carts and channels. The work at the forming press is so tedious that it is the biggest bottleneck in the factory. With our new process, the plan is to make it easier for the operators by separating the biggest concern items, foamed panels.

3.4 Future State

Knowing what our problem areas were, research was done to look into automated machinery to minimize transportation and eliminate the potential material damage due to handling. From a trip to a fabrication convention (FabTech), a solution was found to tackle not one, but multiple issues. Upon further research and discussions with the machine developers, we settled on a combination punch and bend machine. This would effectively eliminate the WIP as well as time spent waiting. It was also a machine equipped with a robotic arm to bend panels which meant no operator involvement until the final product was ready.

Knowing that our press brake operators especially newer workers had issues with the separation of primarily foamed and non-foamed parts, that became the focal point of the project; separation of foamed/non-foamed parts. This would create two separate fabrication lines where we would be able to eliminate WIP and have a smoother flow. From an ergonomic standpoint, there was a win as we were moving the bulkier and bigger parts to an automated machine so we could improve safety in the shop for the operators.

Future state flow map / layout (Proposal)

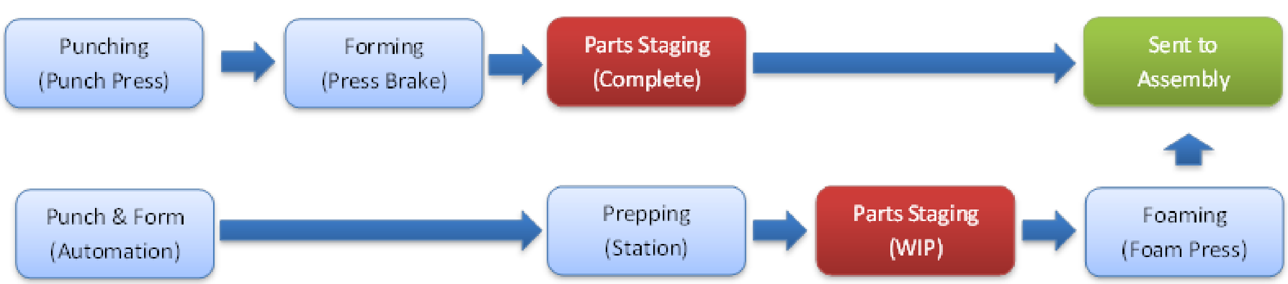

Figure 6; Future State Parts Flow Map

Value stream map (Future state)

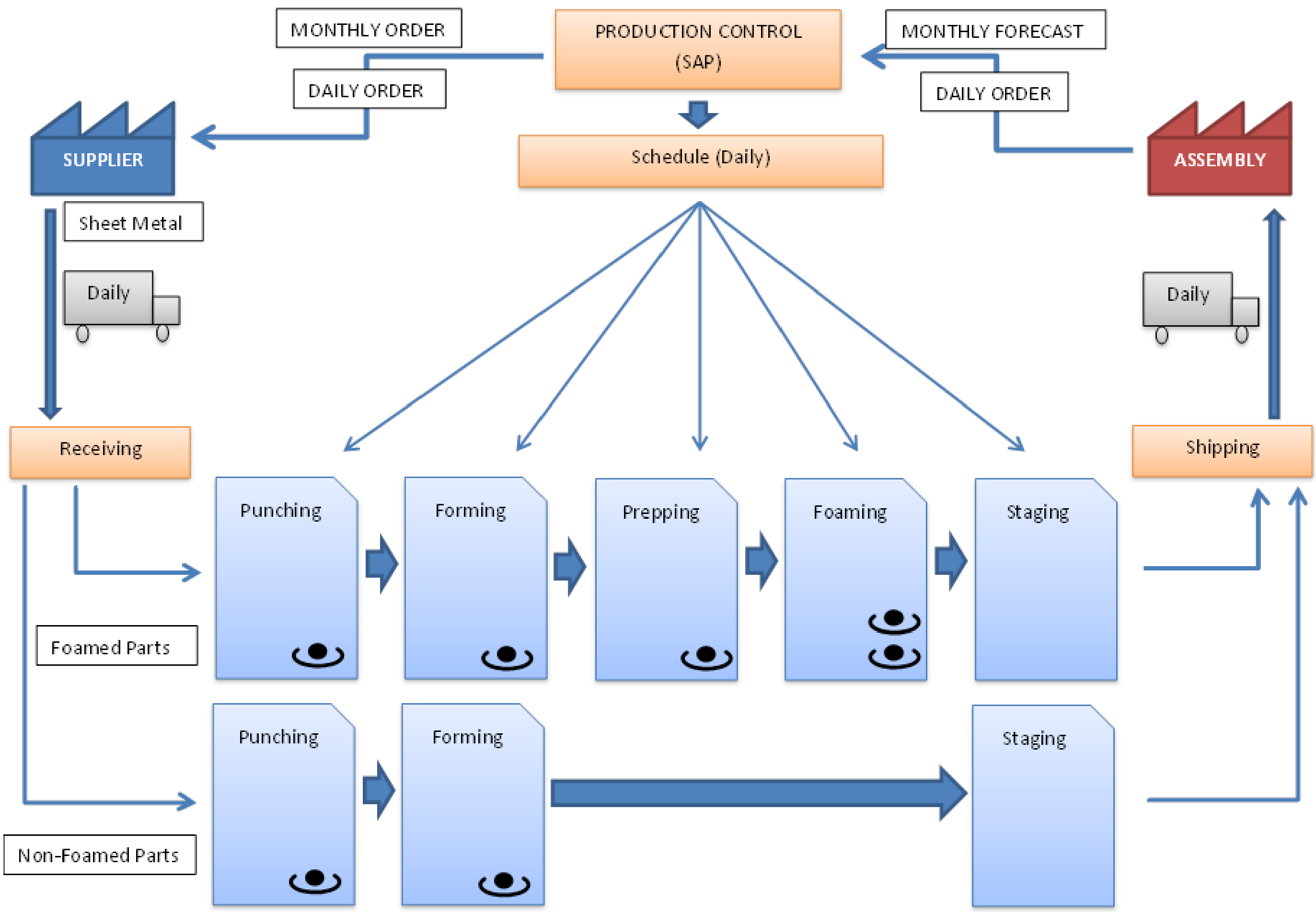

Figure 7; Future State VSM

The proposed change to the VSM shows where we have a separation of product between the foamed and non-foamed parts. This initially seemed like a process creating more work for the operators but our brainstorming sessions were able to clarify the improvements to be gained from the separation; one process would be more streamlined as they would just be staged once parts were formed and the new machine would take care of the foamed parts where we would have more labor available to process and prep the parts as they were formed.

3.5 Implementation

The implementation was three-fold. First, the machine would be developed in Europe and we would fly there to see the machine run before signing off on it to be shipped to Minneapolis. Second, the machine would be set up by the developers. Then the final stage was testing to have the entire machine run during production.

This implementation process took months to finalize as there were training sessions with operators and weekly meetings held in order to reiterate the culture change to lean production throughout the facility.

Chapter 4

RESEARCH

4.1New Process

Sample run off tests were conducted at the production facilities in Italy and Finland where the machine was developed. The punch machine was built in Finland where sample programs were run to satisfaction and the bend machine was built in Italy where hurdles were encountered but the development team worked diligently to overcome. The testing was a success and the test numbers were sent back to Minneapolis to confirm and re-evaluate what the potential savings would be.

The new production flow map showed a clearer vision of how the facility production would be changing as shown below. From the previous process, we would eliminate the wait and WIP build up before the forming when it came to foamed panels. This separation also gave us some relief by increasing our punch capacity on the manual punch presses.

Overall, this new process and machine acquisition became a capacity expansion project where we were not only able to improve our manufacturing process and ergonomics, but we were able to effectively eliminate the third shift production and still go from a $70 million business to a $90 million business allowing our sales to promise shorter lead times and effectively sell more product.

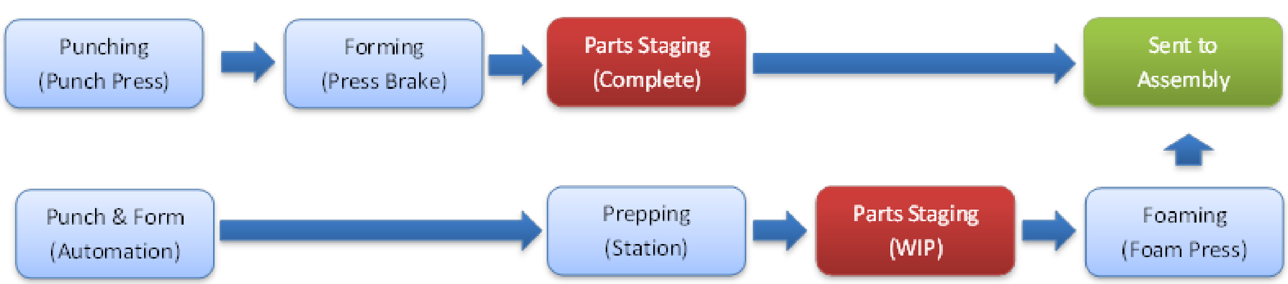

Figure 8; New Process Parts Flow

4.2 Time Study Results

Punch Press					
Sheet	Loading Sheets on Machine	Loading Programs	Punching	Shaking Sheets / Collecting Parts	Transfer to Press Brake (Approx.)
1	0:46	0:32	12:02	3:06	4hrs
2	1:01	0:26	8:51	4:23	4hrs
3	1:42	0:54	11:16	4:56	12hrs+
4	0:36	0:15	10:54	4:15	2hrs
5	1:20	0:19	7:01	2:03	12hrs+
6	0:48	0:22	16:51	5:51	12hrs+
7	0:32	0:09	5:33	2:33	12hrs+
8	0:36	0:31	8:25	5:52	12hrs+
9	0:51	0:36	12:52	7:03	4hrs
10	1:09	0:19	8:56	4:16	4hrs
11	1:22	0:11	12:47	3:56	12hrs+
12	0:35	0:16	10:09	4:53	12hrs+
13	0:44	0:24	6:00	2:12	3hrs
14	0:55	0:22	9:23	4:21	12hrs+
15	0:51	0:35	7:41	3:37	3hrs
16	0:41	0:54	9:17	3:01	1hr
17	0:59	0:20	12:56	4:17	12hrs+
18	0:40	1:02	9:21	3:44	12hrs+
19	0:33	0:17	8:42	2:09	12hrs+
20	0:57	0:54	8:13	6:13	12hrs+
21	0:59	0:24	8:19	3:17	12hrs+
22	0:44	0:41	11:30	7:41	12hrs+
23	0:41	0:32	-	-	12hrs+
24	1:20	0:24	-	-	12hrs+
25	0:57	0:36	-	-	12hrs+
26	1:11	0:27	5:21	2:11	3hrs
27	0:45	0:55	10:32	8:31	<2hrs
28	1:03	0:29	11:01	4:33	<2hrs
29	0:45	0:51	7:22	5:44	2hrs
30	0:51	0:36	6:14	6:03	2hrs
31	0:49	0:21	8:51	3:47	12hrs+
32	0:33	0:25	8:36	1:33	12hrs+
33	0:54	0:29	16:32	4:01	12hrs+
34	0:56	0:34	3:52	1:57	12hrs+
35	1:02	0:44	11:33	6:00	12hrs+
36	0:36	0:26	14:29	4:26	<1hr
37	0:24	0:51	9:34	3:33	<1hr
38	0:42	0:41	8:08	3:58	12hrs+
39	1:21	0:59	8:34	4:37	12hrs+
40	0:54	0:26	14:46	3:16	12hrs+
41	1:46	0:19	10:09	7:51	12hrs+
42	0:56	0:24	8:45	3:41	6hrs
43	0:49	0:23	6:46	2:38	6hrs
44	0:36	0:16	7:51	4:18	12hrs+
45	1:05	0:52	8:37	8:02	12hrs+
46	1:00	0:30	12:49	4:49	6hrs
47	0:39	0:58	-	-	12hrs+
48	1:06	0:41	-	-	12hrs+
49	0:37	0:32	7:02	5:15	12hrs+
50	0:51	0:23	9:25	4:31	1hr

Figure 9; Punch Press

Figure 10; Press Brake

Press Brake			
Part	Loading Programs for Parts	Bending	Transfer to Cart
1	0:42	2:59	0:06
2	0:31	3:51	0:09
3	0:39	2:16	0:04
4	0:16	4:55	0:05
5	0:44	4:27	0:16
6	0:41	0:48	0:03
7	0:33	3:36	0:02
8	0:45	2:49	0:06
9	0:21	6:21	0:06
10	0:05	3:17	0:01
11	0:35	4:32	0:09
12	1:01	3:06	0:11
13	0:42	2:51	0:04
14	0:37	6:19	0:06
15	0:33	10:45	0:06
16	0:28	1:45	0:04
17	0:46	4:11	0:02
18	1:04	3:40	0:03
19	0:51	3:56	0:06
20	0:46	1:50	0:08
21	0:41	3:01	0:06
22	0:37	0:52	0:09
23	1:02	3:41	0:04
24	0:49	2:11	0:07
25	0:33	2:38	0:03
26	0:45	3:06	0:03
27	0:26	2:14	0:06
28	0:05	3:55	0:05
29	0:48	6:03	0:08
30	0:33	-	-
31	0:31	-	-
32	0:46	-	-
33	0:57	-	-
34	0:44	-	-
35	1:21	-	-
36	0:14	0:06	0:03
37	0:26	0:53	0:06
38	0:21	2:30	0:03
39	0:33	3:16	0:01
40	0:55	2:01	0:02
41	0:51	4:29	0:09
42	0:32	5:13	0:06
43	0:46	4:48	0:04
44	1:01	5:02	0:04
45	0:34	2:08	0:06
46	0:45	3:35	0:05
47	0:49	2:42	0:02
48	0:38	2:16	0:04
49	0:31	3:45	0:03
50	0:09	0:53	0:06

Prima								
Part	Loading Sheets on Machine	Loading Programs	Punching	Shaking Sheets / Collecting Parts	Transfer to Press Brake	Loading Programs for Parts	Bending	Transfer to Cart
1	0:35	2:30	4:23	0:00	0:30	0:00	0:45	0:00
2	0:35	2:16	5:32	0:00	0:30	0:00	0:45	0:00
3	0:35	1:42	4:01	0:00	0:30	0:00	0:45	0:00
4	0:35	1:11	4:22	0:00	0:30	0:00	0:45	0:00
5	0:35	1:26	4:57	0:00	0:30	0:00	0:45	0:00
6	0:35	1:03	3:16	0:00	0:30	0:00	0:45	0:00
7	0:35	1:54	4:21	0:00	0:30	0:00	0:45	0:00
8	0:35	3:52	4:26	0:00	0:30	0:00	0:45	0:00
9	0:35	2:06	3:51	0:00	0:30	0:00	0:45	0:00
10	0:35	2:13	2:34	0:00	0:30	0:00	0:45	0:00
11	0:35	2:54	4:53	0:00	0:30	0:00	0:45	0:00
12	0:35	1:34	4:16	0:00	0:30	0:00	0:45	0:00
13	0:35	3:21	4:33	0:00	0:30	0:00	0:45	0:00
14	0:35	1:09	5:43	0:00	0:30	0:00	0:45	0:00
15	0:35	1:54	5:08	0:00	0:30	0:00	0:45	0:00
16	0:35	1:46	4:02	0:00	0:30	0:00	0:45	0:00
17	0:35	1:20	4:55	0:00	0:30	0:00	0:45	0:00
18	0:35	2:06	4:34	0:00	0:30	0:00	0:45	0:00
19	0:35	2:05	3:17	0:00	0:30	0:00	0:45	0:00
20	0:35	1:53	4:08	0:00	0:30	0:00	0:45	0:00
21	0:35	6:32	3:19	0:00	0:30	0:00	0:45	0:00
22	0:35	4:14	9:03	0:00	0:30	0:00	0:45	0:00
23	0:35	2:06	3:56	0:00	0:30	0:00	0:45	0:00
24	0:35	1:09	4:09	0:00	0:30	0:00	0:45	0:00
25	0:35	1:16	4:37	0:00	0:30	0:00	0:45	0:00
26	0:35	1:49	4:05	0:00	0:30	0:00	0:45	0:00
27	0:35	5:02	3:51	0:00	0:30	0:00	0:45	0:00
28	0:35	2:48	4:37	0:00	0:30	0:00	0:45	0:00
29	0:35	1:42	5:32	0:00	0:30	0:00	0:45	0:00
30	0:35	1:31	2:19	0:00	0:30	0:00	0:45	0:00
31	0:35	1:59	5:34	0:00	0:30	0:00	0:45	0:00
32	0:35	2:12	2:31	0:00	0:30	0:00	0:45	0:00
33	0:35	3:16	5:01	0:00	0:30	0:00	0:45	0:00
34	0:35	3:48	4:36	0:00	0:30	0:00	0:45	0:00
35	0:35	1:13	4:14	0:00	0:30	0:00	0:45	0:00
36	0:35	1:51	4:47	0:00	0:30	0:00	0:45	0:00
37	0:35	1:53	3:26	0:00	0:30	0:00	0:45	0:00
38	0:35	2:41	1:54	0:00	0:30	0:00	0:45	0:00
39	0:35	2:56	4:26	0:00	0:30	0:00	0:45	0:00
40	0:35	1:09	4:54	0:00	0:30	0:00	0:45	0:00
41	0:35	1:28	6:03	0:00	0:30	0:00	0:45	0:00
42	0:35	3:06	4:11	0:00	0:30	0:00	0:45	0:00
43	0:35	1:16	4:52	0:00	0:30	0:00	0:45	0:00
44	0:35	1:53	3:19	0:00	0:30	0:00	0:45	0:00
45	0:35	1:44	3:18	0:00	0:30	0:00	0:45	0:00
46	0:35	2:22	3:19	0:00	0:30	0:00	0:45	0:00
47	0:35	1:03	4:26	0:00	0:30	0:00	0:45	0:00
48	0:35	1:32	4:47	0:00	0:30	0:00	0:45	0:00
49	0:35	4:12	4:35	0:00	0:30	0:00	0:45	0:00
50	0:35	1:16	5:05	0:00	0:30	0:00	0:45	0:00

Figure 11; Prima

4.3 Time Study Data

The data from the time study prior to the installation of the automated machinery was gathered in the early stages of the project. Fifty random sheets and fifty random parts were selected, times, and the data tabulated.

The data gathered for the automated machinery (Prima) was collected a few months after the installation of the machine. There were some hurdles which took months to resolve but eventually the machine lived up to what was promised. In this case, fifty random sheets were also timed along with fifty panels, one on each sheet as one sheet would contain anywhere from one part up to a possible six parts.

Chapter 5

ANALYSIS

5.1 Old Process vs. New Process

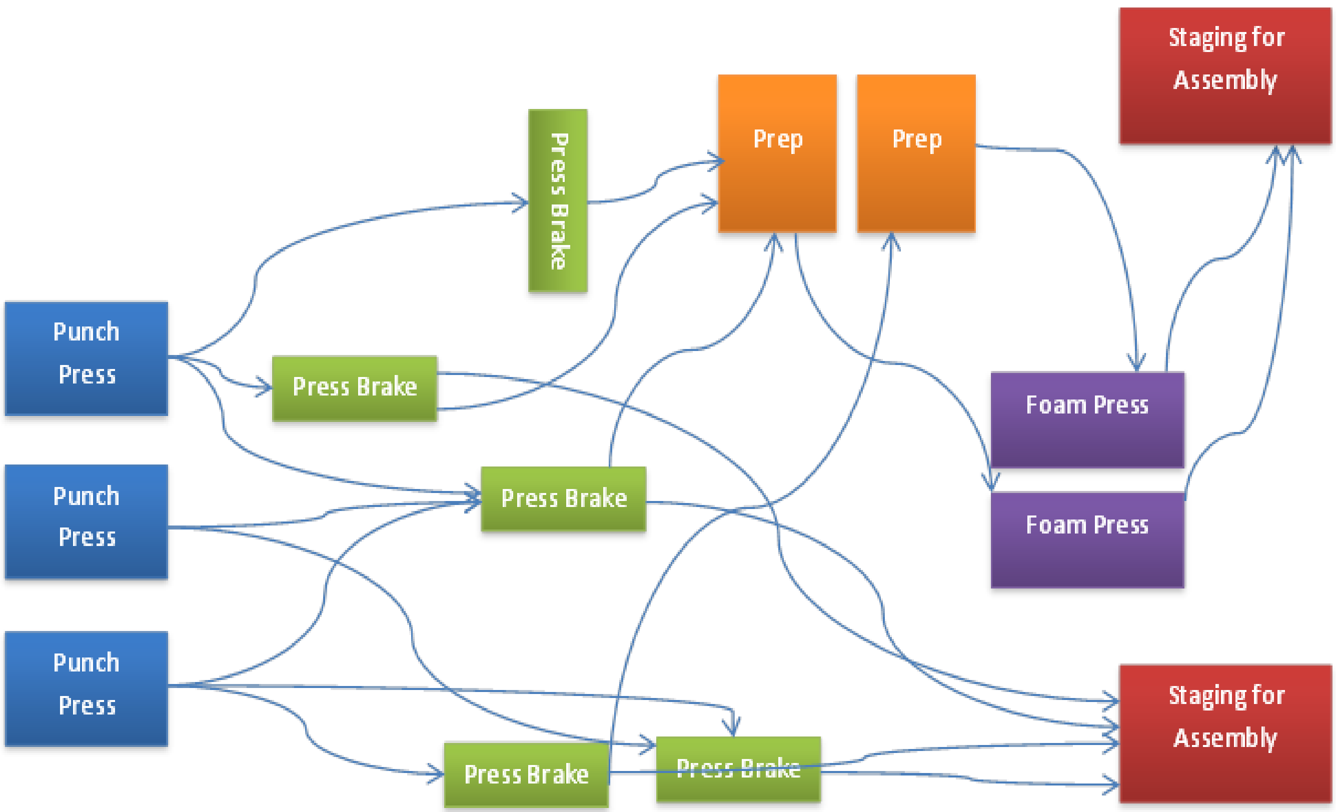

Figure 12; Product Flow Before

There was a huge opportunity to streamline the production flow as the process was broken down. Through the purchase of the automated machinery, product types were separated between the parts that were foamed and those that were not.

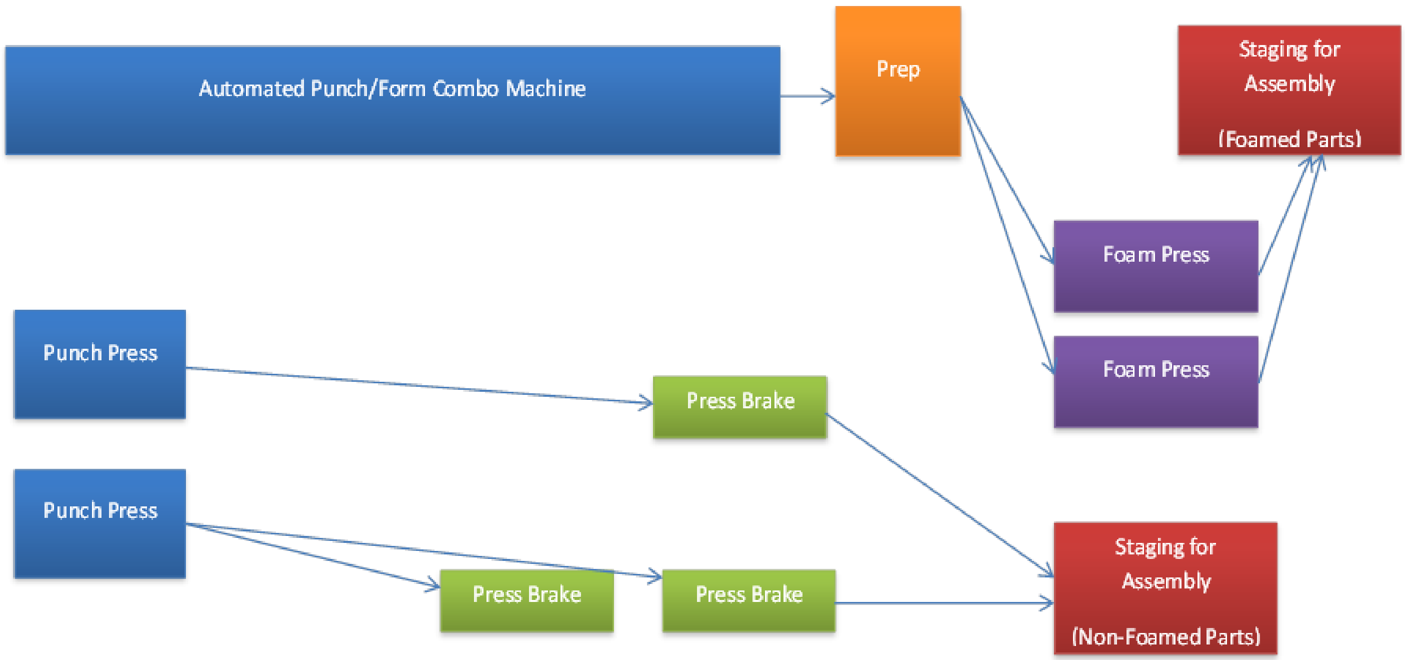

Figure 13; Product flow after

The new process flow as shown above is more direct and easier to navigate. Operators are able to easily store parts where they are supposed to and there is now a lot less confusion on which parts are to be going to certain operations now that they are separated.

5.2 Added Benefits

Instances Of Re-Produced Parts Due To Operator Misplacement				
	Old Process		New Process	
Week	Foamed	Non-Foamed	Foamed	Non-Foamed
1	52	46	2	11
2	74	98	6	21
3	46	77	1	8
4	26	74	3	3
5	59	22	0	5

Figure 14; Added Benefits

As shown in the table above, one major benefit was a huge reduction of parts considered to be "lost" in the factory due to misplacement by the operators

5.3 Validation of the Project

Overall, the project was a major success as the manufacturing process was streamlined and improved. There was an increase in the production capacity of the factory and quality was improved. Below is a table to summarize the project.

Improvements	Units
Labor Savings	$250,000/Year
Production Capacity Increase	25%
Reduced Rework	2Hrs/Day
Lead Time Reduction (Reduced Handoffs)	20% of Old Process Time
Safety	Reduced Occurrences
Floor Space Savings	1,200 Sq. Ft.
Walking (Miles Walked)	300 Miles/Year

Figure 15; Project Improvements

LABOR

The estimated savings on labor are attributed to the streamlining of the process. Thinking of the DOWNTIME acronym, we were able to find significant reductions in waste, labor, processing times, therefore reducing our overall lead times for our product.

PRODUCTION CAPACITY INCREASE

As a result of reductions and elimination of waste, our production process gained an overall capacity increase of roughly 25%.

REDUCED REWORK

By separating the lines between foamed and non-foamed product, we were able to significantly reduce our rework occurrences within the Fabrication department itself.

LEAD TIME REDUCTION

Faster processing gives us a significant gain in speed, reducing the overall lead times from what was estimated to be 5 days down to 3 days.

SAFETY

Incidents of safety-related accidents were reduced as the bigger, bulkier panels were being handled by a machine instead of the operators.

FLOOR SPACE SAVINGS

Streamlining the process brought some gains in production floor space.

WALKING

Operators walking back and forth were significantly reduced as they no longer.

Chapter 6

DISCUSSION

6.1 Conclusions

This study analyzed the existing state of producing and manufacturing a product in batches on manually operated machinery; specifically, an operator run turret punch press and press brake. The plan was to develop a method of implementing lean in the production process by switching from a batch manufacturing process to a one-piece flow.

The plan was implemented and the results show a significant improvement in productivity, reduction in lead times, increase in capacity, and better quality product.

Chapter 1 highlighted some issues company X was facing which led to the plan to implement lean, and Chapter 2 reviewed the literary content as to what drives companies to implement lean based on the potential improvements. Chapter 3 outlined the methods used in this project from the steps used in data collection to conceptualization and implementation. Chapter 4 focused on the results of the implementation and Chapter 5 analyzed those results to support the case for lean through the measurable improvements.

Overall, the results of the study were a success with the implementation of lean principles via automation of the shop machinery. The best solution was implemented and the shop operators, management and stakeholders are happy with the process and where the project ended.

6.2 Lessons Learned

There were some limitations to the project:

1. The project was limited to the Fabrication shop floor with machinery. There were brainstorming sessions that would constantly go out of scope due to the enormous potential to improve the entire manufacturing process down to the Assembly shop area. There have been other projects that have spawned from this initial one as those out of the project scope were too good to pass up for improvements.
2. Not all lean and manufacturing tools were used. There are a plethora of engineering and manufacturing tools available to use in order to improve a process. This is the beauty of manufacturing. Some tools such as the fish-bone/Ishakawa diagram, Yamazumi board, A3 Project board, etc. could have been used but it would have provided no benefit to the project.

There were also some issues that stemmed from change, in general. As with any new manufacturing process, change is not easy to bring into a facility where the norm is “We have always done it that way”. There was some resistance and push back from the company’s veteran machine operators who had a lot of experience and were passionate about “their” machines.

Lean is a culture change and it takes many years to implement. One of the toughest roads was successfully getting the buy-in of the veteran machine operators and middle management that were resistant to change due to the old mindset that was firmly against change. Unknowingly, these were the biggest assets to the project as every obstacle, scenario and question they threw at the project team became a potential problem to solve. This made the project successful as the final machine product was able to tackle just about everything it was given.

6.3 Future Work

This project is one huge step towards improving the overall facility production. When it comes to lean, there is the misconception that it deals with "leaning out people". Company X is dedicated to its employees and lean is seen as a "leaning out the process"; basically, there are no jobs taken away and personnel get reassigned to where work is needed more due to the change.

The next steps would be the acquisition of newer technology to replace some punch machines and have a truly lean facility. An example of one of the many potential future layouts is presented below:

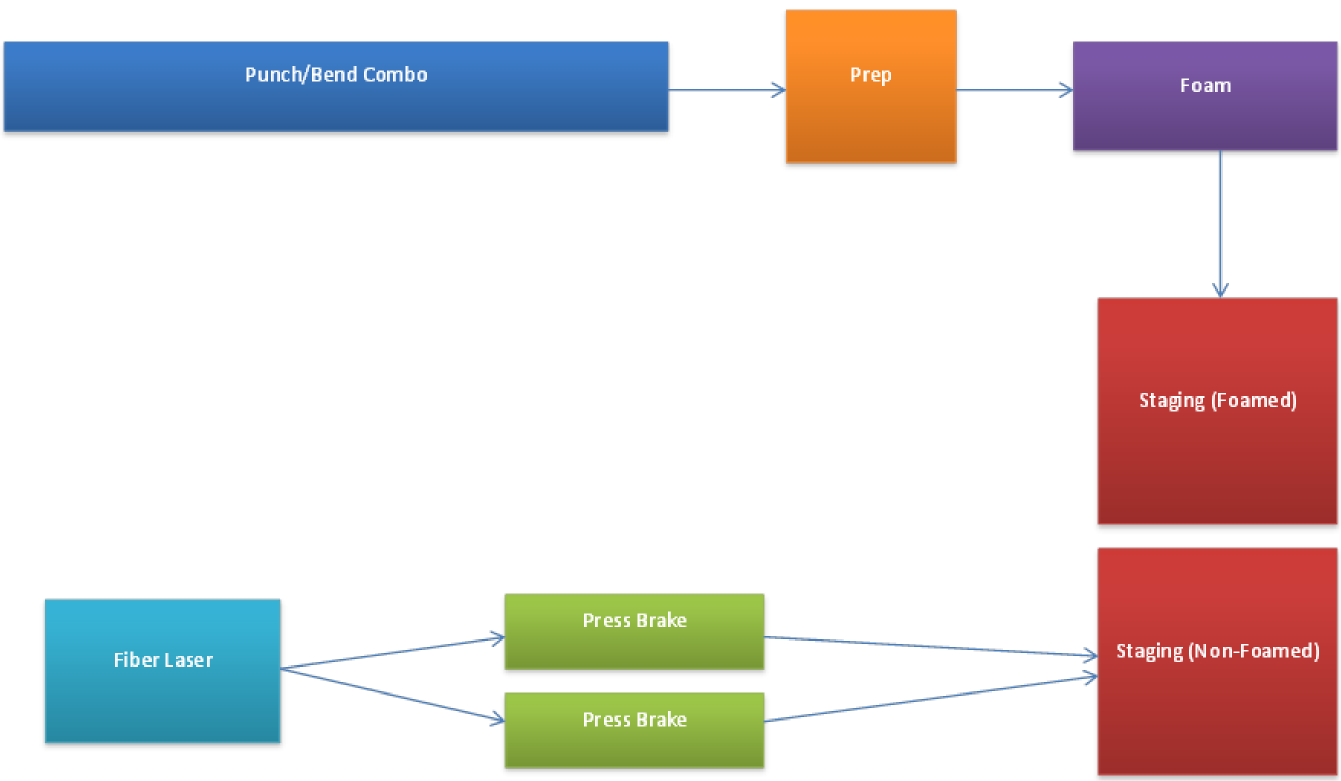

Figure 16; Proposed Future State

With this mindset of continuous improvement, Company X is constantly looking to the future where they want to be leaders in the HVAC industry from their product and facility.

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APPENDIX

Figure 1 – Part Process; Page 5

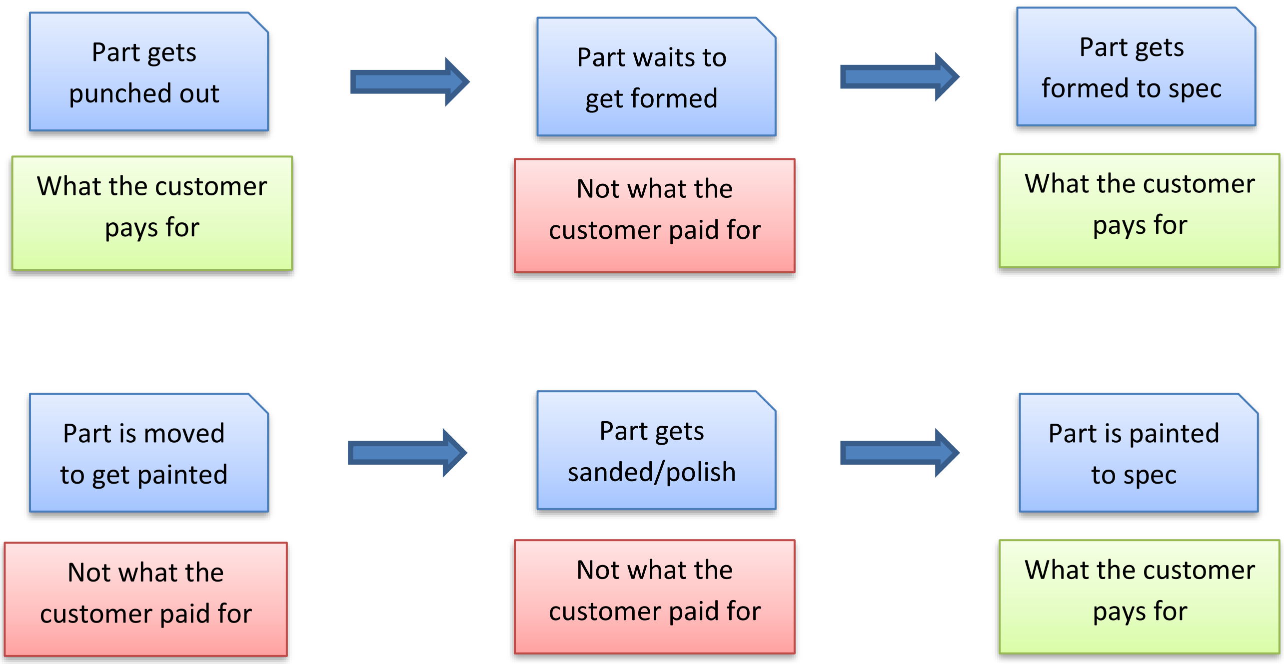

Figure 2 – Four Steps to Change Management (Kjaerulff, 2016); Page 12

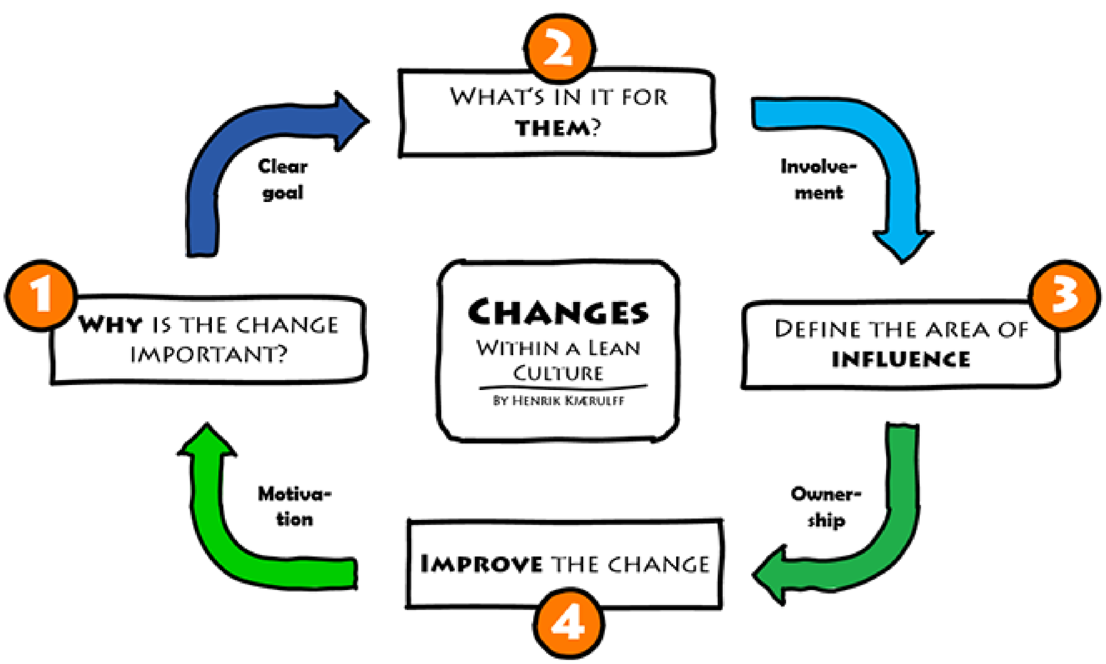

Figure 3 – Methodology Flow Chart; Page 13

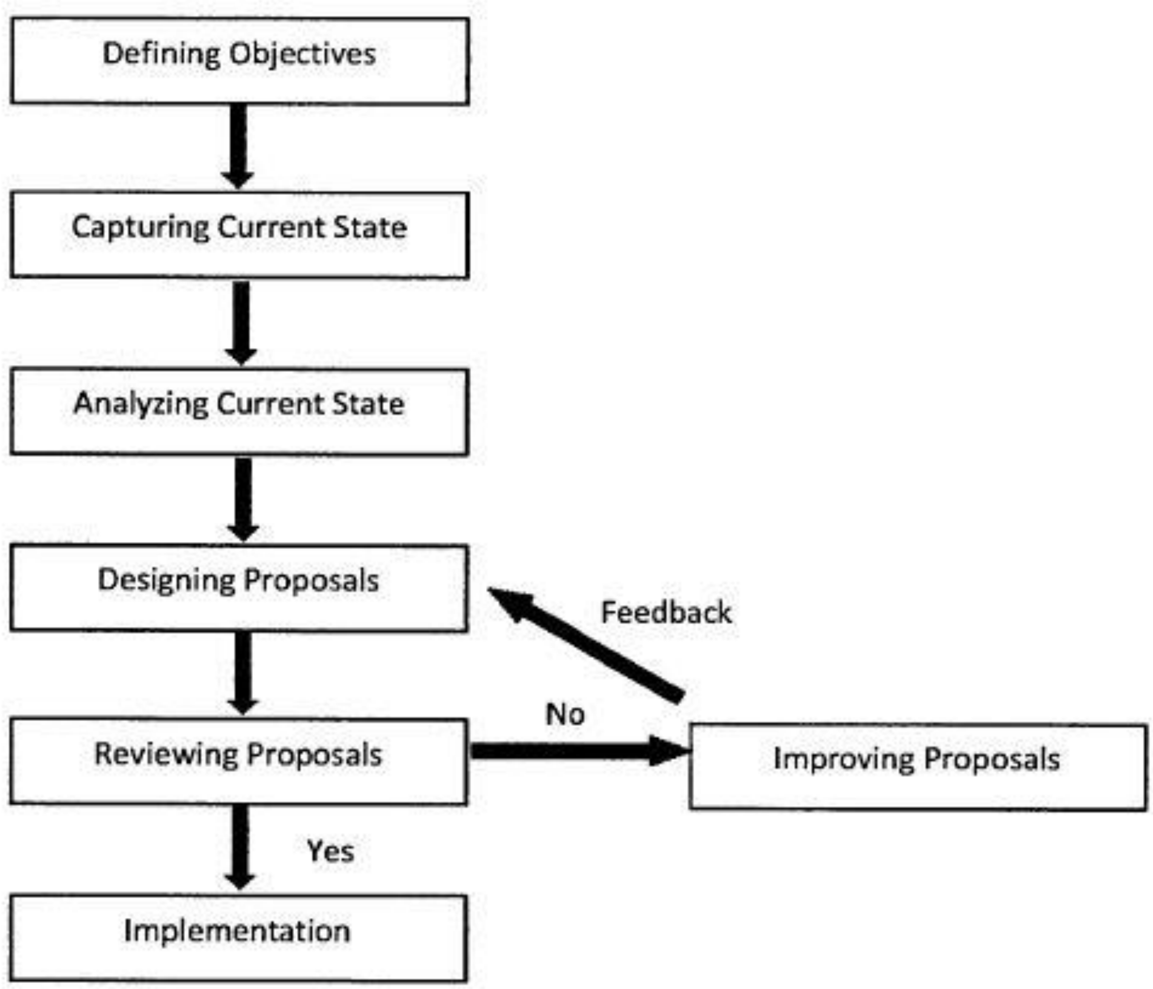

Figure 4 – Current State Parts Flow Map; Page 15

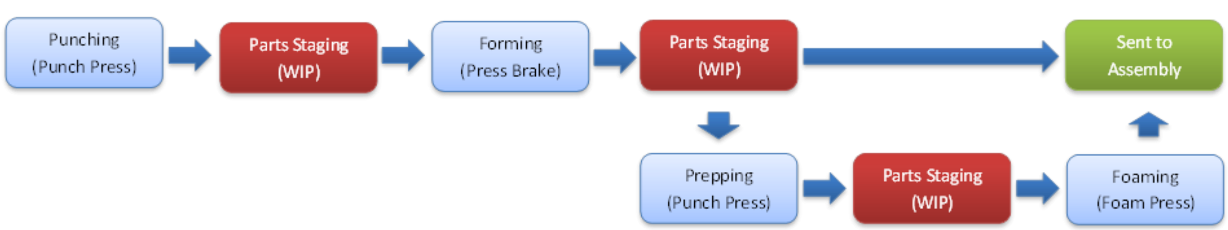

Figure 5 – Current State VSM; Page 16

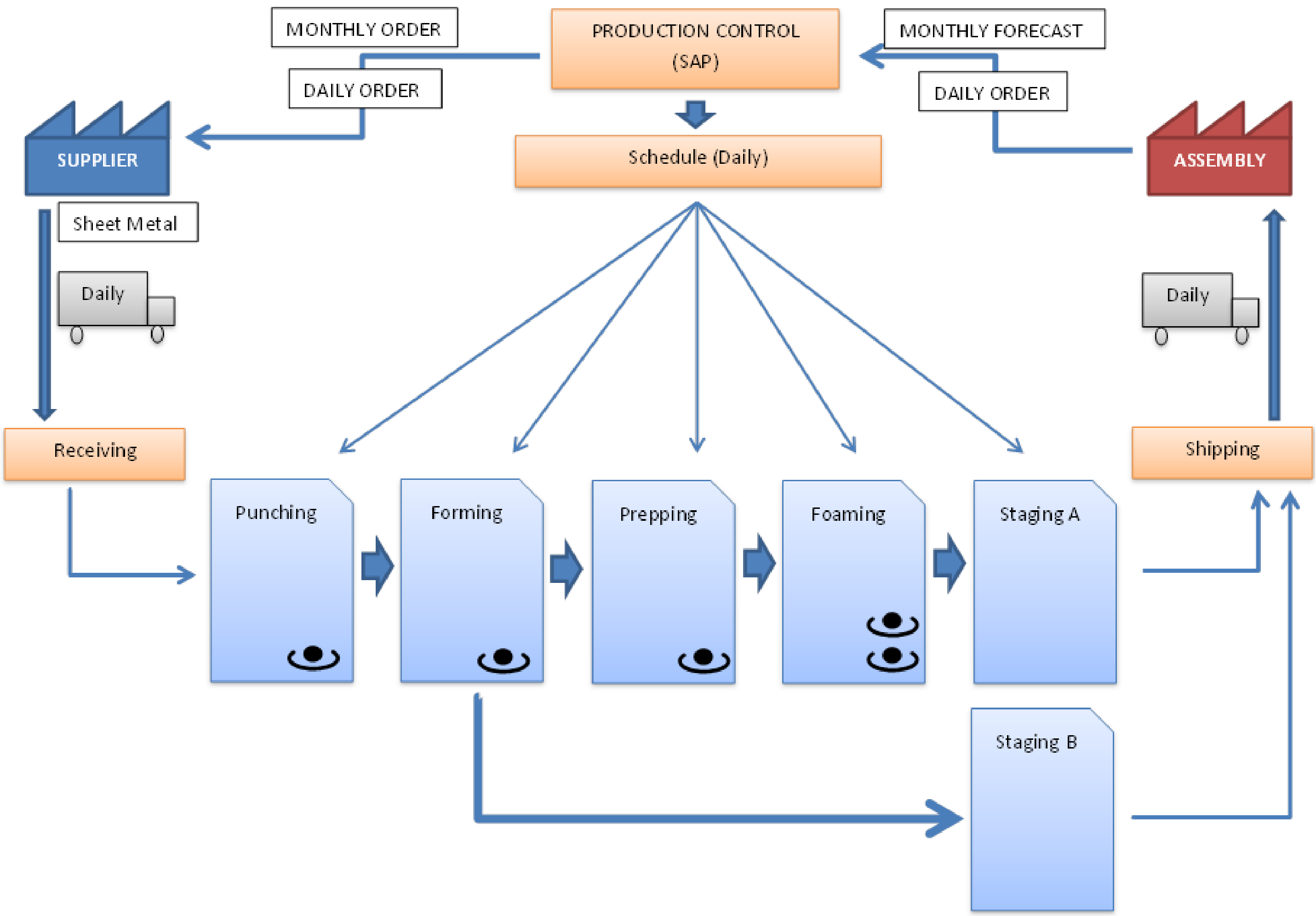

Figure 6 – Future State Parts Flow Map; Page 17

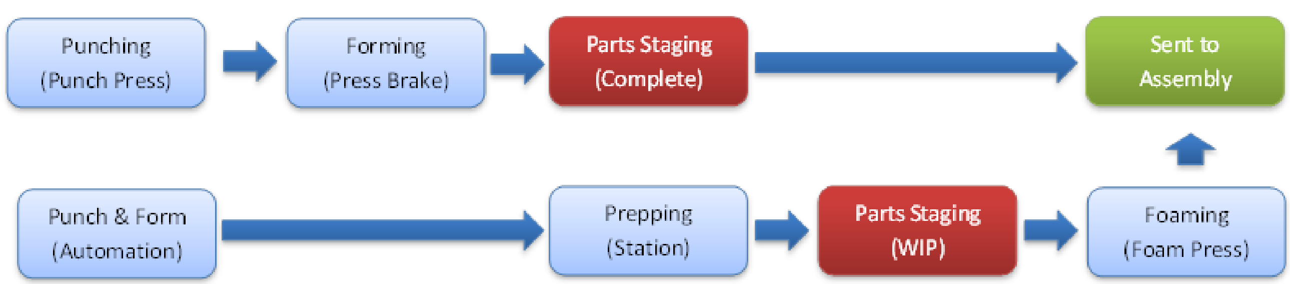

Figure 7 – Future State VSM; Page 18

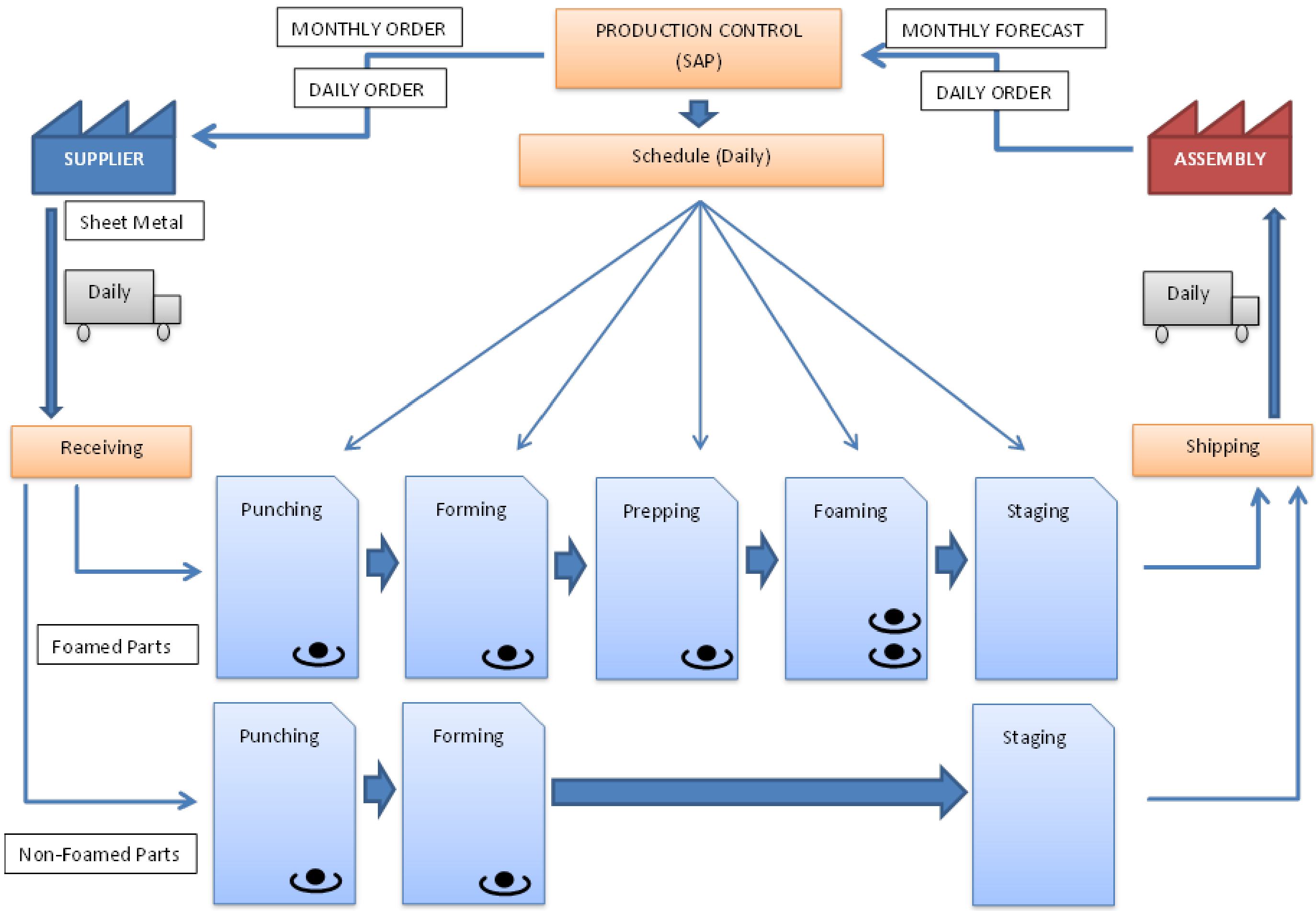

Figure 8 – New Process Parts Flow; Page 20

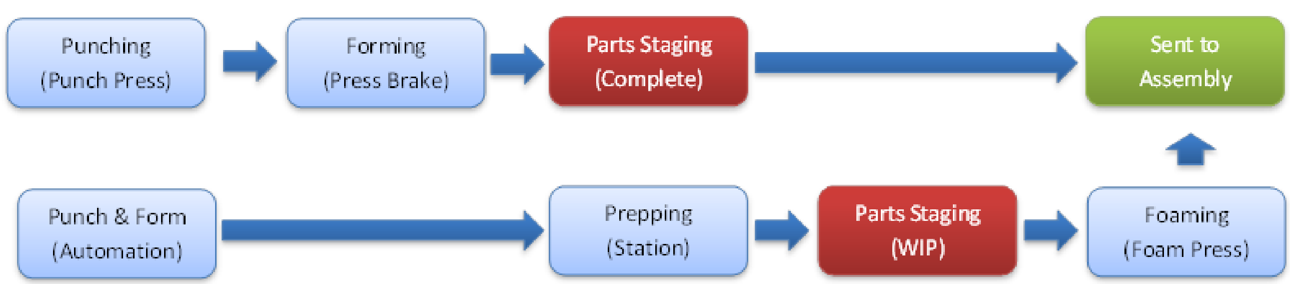

Figure 9 – Punch Press Time Study; Page 21

Punch Press					
Sheet	Loading Sheets on Machine	Loading Programs	Punching	Shaking Sheets / Collecting Parts	Transfer to Press Brake (Approx.)
1	0:46	0:32	12:02	3:06	4hrs
2	1:01	0:26	8:51	4:23	4hrs
3	1:42	0:54	11:16	4:56	12hrs+
4	0:36	0:15	10:54	4:15	2hrs
5	1:20	0:19	7:01	2:03	12hrs+
6	0:48	0:22	16:51	5:51	12hrs+
7	0:32	0:09	5:33	2:33	12hrs+
8	0:36	0:31	8:25	5:52	12hrs+
9	0:51	0:36	12:52	7:03	4hrs
10	1:09	0:19	8:56	4:16	4hrs
11	1:22	0:11	12:47	3:56	12hrs+
12	0:35	0:16	10:09	4:53	12hrs+
13	0:44	0:24	6:00	2:12	3hrs
14	0:55	0:22	9:23	4:21	12hrs+
15	0:51	0:35	7:41	3:37	3hrs
16	0:41	0:54	9:17	3:01	1hr
17	0:59	0:20	12:56	4:17	12hrs+
18	0:40	1:02	9:21	3:44	12hrs+
19	0:33	0:17	8:42	2:09	12hrs+
20	0:57	0:54	8:13	6:13	12hrs+
21	0:59	0:24	8:19	3:17	12hrs+
22	0:44	0:41	11:30	7:41	12hrs+
23	0:41	0:32	-	-	12hrs+
24	1:20	0:24	-	-	12hrs+
25	0:57	0:36	-	-	12hrs+
26	1:11	0:27	5:21	2:11	3hrs
27	0:45	0:55	10:32	8:31	<2hrs
28	1:03	0:29	11:01	4:33	<2hrs
29	0:45	0:51	7:22	5:44	2hrs
30	0:51	0:36	6:14	6:03	2hrs
31	0:49	0:21	8:51	3:47	12hrs+
32	0:33	0:25	8:36	1:33	12hrs+
33	0:54	0:29	16:32	4:01	12hrs+
34	0:56	0:34	3:52	1:57	12hrs+
35	1:02	0:44	11:33	6:00	12hrs+
36	0:36	0:26	14:29	4:26	<1hr
37	0:24	0:51	9:34	3:33	<1hr
38	0:42	0:41	8:08	3:58	12hrs+
39	1:21	0:59	8:34	4:37	12hrs+
40	0:54	0:26	14:46	3:16	12hrs+
41	1:46	0:19	10:09	7:51	12hrs+
42	0:56	0:24	8:45	3:41	6hrs
43	0:49	0:23	6:46	2:38	6hrs
44	0:36	0:16	7:51	4:18	12hrs+
45	1:05	0:52	8:37	8:02	12hrs+
46	1:00	0:30	12:49	4:49	6hrs
47	0:39	0:58	-	-	12hrs+
48	1:06	0:41	-	-	12hrs+
49	0:37	0:32	7:02	5:15	12hrs+
50	0:51	0:23	9:25	4:31	1hr

Figure 10 – Press Brake Time Study; Page 22

Press Brake			
Part	Loading Programs for Parts	Bending	Transfer to Cart
1	0:42	2:59	0:06
2	0:31	3:51	0:09
3	0:39	2:16	0:04
4	0:16	4:55	0:05
5	0:44	4:27	0:16
6	0:41	0:48	0:03
7	0:33	3:36	0:02
8	0:45	2:49	0:06
9	0:21	6:21	0:06
10	0:05	3:17	0:01
11	0:35	4:32	0:09
12	1:01	3:06	0:11
13	0:42	2:51	0:04
14	0:37	6:19	0:06
15	0:33	10:45	0:06
16	0:28	1:45	0:04
17	0:46	4:11	0:02
18	1:04	3:40	0:03
19	0:51	3:56	0:06
20	0:46	1:50	0:08
21	0:41	3:01	0:06
22	0:37	0:52	0:09
23	1:02	3:41	0:04
24	0:49	2:11	0:07
25	0:33	2:38	0:03
26	0:45	3:06	0:03
27	0:26	2:14	0:06
28	0:05	3:55	0:05
29	0:48	6:03	0:08
30	0:33	-	-
31	0:31	-	-
32	0:46	-	-
33	0:57	-	-
34	0:44	-	-
35	1:21	-	-
36	0:14	0:06	0:03
37	0:26	0:53	0:06
38	0:21	2:30	0:03
39	0:33	3:16	0:01
40	0:55	2:01	0:02
41	0:51	4:29	0:09
42	0:32	5:13	0:06
43	0:46	4:48	0:04
44	1:01	5:02	0:04
45	0:34	2:08	0:06
46	0:45	3:35	0:05
47	0:49	2:42	0:02
48	0:38	2:16	0:04
49	0:31	3:45	0:03
50	0:09	0:53	0:06

Figure 11 – Prima Time Study; Page 23

Prima								
Part	Loading Sheets on Machine	Loading Programs	Punching	Shaking Sheets / Collecting Parts	Transfer to Press Brake	Loading Programs for Parts	Bending	Transfer to Cart
1	0:35	2:30	4:23	0:00	0:30	0:00	0:45	0:00
2	0:35	2:16	5:32	0:00	0:30	0:00	0:45	0:00
3	0:35	1:42	4:01	0:00	0:30	0:00	0:45	0:00
4	0:35	1:11	4:22	0:00	0:30	0:00	0:45	0:00
5	0:35	1:26	4:57	0:00	0:30	0:00	0:45	0:00
6	0:35	1:03	3:16	0:00	0:30	0:00	0:45	0:00
7	0:35	1:54	4:21	0:00	0:30	0:00	0:45	0:00
8	0:35	3:52	4:26	0:00	0:30	0:00	0:45	0:00
9	0:35	2:06	3:51	0:00	0:30	0:00	0:45	0:00
10	0:35	2:13	2:34	0:00	0:30	0:00	0:45	0:00
11	0:35	2:54	4:53	0:00	0:30	0:00	0:45	0:00
12	0:35	1:34	4:16	0:00	0:30	0:00	0:45	0:00
13	0:35	3:21	4:33	0:00	0:30	0:00	0:45	0:00
14	0:35	1:09	5:43	0:00	0:30	0:00	0:45	0:00
15	0:35	1:54	5:08	0:00	0:30	0:00	0:45	0:00
16	0:35	1:46	4:02	0:00	0:30	0:00	0:45	0:00
17	0:35	1:20	4:55	0:00	0:30	0:00	0:45	0:00
18	0:35	2:06	4:34	0:00	0:30	0:00	0:45	0:00
19	0:35	2:05	3:17	0:00	0:30	0:00	0:45	0:00
20	0:35	1:53	4:08	0:00	0:30	0:00	0:45	0:00
21	0:35	6:32	3:19	0:00	0:30	0:00	0:45	0:00
22	0:35	4:14	9:03	0:00	0:30	0:00	0:45	0:00
23	0:35	2:06	3:56	0:00	0:30	0:00	0:45	0:00
24	0:35	1:09	4:09	0:00	0:30	0:00	0:45	0:00
25	0:35	1:16	4:37	0:00	0:30	0:00	0:45	0:00
26	0:35	1:49	4:05	0:00	0:30	0:00	0:45	0:00
27	0:35	5:02	3:51	0:00	0:30	0:00	0:45	0:00
28	0:35	2:48	4:37	0:00	0:30	0:00	0:45	0:00
29	0:35	1:42	5:32	0:00	0:30	0:00	0:45	0:00
30	0:35	1:31	2:19	0:00	0:30	0:00	0:45	0:00
31	0:35	1:59	5:34	0:00	0:30	0:00	0:45	0:00
32	0:35	2:12	2:31	0:00	0:30	0:00	0:45	0:00
33	0:35	3:16	5:01	0:00	0:30	0:00	0:45	0:00
34	0:35	3:48	4:36	0:00	0:30	0:00	0:45	0:00
35	0:35	1:13	4:14	0:00	0:30	0:00	0:45	0:00
36	0:35	1:51	4:47	0:00	0:30	0:00	0:45	0:00
37	0:35	1:53	3:26	0:00	0:30	0:00	0:45	0:00
38	0:35	2:41	1:54	0:00	0:30	0:00	0:45	0:00
39	0:35	2:56	4:26	0:00	0:30	0:00	0:45	0:00
40	0:35	1:09	4:54	0:00	0:30	0:00	0:45	0:00
41	0:35	1:28	6:03	0:00	0:30	0:00	0:45	0:00
42	0:35	3:06	4:11	0:00	0:30	0:00	0:45	0:00
43	0:35	1:16	4:52	0:00	0:30	0:00	0:45	0:00
44	0:35	1:53	3:19	0:00	0:30	0:00	0:45	0:00
45	0:35	1:44	3:18	0:00	0:30	0:00	0:45	0:00
46	0:35	2:22	3:19	0:00	0:30	0:00	0:45	0:00
47	0:35	1:03	4:26	0:00	0:30	0:00	0:45	0:00
48	0:35	1:32	4:47	0:00	0:30	0:00	0:45	0:00
49	0:35	4:12	4:35	0:00	0:30	0:00	0:45	0:00
50	0:35	1:16	5:05	0:00	0:30	0:00	0:45	0:00

Figure 12 – Product Flow Before; Page 25

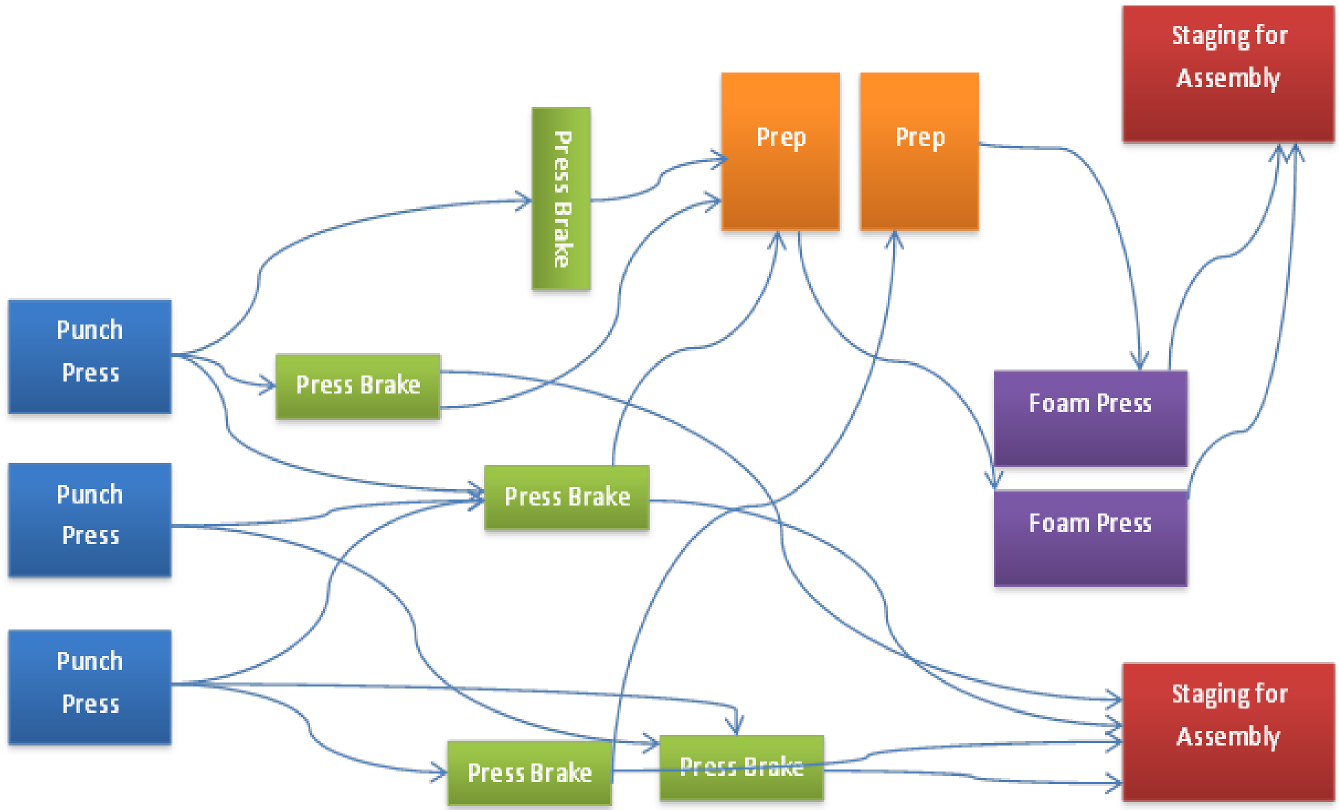

Figure 13 – Product Flow After; Page 26

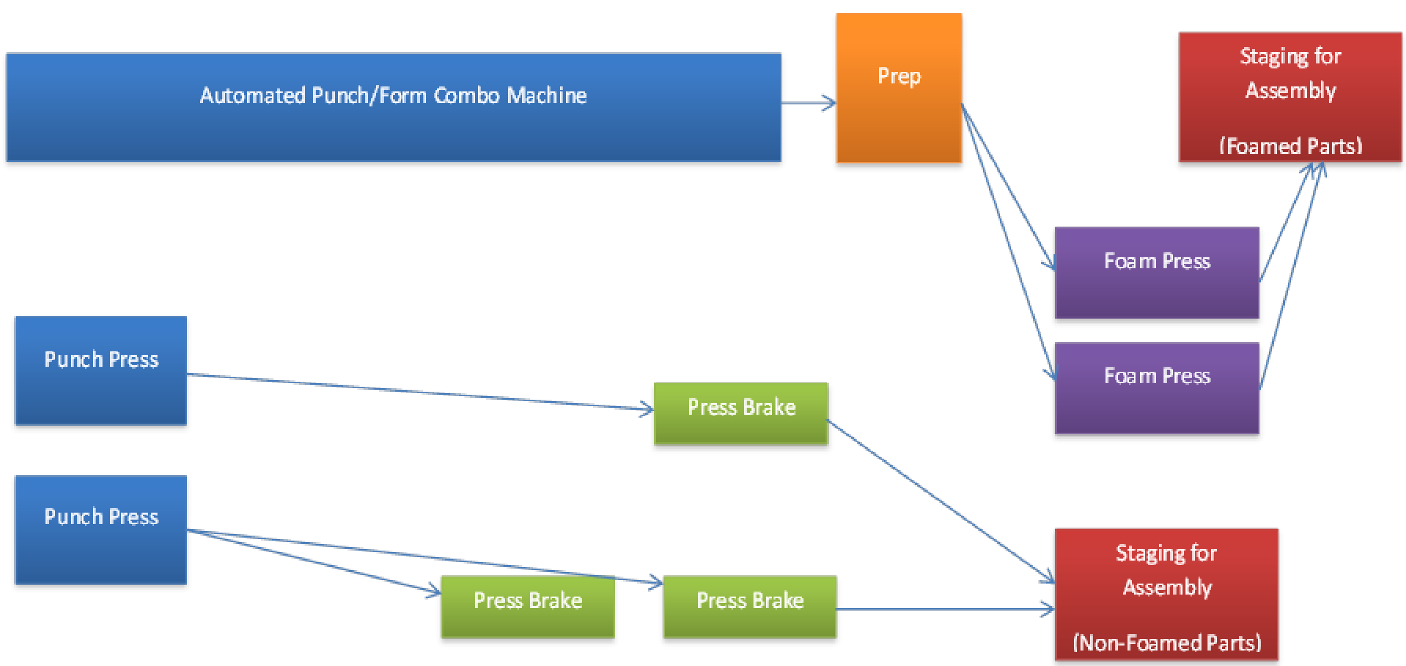

Figure 14 – Added Benefits; Page 26

Instances Of Re-Produced Parts Due To Operator Misplacement				
	Old Process		New Process	
Week	Foamed	Non-Foamed	Foamed	Non-Foamed
1	52	46	2	11
2	74	98	6	21
3	46	77	1	8
4	26	74	3	3
5	59	22	0	5

Figure 15 – Project Improvements; Page 27

Improvements	Units
Labor Savings	$250,000/Year
Production Capacity Increase	25%
Reduced Rework	2Hrs/Day
Lead Time Reduction (Reduced Handoffs)	20% of Old Process Time
Safety	Reduced Occurrences
Floor Space Savings	1,200 Sq. Ft.
Walking (Miles Walked)	300 Miles/Year

Figure 16 – Proposed Future State; Page 31