Continuous Improvement Efforts in J. Carroll's Screen Printing Process

By

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Abstract

The following report details the analysis and procedure taken not only to determine the issues limiting J. Carroll's screen printing capacity, but also provides the solutions necessary to address these issues. The report addresses one crucial operation in the screen printing process, changeovers, which contribute to roughly 24% of the screen printing process time and more than any other operation in the screen printing process. Within the changeover operation two specific tasks appear to be plaguing long changeover times: they are test print and design approval. The report elaborates on the Fishbone Diagrams utilized to bring up the potential causes of why these two tasks contribute roughly 60% of the changeover times. From this analysis numerous issues such as: unnecessary design approvals, designers not being available to approve design, miscommunication, operator error, and bad item placement (test print shirts) were mentioned. As a result the following cost effect solutions were implemented: implementation of new design approval policy, relocation of test print shirts, staging for next job initiative, and the use of a PDF as a reference for screen printers to check work. After implementation of the previously mentioned solutions a 25% reduction in changeover times or 5 minute savings in machine idle time was observed which constitutes an annual cost savings of $31,200.

Executive Summary

After the implementation of new design approval policy, relocation of test print shirts, staging for next job initiative, and the use of a PDF to be used as a reference for screen printers to check work, a 25% reduction in changeover times or 5 minute savings in machine idle time was obtained. Such savings will amount to an annual savings of $31,200 for machine idle time, and $1,300 for labor savings.

Introduction

The report investigates the issues that may be compromising J. Carroll's t-shirt making process. Currently J. Carroll has at least one known bottleneck in their t-shirt making process. This was mentioned by Josh Jacobson, the company's owner on a facility visit. On that visit it was discussed that Mr. Jacobson's goal for my senior project would be to highlight issues in his operation and help the overall effectiveness of the way they work. Mr. Jacobson feels that if the effectiveness of his process is increased J. Carroll would be able to increase their printing capacity and thus allow J. Carroll to accommodate extra customers which is a concern as several other t-shirt making companies in town went under. Some methods that will be used in this project to help J. Carroll meet their goal of obtaining higher efficiency and work effectiveness will be the use of work design and measurement techniques. With the aid of these techniques a baseline of the current process will be obtained. This baseline will later be used to differentiate if any improvements have been obtained. After such preliminary analysis is done, Lean manufacturing principles applicable to J. Carroll's t-shirt making process will be implemented. One lean principle of particular importance for J. Carroll's process is the 5S methodology. The reason why 5S holds such importance for this project is because this methodology has worked very well in increasing efficiency where clutter or disorganization appears to be an issue. For this project the deliverables or objectives are to:

- Conduct work design and measurement techniques and observations to gather data essential for the development of a baseline of the current process.
- Implement changes to J. Carroll's current process in order to increase efficiency and work effectiveness.
- Design a new changeover process

- Give cost and time saving recommendations.

In order to complete the above objectives the following courses will be used: Work Design and Measurement, Project Organization and Management, and Inventory Control Systems. The organization of this report will begin with the literature review about the different types of printing, the process involved in silk screen printing, and lastly Lean manufacturing principles that may be applicable to a t-shirt making process. Followed by the description of the 5S implementation plan designed to correct issues uncovered during the preliminary data collection and analysis. The design portion of the report will then be followed by methodology, which will explain if such changes did in fact lead to increases in efficiency and work effectiveness. Methodology will then be followed by results and immediately followed by the conclusion. The report will then be completed with addition of the Bibliography and Appendix.

Background

The project fits is a high priority for J. Carroll. The reason lies in the fact that the project will highlight efficiency and effectiveness issues in J. Carroll's t-shirt making process. This is important for J. Carroll because highlighting these issues will then allow for solutions to be developed. In terms of the potential benefit of this project for J. Carroll it is high considering that it has the potential to make J. Carroll much more profitable, but most importantly it will bring a level of understanding to their current operation. Understanding the current operation and knowing where task effectiveness is lacking can prove beneficial and almost serve as a competitive advantage in a capitalistic society where competition is evitable and being steps ahead of the competition is vital. Fortunately for J. Carroll up to this point they have done quite well at this, and for this reason they have been able to be profitable at what they are doing. But being profitable does not mean that improvements can not be made, as a result this project hopes

to understand the current efficiency and effectiveness issues in J. Carroll's process and implement solutions that should address these issues; thus making J. Carroll much more profitable and their task much more efficient and effective. In order to get a better understanding of J. Carroll some time should be spent on what makes J. Carroll, the exceptional company that it is.

J. Carroll is a screen printing and embroidery business, comprised of thirteen employees, located in San Luis Obispo, CA. J. Carroll has been in business for fifteen years and has been able to as their website states, "provide a sturdy and solidly-wearable product, printed and stitched with accuracy, that reflects the caliber of the company logo or any one-of-kind design." J. Carroll's ability to do just this is why they have been able to receive many contracts from Cal Poly clubs, athletics, and other community groups. With so much success it is no wonder why J. Carroll is the go to spot for all screen printing and embroidery needs. J. Carroll in terms of its screen printing department consists of 4 employees Jesse, Paul, Arturo, and Rob. Screen printing production is done by Jesse and Paul. Rob is in charge of screen development and Arturo is more of a utility worker who is assigned to package and clean up equipment. Although J. Carroll's facility size is unknown because no blue prints where available for validation its screen printing department is approximately 2275 square feet.

Literature Review

This literature review will investigate and discuss the following questions. What are the four types of printing? What is silk screen printing? What does the process of silk screen printing consist of? In addition literature about Lean manufacturing techniques applicable to the t-shirt screen printing process will be evaluated.

The process of printing can be classified into four distinct types. The first is Typesetting which made an appearance during the late 19th century when typesetting machines such as Linotype, Intertype, and Monotype were created. The first two machines were fairly similar in the sense that they created print by producing metal slugs that contained certain sentences or phrases. These slugs would then be put side by side along other slugs to produce written material on paper when ink was applied. The last typesetting machine created was Monotype. The difference between a Monotype typesetting machine and the first two is that characters and letters were created on single slugs as opposed to long metal slugs. As a result Monotype was adventitious in the fact that single slugs could be interchanged by hand and thus reused more easily.

The second type is Intaglio printing. In this printing process the design would be engraved a certain depth from the surface of the plate. Once ink was added to the plate and the plate surface wiped clean the ink would be left in the impression. All that would be left to do was have the printing press apply pressure which would then result in transferring the design to the paper.

The third type of printing is Lithography also known as planographic printing [1]. In Lithographic printing a thin plate made out of metal, plastic, or paper would have a design etched on it with greasy ink, or crayon [1]. Once the design is completed on the plate, the plate is dipped in water and then ink. As a result the ink would only adhere to the greasy ink or crayon while all other parts on the plate would remain without color. Consequently the plate can then be used to transfer the design to other material.

The last of these printing types is stencil printing. One of he mostly widely know stencil printing forms is silk screen printing. In silk screen printing ink is applied to a image carrier such as a silk screen, using a squeegee pressed against the screen in an angled motion ink is then forced through porous areas in the stencil design [1]. Typical process uses for silk screen printing is on posters, glass, plastics, and textured surfaces [1]. Considering the versatility of use in many areas specifically its use in textured surfaces such as clothing one should take the time to look into screen printing in more grave detail.

The process of silk screen printing is usually performed with the aid of the following items: computer and printer with graphic software, inkjet or laser film, emulsion, mesh screen and frame, exposure unit, dip tank, wash out booth, garden hose, drying rack, ruler and t-square, ink, squeegee, tape, flash cure unit, and screen printing press.

The process of silk screen printing begins with a design. A computer with graphic software is used to break up the design into layers. If the design contains multiple colors each color would be pulled out from the design and put on a separate layer so that it may be printed in

black by itself [8]. In other words each layer would be printed on a separate film transparency. These film transparencies are known as film positives and are essentially opaque images of the different layers of your design. Once the films are printed, a mesh screen will be prepared for each film. The mesh screen is prepared by stretching the mesh screen to the appropriate tension on the wooden frame. As soon as this step is completed the mesh screen is ready for emulsion. Using a scoop coater, emulsion is added to the front and back of the screen. Once added the mesh screen with the emulsion coat should be left to dry. After drying the film positive is aligned and placed with the mesh screen in order to go through an exposure unit which exposes both the mesh screen and film positive with UV light in order to ultimately develop the stencil. Once the stencil is made on the screen, the screen is dipped in a chemical dip tank that helps dissolve the emulsion that did not have UV light penetrate through it. What results is the creation of the stencil. After a couple minutes of being dipped in the chemical dip tank the screen is removed and a water hose is used to spray water at the stencil. Doing this helps clear the pores of any emulsion left over with in the stencil design. After the screen is washed out it is placed on drying racks to dry. Now that the screen is dry and complete some things necessary before any screen printing takes place, have to be taken care of. The first is that tape must be applied to the edges of the screen to avoid ink going through the screen where it is not wanted. After this is done the screen must be added to the screen printing press. A t-square is then used to mark the pallet (what the t-shirt rest on during screen printing) in order to align the screens appropriately to where the design will be placed on the shirt. After all is aligned a t-shirt can then be placed on the pallet, ink can be added to the screen, and a squeegee can be used to push the ink through the

mesh pores where the stencil allows it to. What would then result is the design on the t-shirt. The only operation left for the t-shirt to go through is the flash cure unit which applies heat to the t-shirt in order to have the ink dry and the design remain permanently on the fabric. Now that the process of screen printing has been explained the topic of Lean manufacturing and its best process improvement techniques will be evaluated.

Lean manufacturing is described as a manufacturing paradigm based on the fundamental goal of Toyota Production System: minimizing waste and maximizing flow [2]. In the research it was uncovered that when interested in applying Lean manufacturing principles it is understood that a good starting point for a lean transformation is 5S [3]. The 5S principle is described as the process of creating a clutter-free workplace with visual controls through 5 steps: sort, set in order, shine, standardize and sustain [3]. These steps are evaluated in more detail and described below.

Sort — eliminate from the workplace or office all items that are not needed for current production or office operations [4].

Set — in order -organize what remains. Assign a location for all essential items and label them so they can be retrieved quickly and easily. Anyone should be able to locate the item or put it away where it belongs [4].

Shine — keep the workplace swept and clean. Keep everything in prime condition so when somebody needs an item, it's ready to be used [4].

Standardize — Practice the first 3Ss at regular and frequent intervals, integrating the cleaning and maintenance of equipment and tools in regular work activities. This prevents backsliding in the first three pillars [4].

Sustain — Stick to the 5S procedures. Make following them a habit. Provide time and resources for implementing the 5S effort. Create tangible and intangible rewards for success. Note: this is the toughest pillar because it requires the most discipline [4].

Signs of how effective 5S can be in the work place can be seen in a case study done on Maytag, the popular home and commercial appliance company. In 2002 Maytag executives credited some of the 3rd quarter sale increases to lean initiatives [3]. One of Maytag's lean initiatives involved the implementation of 5S throughout their facility. From the case study David Speer, Maytag's Director of the Lean Sigma program, essentially the man responsible for the lean initiatives rolled out at Maytag's facility mentioned that one of the biggest benefits resulting from a 5S effort was boost in morale, "People feel better about working in this environment" [3]. Another example where the success of 5S implementation can be seen is at Boeing's Arnprior's facility. From its initial opening in 1992 Lean manufacturing practices have been seen as the primary reasons why on-time customer deliveries grew from 27 percent to 97 percent or higher, and why cycle time decreased from 40 days to 4 and a half days [4]. With such success seen in the previous two companies, Lean manufacturing principles appear almost a given in any manufacturing process. But with so many lean manufacturing tools available to implement in a manufacturing process it is often difficult to assume that Lean manufacturing

implementation success can be solely traced to one specific principle. However what is easy to see is that through the research conducted most Lean manufacturing success stories have mentioned or touched on the implementation of 5S. Although simple and straight forward, 5S has the potential of having a significant impact on efficiency and product flow. For this reason it is considered to be the primary starting place for any Lean initiatives. Although 5S proves to be simple in practice certain things should be considered when trying to increase the probability of success after implementation. The first thing to consider is to accurately and thoroughly understanding the current process. For this reason one of the first things to be completed for this particular project will be to come up with is a flow process chart of your process in order to identify the areas with the greatest amount of delays or time consumption. A Flow process Chart is a simple half-text, half-picture method of showing the steps in a process, using symbols to indicate the type of action being taken and text to give details of the action [10]. Creating a flow process chart alongside a Pareto chart describing the duration of all the tasks in a screen printing operation should indicate the area(s) where 5S and other potential Lean initiatives would be most beneficial. The reason why Lean initiatives applied to the most time consuming task(s) in the process would be most beneficial lies in the understanding that these particular task(s) are the main contributors to delaying product flow. The goal of 5S implementation on a bottleneck task would be to increase capacity, and a capacity increase in a bottleneck operation consequently leads to greater throughput and overall process effectiveness. Another thing to be aware of when juggling the idea of 5S implementation is that upon implementation the first three Ss should be the initial steps to consider. It is recommended that the first three steps should be focused on since they would help you do the following 1) find what is out of place and either eliminate or

relocate it, 2) find the best location for what you do have, 3) find the sources of contamination, dirt and problems and eliminate them [5]. It is worthy to mention that if 5S implementation has taken place in an area and there stills seems to be a bit of organization issues the use of visual single-point lessons may be the fastest way to spread the use of new best practices [6].

In conclusions this project differs from anything else ever done because it strives to increase the effectiveness of the screen printing process by finding efficiency solutions to the current screen printing tasks and applying them. While most project efforts in screen printing concentrate on advising on what may be done to increase efficiency; never really taking the opportunity to test such recommendations. For example one online screen printing article speaking on increasing screen printing efficiency solely stated things like speed up setup and teardown [9]. However not one time does this article mention anything about the possibility of setup or tear down being a bottleneck. Nor did it mention what may be causing such delays in set up or tear down. My project on the other hand, contrary to what has been done aspires to view the entire screen printing process from start to end in order to find existing bottlenecks or process effectiveness issues. After they are found possible solutions would then be implemented in order to obtain better process effectiveness which will then consequently improve efficiency and capacity. Unlike other studies where individuals solely mention decreasing the time to perform an activity these recommendations will result in improvements. This notion may prove problematic considering simply decreasing the time to do a task doesn't guarantee or lead directly to overall process improvements nor does it discover the root cause of why this task is problematic. Simply reducing the time to complete the task may just lead to later problems down

the road. Another thing to consider is that, efficiency may increase for this particular task, but not necessarily for the entire process. In conclusion my project relates more to the understanding of Little's Law which states that process lead time equates to work-in-progress divided by exit rate [7]. In other words if your current process contains high work in progress and low exit rate you would most certainly have capacity issues or what is called a bottleneck. However if this bottleneck is reduced your process lead time would as a result drop which ultimately means higher efficiency and throughput. As you can see the project hopes to find the current screen printing process bottleneck and then resolve it for the biggest impact on efficiency unlike other improvement efforts which concentrated on improvements in particular aspects of screen printing that may or may not be causing bottlenecks in the screen printing process.

Design

Overall Approach

My overall approach for this project consisted of applying a Six Sigma approach to process improvement known as DMAIC, which is an acronym for the following terms: Define, Measure, Analyze, Improve, and Control. Knowing the process improvement approach that would be used for this senor project I was able to move forward and define the problem.

Defining the Problem

Initially when the project began Josh Jacobson the owner of J. Carroll Corporation defined the only constraint for the project and stated exactly what he wanted. Josh expressed that my constraint was that my analysis was to be focused only on the approximate 2275 square foot screen printing department and not the embroidery or design departments. Lastly Josh asked that the screen printing throughput be increased after this project was complete. With these two items

known, the constraint in place, objective in place, and no clear problem for me to begin solving I began by taking every operation that takes place in the screen printing department and began taking time studies, see Table 1.

Table 1: Time Study Sheet for entire screen printing operation

Time Studies for entire Screen Printing Operation												
Standard Times Calculation Sheet												
Operation: Entire operation								Date: 02/7/11				
Observer: Millan Arellano								Study Start Time:				
Operator: Rob, Jesse, Arturo								Study End Time:				
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Film Stripping Station	R	90	85	85	90	80	85	515	85.83		
		T	102	110	108	100	112	107	639	106.5		91.41
2	Screen Imaging System	R	90	90	80	90	80	90	520	86.67		
		T	145	148	189	142	166	145	935	155.8		135.1
3	Washout	R	85	90	80	80	85	80	500	83.33		
		T	189	167	80	76	110	93	715	119.2		99.31
4	Rinse	R	90	86	90	88	90	90	534	89		
		T	124	130	127	118	120	122	741	123.5		109.9
5	Drying	R	90	90	88	88	85	70	511	85.17		
		T	1600	1595	1550	1668	1680	1703	9796	1633		1390
6	Taping	R	95	85	85	90	85	90	530	88.33		
		T	120	132	137	125	130	128	772	128.7		113.7
7	Setup	R	90	90	70	90	75	80	495	82.5		
		T	877	890	607	840	721	768	4703	783.8		646.7
8	Screen Printing	R	70	70	90	90	90	90	500	83.33		
		T	105	110	76	79	90	87	547	91.17		75.97
9	Furnace	R	95	95	95	95	95	95	570	95		
		T	65	69	66	64	66	64	394	65.67		62.38
10	Changeover (optional)	R	90	65	95	75	70	85	480	80		
		T	824	2026	769	1063	633	1237	6552	1092		873.6
11	Packaging	R	95	90	95	95	95	95	565	94.17		
		T	17	15	17	16	16	16	97	16.17		15.22
* Observed Time = Average Time			**Non-Cyclic Elements**			**Frequency**				Total NT =		3614
* Time in seconds		1						**Allowance**				0.08
		2						**Standard Time (Seconds/unit)**				3902.768
		3						**Output/8 Hour Shift**				7.379379

From these time studies a Pareto Chart seen in Figure 1 below and a Flow Process Chart seen in Table 2 was developed in order to obtain some sort of baseline.

Figure 1: Pareto Chart of entire screen printing operation

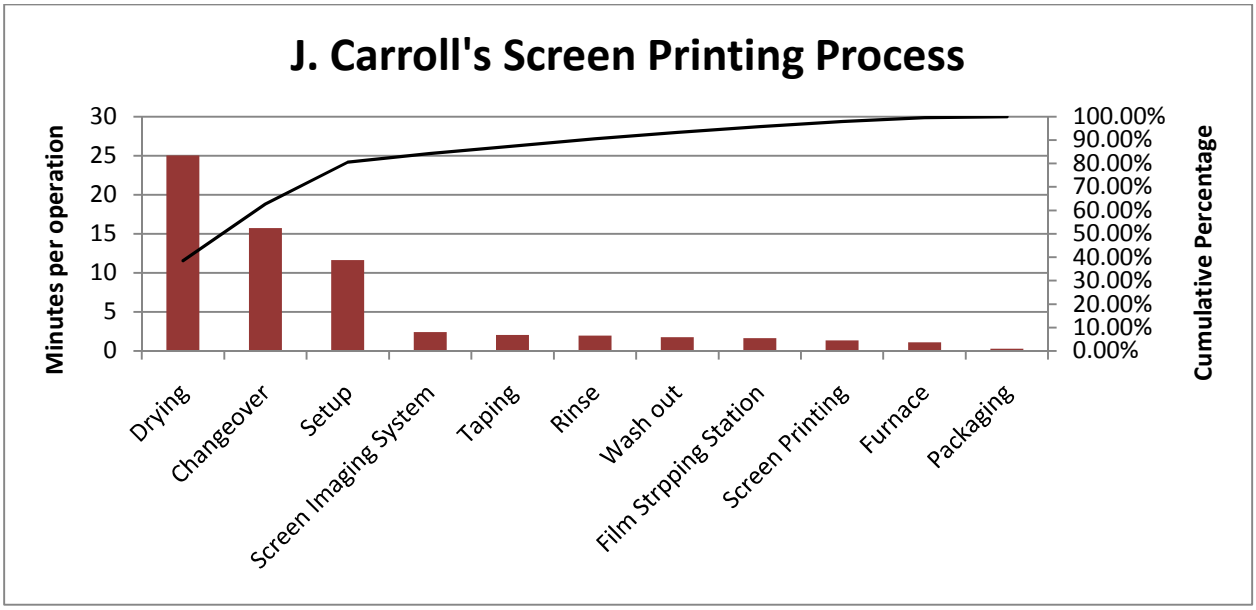


Table 2: Flow Process Chart

Flow Process Chart

Flow Process Chart

Location:	**J. Carroll**		**Summary**		
Activity:	**Flow of Material through the screen printing process**		**Event**	**Present**	**Proposed**	**Savings**
Date:	**15-Mar-11**		Operations	6		
Operator:	Rob, Jesse, Arturo	**Analyst: Millan**	Transport	7		
Circle Appropriate Method and Type			Delay	6		
Method:	***Present*** Proposed		Inspection	0		
Type:	Worker ***Material*** Machine		Storage	1		
Remarks	Analysis of current process to highlight possibilities of		Time (Secs)	4541.3		
	improvement. Worker resposible for event will be noted with Rob, Jesse,		Distance (ft)	174.4		
	or Arturo in notes.		Cost			

Event Description						Time (Secs)	Dist (ft)	Notes/Method Recommendation
Align film strip	●	⇨	◗	□	▽	102	0	Rob
Transport to Screen Imaging System (SIS)	○	➡	◗	□	▽	6.6	21.6	Rob
Go retrieve mesh screen	○	⇨	●	□	▽	7.26	8.3	Rob
Transport screen to SIS	○	➡	◗	□	▽	4.84	8.3	Rob
Set film & screen in SIS for treatment	●	⇨	◗	□	▽	151	0	Rob
Transport screen to chemical tub	○	➡	◗	□	▽	5.3	14.3	Rob
Let screen sit in chemical tub	●	⇨	◗	□	▽	120	0	Rob
Transport screen to rinsing area	○	➡	◗	□	▽	3.2	10	Rob
Rinse screen w/ water to clean up stencil	●	⇨	◗	□	▽	111	0	Rob
Transport screen to drying racks	○	➡	◗	□	▽	7	15.2	Rob
Let screen dry	○	⇨	●	□	▽	1856	0	Rob
Transport screen to waiting area	○	➡	◗	□	▽	8.3	25.25	Rob
Store screen until ready for printing press	○	⇨	◗	□	▼	270	0	Rob, screens wait for Range couple min/1 day
Retrieve T-Shirts for order	○	⇨	●	□	▽	582.1	10.2	Jesse
Retrieve screen(s) for order	○	⇨	●	□	▽	48.2	55.4	Jesse
Setup screen printing press (SPP) for order	○	⇨	●	□	▽	1063	0	Jesse
Screen print design on T-Shirt	●	⇨	◗	□	▽	120	0	Jesse
Remove T-Shirt and place on conveyor belt	○	⇨	●	□	▽	5.6	2.1	Jesse
Heat T-Shirt	●	⇨	◗	□	▽	66	0	T-shirt placed in furnace
Remove T-Shirt and prep for packaging	○	➡	◗	□	▽	3.9	3.75	Arturo/Ana
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
	○	⇨	◗	□	▽			
		TOTAL				4541	174.4	

From this Pareto Chart three specific items clearly showed to consume more time to perform than any other operations in the screen printing department. These items were drying, changeover, and setup. Although drying represented the highest overall time per operation it was not chosen to be the primary item to focus on because its high operation time results not from difficulties in the operation, but from the fact that J. Carroll's initial operations of the screen printing department consist of a push system. Meaning that Rob the screen developer focuses on developing as many screens throughout the day, often times working on screens that will not be used until three days later. As a result Rob will often put screens to dry and due to the lack of priority of the screens, as well as the overwhelming list of other small item tasks he must complete throughout his day he often will leave the screens drying longer than is needed; thus resulting in a long drying operation time. It is recommended that if J. Carroll tries to make their entire screen printing operation a pull system. Meaning that they work on orders as they are obtained, then the screen drying operation should be limited to approximately 7 minutes. This value was determined after a screen mesh popped and Rob had to quickly develop a new screen in order to get the screen printing operation up and running again. Since the screen was urgently needed and was only allowed to dry for 7 minutes and worked properly after implementation. It is recommended that if a pull system was required then screens should only be allowed to dry for approximately 7 minutes. The next two items in the Pareto Chart that were alarming consisted of the changeover and setup times. Since setup is actually performed also in the changeover operation, the changeover was determined to be the prime problem candidate needed to be solved in order to increase throughput; thus the changeover was the primary focus of this senior project.

Root Cause Analysis

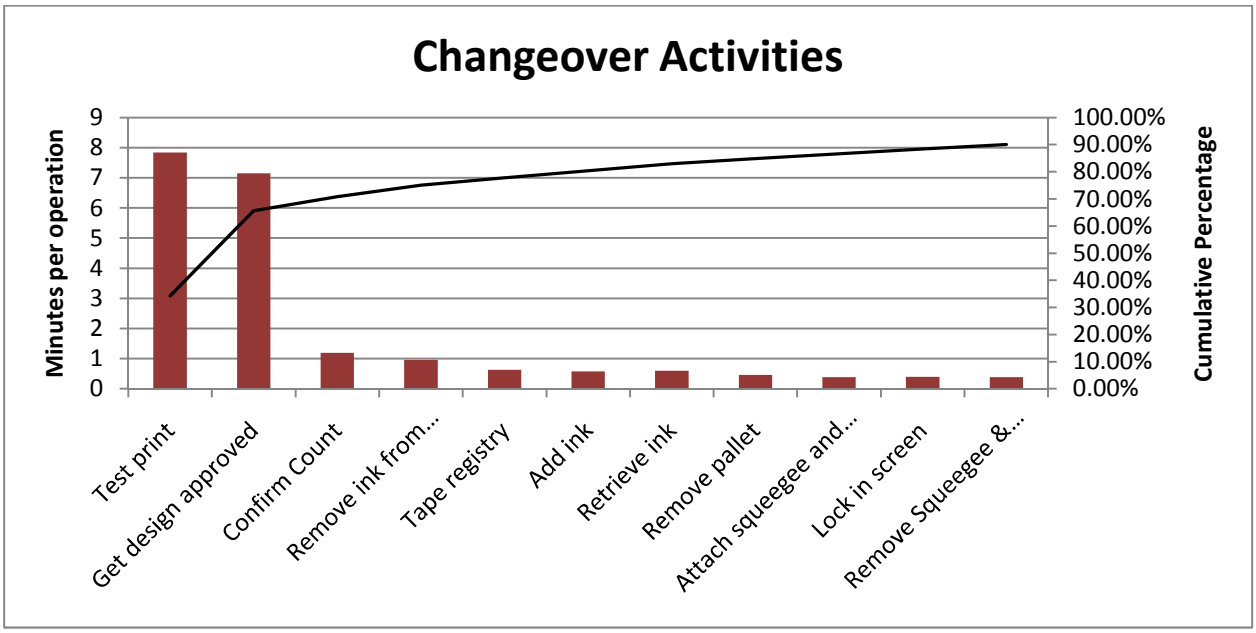
Once the changeover was chosen as the area of focus, every single task within the changeover operation was broken up and a time study was conducted once again, refer to Table 3.

Table 3: Changeover Time Studies prior to changes

Changeover Time Studies												
Standard Times Calculation Sheet												
Operation: Changeover								Date: 4/7/11				
Observer: Millan Arellano								Study Start Time:				
Operator: Jesse								Study End Time:				
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Confirm Count	R	120	100	95	110	100	110	635	105.8		
		T	11.9	87.5	93.5	47.7	85	50	375.6	62.6		66.25
2	Remove ink traps	R	120	100	105	110	105	105	645	107.5		
		T	7.3	24.6	17.9	12.2	19.4	22.1	103.5	17.25		18.54
3	Remove Squeegee & Flood bar	R	110	110	100	99	100	100	619	103.2		
		T	14.3	15.2	24.8	20.9	25.6	23	123.8	20.63		21.29
4	Remove screen	R	105	100	100	105	105	100	615	102.5		
		T	11.6	19.7	20.9	14.2	14	20.8	101.2	16.87		17.29
5	Remove ink from screen/squeegees/inktraps	R	110	100	105	110	105	115	645	107.5		
		T	33.4	65.5	55.6	39.7	60.7	43.5	298.4	49.73		53.46
6	Place screen on press	R	105	105	80	100	100	105	595	99.17		
		T	9	9.1	35	13.2	12.5	10.1	88.9	14.82		14.69
7	Remove pallet	R	120	105	100	96	105	100	626	104.3		
		T	5.7	23.9	29.9	32.1	25.9	28.2	145.7	24.28		25.34
8	Place trilock on	R	100	105	100	105	100	100	610	101.7		
		T	12.6	9.9	13	10.8	12.9	12.6	71.8	11.97		12.17
9	Lock in screen	R	100	100	105	110	105	100	620	103.3		
		T	22.2	23.4	20	18.1	19.3	24	127	21.17		21.87
10	Remove trilock	R	115	105	105	100	105	100	630	105		
		T	10.3	16.6	16.4	20.3	17.4	21.8	102.8	17.13		17.99
11	Place pallet on	R	100	105	100	100	100	100	605	100.8		
		T	13.1	11.7	13.4	14.3	15.4	13.1	81	13.5		13.61
12	Attach squeegee and flood bar	R	100	90	100	100	90	100	580	96.67		
		T	20.1	32.2	18.8	18.8	25.3	19.3	134.5	22.42		21.67
13	Attach ink traps	R	120	105	100	100	100	115	640	106.7		
		T	9.4	17.5	20.1	20.5	20.4	12.6	100.5	16.75		17.87
14	Retrieve Ink	R	105	100	105	100	95	100	605	100.8		
		T	22.4	33.3	25.6	31.2	48	35.8	196.3	32.72		32.99
15	Add ink	R	110	100	105	100	100	95	610	101.7		
		T	23.5	33.7	29.6	33.5	32.7	36.2	189.2	31.53		32.06
16	Test print	R	105	100	80	100	90	120	595	99.17		
		T	308.8	406.5	633	423	582	283	2636	439.4		435.7
17	Get design approved	R	100	85	120	90	120	85	600	100		
		T	303.9	550	215	429	290	596	2384	397.3		397.3
18	Tape Registry (optional)	R	110	95	100	100			405	101.3		
		T	24.7	40	36.9	37.9			139.5	34.88		35.31
19	Zero out counter	R	100	110	115	110	100	105	640	106.7		
		T	15.7	13.4	10	12.6	15.7	14.4	81.8	13.63		14.54
* Observed Time = Average Time			Non-Cyclic Elements			Frequency				Total NT =		1270
* Time in seconds		1						Allowance				0.08
		2						Standard Time (Seconds/unit)				1371.57773
		3						Output/8 Hour Shift				20.9977162

From these time studies a Pareto Chart was developed once again in order to give a graphical representation of what our time studies data was telling us, see Figure 2.

Figure 2: Pareto Chart prior to changes being implemented



From this Pareto chart it became clear that the tasks contributing to the changeovers long operation times resulted from two specific tasks. The first was the test print task while the second was the design approval task. For details of how the times were determined for each of these tasks please refer to the Changeover Time Collecting Procedures in the Appendix. Once these two items were identified as the contributing factors to the long changeovers the next step was to determine what were the reason why these two tasks were taking so long to complete. Due to my lack of screen printing experience brainstorming activities were conducted with screen print operators, designers, and the owner. From these brainstorming activities, Fishbone Diagrams were developed one geared towards the causes associated with long test print times seen in Figure 3 in the Appendix and the other geared towards long design approval times seen in Figure

4 of the Appendix. Once these Fishbone diagrams were complete, possible solutions were developed to address each of the causes mentioned during these brainstorming activities. A list of the causes and solutions derived from these brainstorming activities can be view in the Appendix under Brainstorming Exercises.

Solution Implementation

Although multiple solutions were documented not all solutions were chosen for immediate implementation. This was primarily due to the cost and overall difficulty of implementation of some of these solutions. As a result the only solutions put in effect in order to reduce variability and problems involving the test print and design approval tasks were the following:

1. Problem: Designers feel they must confirm every design even if it lies in a typical location and does not contain many colors.

   Solution: Designers should indicate on every design (No Need for Approval Stamp) if it is necessary for designers to view the design on the t-shirt. Designers should only view designs if design belongs to a very critical customer, design is very detailed, or if design contains many Pantone colors.

2. Problem: Misunderstanding of where to measure from (reference points).

   Solution: Standardize measuring locations in order to avoid screen printers taking extra measurements because they do not understand if dimensions given on the screens refer to measurements from bottom of shirt or from the bottom stitching.

3. Problem: Test print shirts are underneath conveyor away from screen printing machine.

   Possible Solutions: Move test print shirts near screen printing machine.

4. Problem: Operator did not properly view work order to verify design is placed on proper location.

   Possible Solutions: PDF of what the design should look like on the shirt in order to facilitate screen order on press and test print design location.

5. Problem: Certain non-value adding items like ink retrieval, tear down, screen retrieval, and test print shirt retrieval have been completed by Jesse the screen print operator.

   Possible Solutions: Have Arturo/utility employee stage certain items for the next run in order to utilize Jesse specifically on tasks vital to getting the screen printing press running.

With the above solutions presented a new design for standard changeover procedures was developed documenting how, and by whom specific tasks during the changeovers should be completed by. Please refer to Appendix under Designs to view the changes to the old standard changeover procedures. Once this new design was develop and put in place in J. Carroll's screen printing operation. The next steps would be to once again perform time studies in order to determine the time reduction from baseline. After conducting the time studies seen in Table 4 a Pareto Chart was once again developed in order to give a graphical representation of the discrepancies from the original baseline graph, refer to Figure 5**.**

Table 4: Changeover times studies after changes

Changeover Time Studies after changes

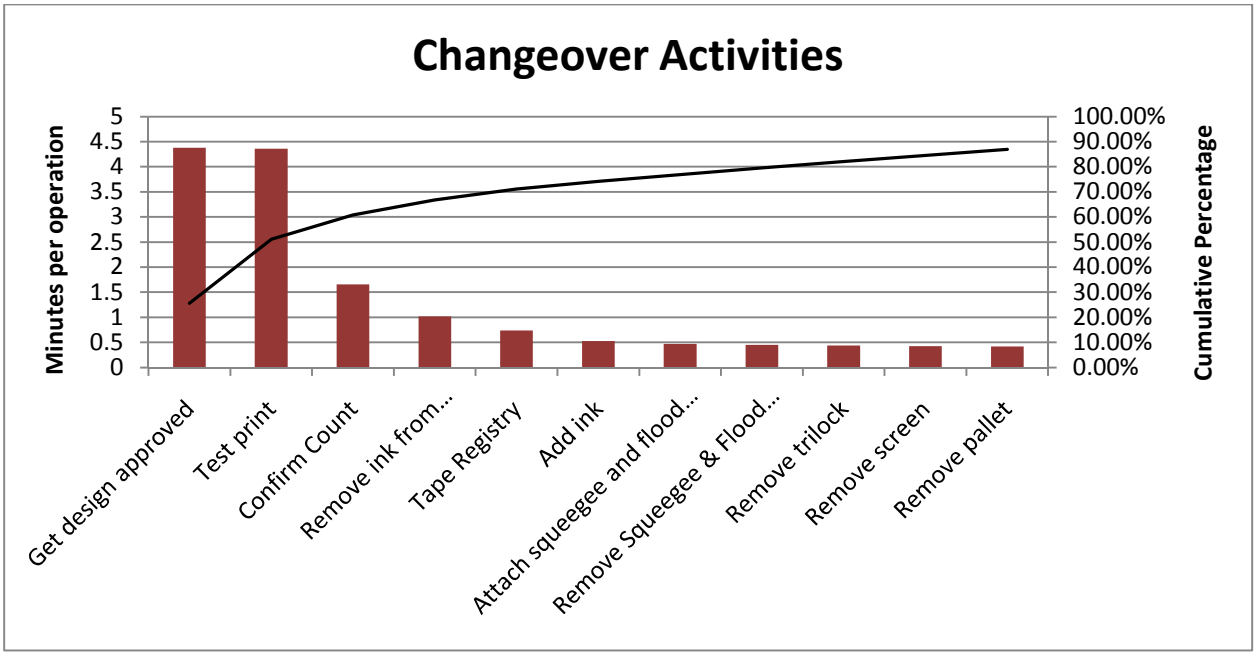
Standard Times Calculation Sheet

Operation: Changeover	Date: 5/13/11
Observer: Millan Arellano	Study Start Time:
Operator: Jesse	Study End Time:

	Element Description		Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Confirm Count	R	110	100	90	50	110	60	520	86.67		
		T	54.1	85	100	178.8	63.2	156.8	637.9	106.3		92.14
2	Remove ink traps	R	105	110	110	105	105	110	645	107.5		
		T	18.2	9.2	8.9	16.3	14.6	9.1	76.3	12.72		13.67
3	Remove Squeegee & Flood bar	R	100	100	100	110	95	110	615	102.5		
		T	27.5	25.1	26.6	17.9	30.2	18.6	145.9	24.32		24.92
4	Remove screen	R	105	100	110	120	120	120	675	112.5		
		T	24.6	27.1	22.1	13.7	18.6	19.6	125.7	20.95		23.57
5	Remove ink from screen/squeegees/inktraps	R	95	115	115	115	115	115	670	111.7		
		T	75	52	34.4	54.2	36.1	51.4	303.1	50.52		56.41
6	Place screen on press	R	100	110	85	100	85	110	590	98.33		
		T	13.6	10.5	17.1	13.1	18	10.8	83.1	13.85		13.62
7	Remove pallet	R	105	100	115	100	100	105	625	104.2		
		T	23.3	25.7	15.6	22.3	26.4	20.1	133.4	22.23		23.16
8	Place trilock on	R	100	100	110	110	100	100	620	103.3		
		T	15.1	16.6	12.3	13.4	14	15.9	87.3	14.55		15.04
9	Lock in screen	R	100	100	90	90	120	120	620	103.3		
		T	22.1	22.1	25.3	25.1	11.2	8	113.8	18.97		19.6
10	Remove trilock	R	70	75	100	95	75	90	505	84.17		
		T	40	33	17.1	21.4	35.5	26.4	173.4	28.9		24.32
11	Place pallet on	R	80	100	80	100	90	80	530	88.33		
		T	21.9	13	19.8	13.2	16.6	18	102.5	17.08		15.09
12	Attach squeegee and flood bar	R	100	100	70	95	100	100	565	94.17		
		T	19.7	21.5	54.8	27.7	19.4	22.2	165.3	27.55		25.94
13	Attach ink traps	R	120	120	90	110	115	110	665	110.8		
		T	9.8	9.5	26.4	16.7	14.6	16.9	93.9	15.65		17.35
14	Retrieve Ink	R	100	120	110	100	100	115	645	107.5		
		T	15.5	10	12.2	16.9	15	11.4	81	13.5		14.51
15	Add ink	R	110	120	110	100	105	95	640	106.7		
		T	22.5	16.4	25.7	33	28.1	38.2	163.9	27.32		29.14
16	Test print	R	110	95	100	98	120	80	603	100.5		
		T	208.7	293.3	233	251.3	72.7	388	1447	241.2		242.4
17	Get design approved	R	120	100	110	80	40	60	510	85		
		T	56.7	151	102	210.7	828.4	368	1717	286.1		243.2
18	Tape Registry (optional)	R			100	80	85		265	88.33		
		T			36.6	55	47		138.6	46.2		40.81
19	Zero out counter	R	88	100	110	95	100	100	593	98.83		
		T	20.1	14.5	9	16.3	13.5	15	88.4	14.73		14.56

* Observed Time = Average Time	Non-Cyclic Elements	Frequency		Total NT =	949.4
* Time in seconds	1			Allowance	0.08
	2			Standard Time (Seconds/unit)	1025.39331
	3			Output/8 Hour Shift	28.0867836

Figure 5: Pareto Chart after changes implemented



Methodology

With time studies completed for both the current state, and the new proposed state an understanding of the performance gained from this new design was obtained. Although gains were measured comparing the times for the two changeover states we can not concretely state that these gains observed were actual improvements made in the process. Even though I believe the improvements did reduce variability which consequently reduced changeover times for the tasks associated with our new changes, because of the high standard deviation of many of the tasks within the changeover and other operations within J. Carroll's process there is not enough time to collect the 134 samples needed to detect a 1 minute reduction in changeover time and state with a 95% confidence level that there was indeed a difference between the old changeover procedure and new changeover procedure. Please refer to Statistics in the Appendix to view the Power and Sample Size calculations done in Minitab. A 1 Sample T-Test was performed initially with the 6 changeover times collected in order to determine how many samples would be needed

to show an actual difference in the process. Considering that a large sample size would be needed, far more than could be obtained during this project, 6 samples were the only amount collected. With 6 samples obtained for the old changeover process and 6 samples for the new changeover process a 2 Sample T-Test was performed to try and reaffirm that more samples would be needed.

Results

Viewing the Two Sample T-Test output from Minitab we obtained a P-Value of .067 which is greater than .05. Due to our P-Value we would fail to reject the H_0 hypothesis that states that there is no difference between the changeover times collected prior to changes being implemented, and the changeover times after changes were implemented. Although we failed to reject the null hypothesis, we should not state that there is no reduction in changeover times. Failing to reject our null hypothesis only reaffirms that more samples would be needed to confirm with a 95% confidence level that there were clear differences in changeover times. Until the appropriate number of samples are collected, could we confirm that there were or weren't any reductions in changeover times. Until then I do believe the 38% and 44% reduction in design approval and test print processes were correct, please refer to Figure 6 and Table 5.

Figure 6: Pareto Chart after changes implemented

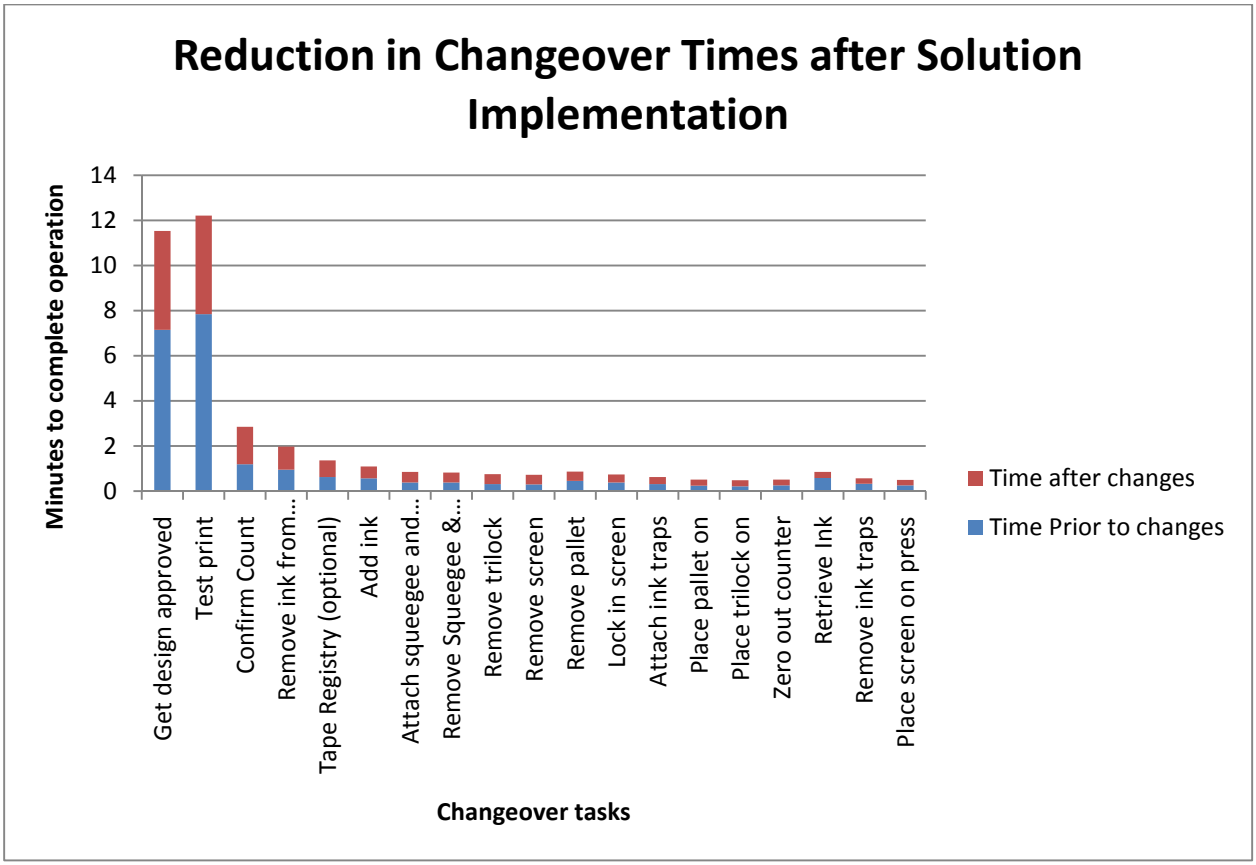


Table 5: Comparison of changeover times before and after changes implemented (only shows tasks that were affected by changes)

Task	Time Prior to changes (min)	Time after changes (min)
Get design approved	7.1517	4.37784
Test print	7.8429925	4.362705
Retrieve Ink	0.5938075	0.261225
Place screen on press	0.2644775	0.245145
Total	22.85962888	17.0898885

Ultimately in a comparison between the six samples collected prior to, and after changes being made there would be an approximate 25% reduction in total changeover time or a total of 5 minutes of changeover time/machine idleness and worker time saved.

Savings Analysis

Considering that the cost of implementation of our solutions to the problems uncovered in the brainstorming exercises were practically nonexistent. We could assume that the savings calculations are based on the following criteria: time saved, number of changeovers per day, cost of an idle screen printing machine, and 260 days of yearly production. Using the values from the previous criteria a cost savings of approximately $31,200 was determined for machine idleness. Also a cost savings of $1,300 would also be potentially obtained annually for employee idleness. Please refer to the Appendix under Savings Calculations to view how the previous two savings figures were obtained.

Conclusion

In conclusion the combination of the brainstorming activities and long evaluation hours paid off. The solutions implemented in J. Carroll's screen printing process have thus far resulted in time savings. With such savings, machine idleness has been reduced, which means increased throughput; which is what the owner Josh Jacobson wanted and was the main objective of this project. Hopefully with the standardization of the newly designed changeover procedures will serve as a control and have these new solutions implemented running smoothly and will not be disregarded after some period of time.

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Appendix

Figures

Figure 3: Fishbone Diagram for test print issues

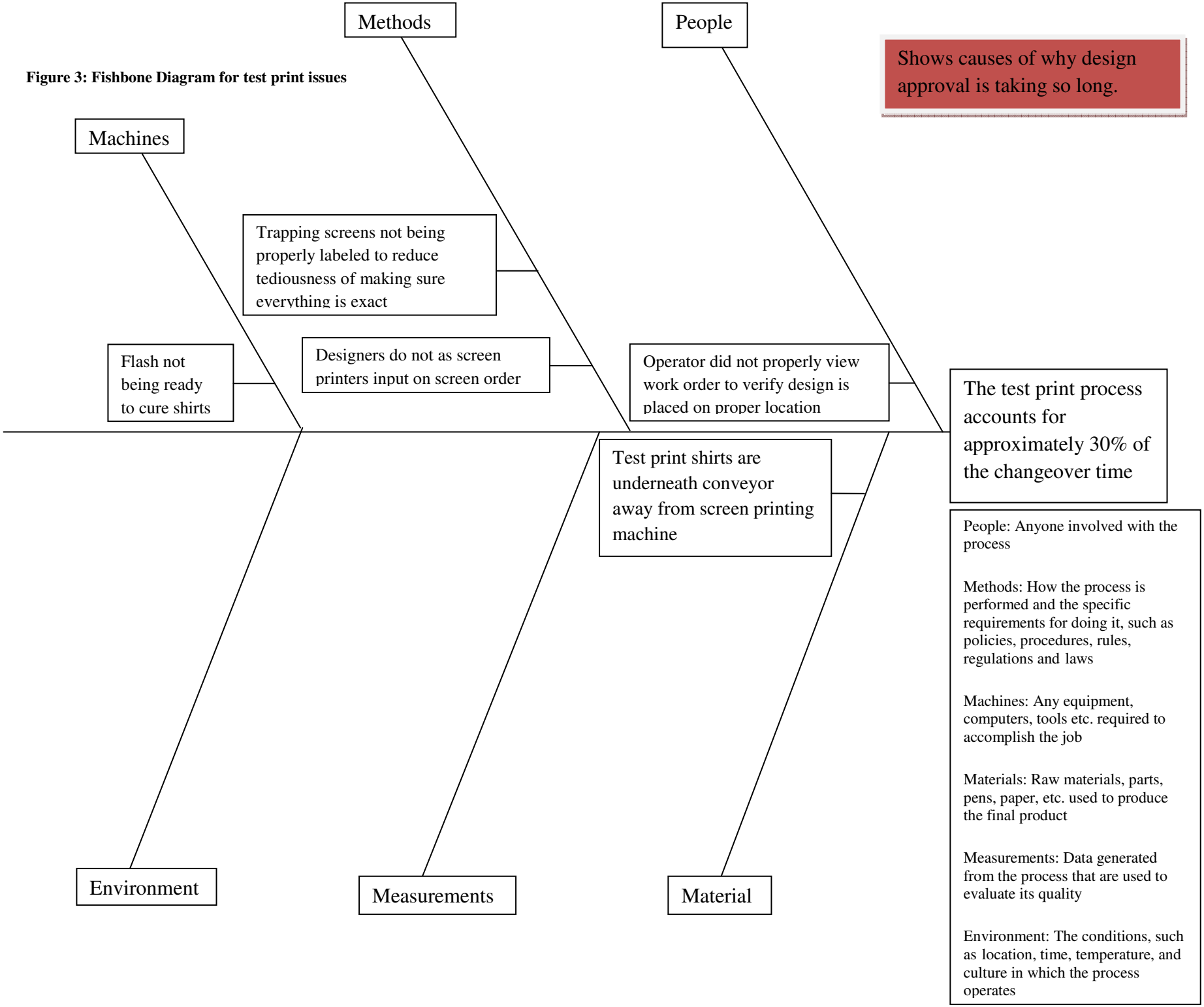
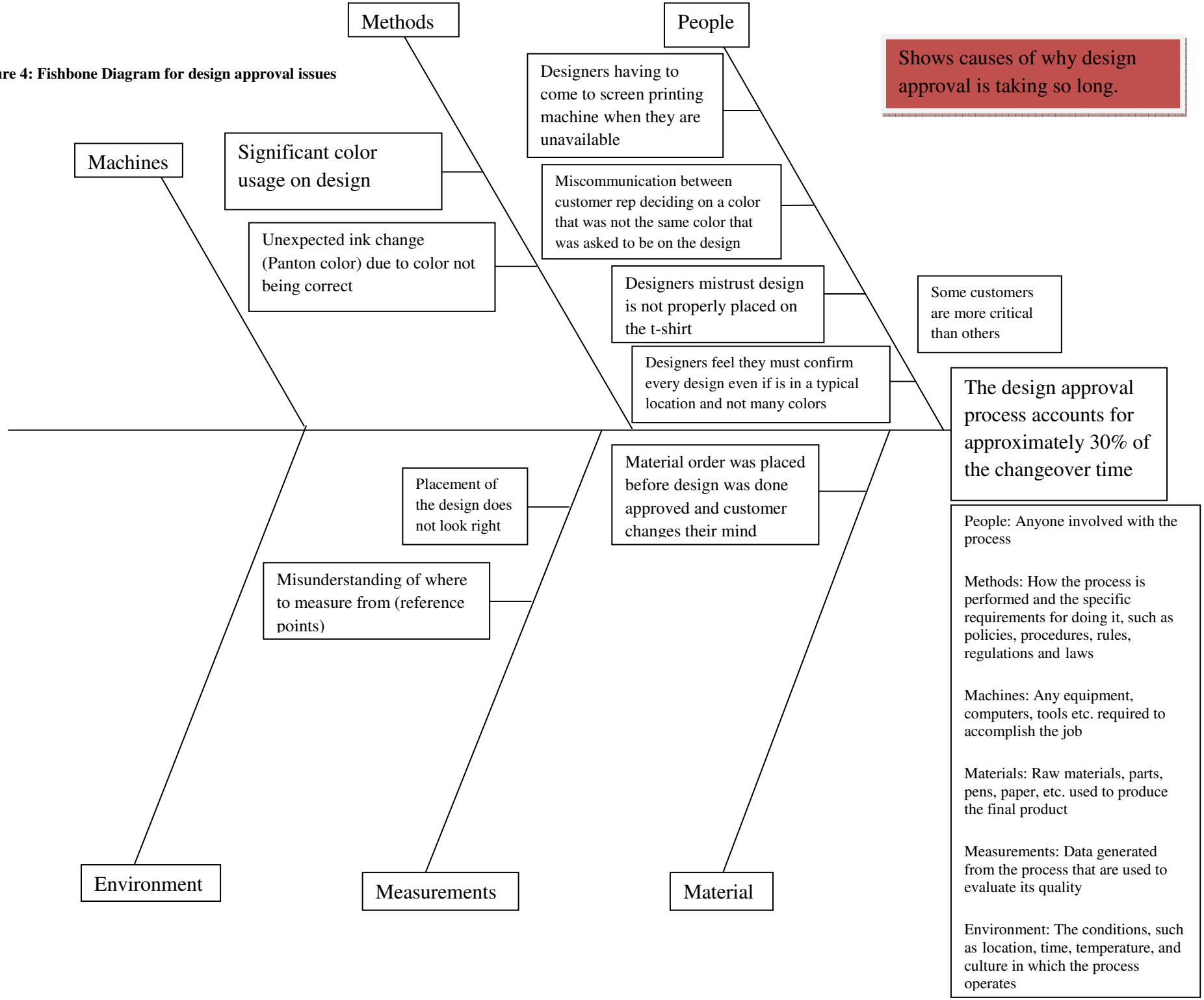


Figure 4: Fishbone Diagram for design approval issues



Brainstorming Exercises

Possible solutions after test print Fishbone Exercise

Problem: Operator did not properly view work order to verify design is placed on proper location

Possible Solutions:

- Checklist or One Point Lesson (OPL) of what should be done in test print process
- PDF of what the design should look like on the shirt.

Problem: Designers do not ask screen printers input on screen order

Possible Solutions:

- Have designers ask screen printers the proper order of the screens.

Problem: Trapping screens not being properly labeled to reduce tediousness of making sure everything is exact

Possible Solutions:

- Screens should be labeled in order to know what screen goes last in order to cover misalignment of previous screen as opposed to having everything align perfectly.

Problem: Flash not being ready to cure shirts

Possible Solutions:

- Standardize flash time in order to quantify how many times to preheat in order to have flash ready by the time the screen reaches flash

Problem: Test print shirts are underneath conveyor away from screen printing machine

Possible Solutions: Move test print shirts near screen printing machine

Possible solutions after design approval Fishbone Exercise

Problem: Designers having to come to screen printing machine when they are unavailable.

Possible Solutions:

- Obtain a webcam in order to allow designers to view screen printing operation and know not to undertake any activity that will not allow them to address the design approval process.

Problem: Customer representative error deciding on a color that was not the same color that was asked to be on the design by the customer.

Possible Solutions:

- Verify all orders completed that are not done by a designer or Josh.

Problem: Designers mistrust design is not properly placed on the t-shirt

- Designers must trust that if design measurements are placed on screen then the design will be properly placed on shirt.

Problem: Designers feel they must confirm every design even if is in a typical location and not many colors

Possible Solutions:

- Designers should indicate on every design if it is necessary for designers to view the design on the t-shirt. Designers should only view designs if design belongs to a very critical customer, design is detailed enough, or if design contains many phantom colors.
- Maybe have a checklist to know if certain things are done then no need to verify design
- Have database of past t-shirts (sizes, styles) show examples (images) of:
    - Rejected design location (Could eliminate approval process)
    - Appropriate design location (Could eliminate approval process)

Problem: Material order was placed before design was done approved and customer changes their mind

Possible Solutions:

- Rowley should make sure design is approved before he goes ahead and places order in advance

Problem: Misunderstanding of where to measure from (reference points)

Possible Solutions:

- Designers should be aware of location where screen printers measure from in order to avoid screen printers taking extra measurements because they do not understand if they should measure from bottom of shirt or from the bottom stitching. (Not exactly sure I understood this correctly).

Other Potential Solutions resulting from brainstorming exercise

Problem: Spatulas and other equipment not being properly cleaned thus creating wasted time from retrieving clean items

Possible Solutions:

- OPL for cleaning spatula, ink traps, squeegees etc.

Problem: Rags, CG2 bottles, and other small items are not found where they should be or there is not enough available.

Possible Solutions:

- List of approved items for Arturo and Ana to do (do in Spanish)
- Assure print screening items are top priority
- Designated areas for tape guns, pallets equipment, CG2 bottles,

Problem: Certain non-value adding items like ink retrieval, tear down, screen retrieval, and test print shirt retrieval have been completed by Jesse the screen print operator.

Possible Solutions:

- Have Arturo/utility employee stage certain items for the next run in order to utilize Jesse specifically on tasks vital to getting the screen printing press running

Statistics

Two-Sample T-Test and CI: Time Prior to changes, Time After changes

```
Two-sample T for Time Prior to changes vs Time After changes

                       N   Mean  StDev  SE Mean
Time Prior to changes  6  20.78   3.18      1.3
Time After changes     6  16.33   4.17      1.7

Difference = mu (Time Prior to changes) - mu (Time After changes)
Estimate for difference:  4.46
95% CI for difference:  (-0.39, 9.30)
T-Test of difference = 0 (vs not =): T-Value = 2.08  P-Value = 0.067  DF = 9
```

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05  Assumed standard deviation = 3.18376

            Sample  Target
Difference    Size   Power  Actual Power
         1     134    0.95      0.950484
```

Savings Calculation

Machine Idleness

Time Saved: 5 minutes

Number of changeovers per day: 4

Machine Idleness Cost: $6/min

Yearly production days: 260

Savings:

4 changeover/day*5 minute/changeover*$6/minute*260days/year = $31,200 per year

Worker Idleness

Time Saved: 5 minutes

Number of changeovers per day: 4

Machine Idleness Cost: $15/hr

Yearly production days: 260

Savings:

$15/hr*5 minute/changeover*4 changeover/day*1hr/60min*260days/year = $1,300 per year

Time Collecting Procedures

Screen Printing Operation Time Collecting Procedures

1. Film Stripping Table
    a. Start: When operator begins using computer film stripping program.
    b. End: When operator places screen and film in screen imaging system.
2. Screen Imaging System
    a. Start: When operator places screen and film in screen imaging system.
    b. End: When operator places screen in dip tank.

3. Washout
    a. Start: When operator places screen in dip tank.
    b. End: When operator grabs screen from dip tank.
4. Rinse
    a. Start: When operator grabs screen from dip tank
    b. End: When operator finishes rinsing out screen with water.
5. Drying
    a. Start: When operator finishes rinsing out screen with water.
    b. End: When operator grabs screen from drying rack.
6. Taping
    a. Start: When operator grabs screen from drying rack.
    b. End: When operator finishes taping screen.
7. Set Up Machine
    a. Start: When operator finishes taping screen.
    b. End: When operator removes practice t-shirt from screen printing machine.
8. Screen Printing
    a. Start: When operator removes practice t-shirt from screen printing machine.

    b. End: When operator removes t-shirt from screen printing machine and places on furnace conveyor.
9. Furnace
    a. Start: When operator removes t-shirt from screen printing machine and places on furnace conveyor.
    b. End: When operator removes t-shirt from opposite end of furnace conveyor belt.
10. Change Over (optional)
    a. Start: When last t-shirt with initial design features is removed from screen printing machine.
    b. End: When t-shirt with initial design features is placed once again on screen printing machine to begin application of other design features.
11. Packaging
    a. Start: When operator removes t-shirt from opposite side of furnace conveyor belt.
    b. End: When operator folds item.

Changeover Time Collecting Procedures

1. Confirm Count
    a. Start: When operator places last t-shirt on conveyor
    b. End: When operator grabs the ink traps
2. Remove ink traps
    a. Start: When operator grabs the ink traps
    b. End: When operator places ink traps on rack
3. Remove squeegee and flood bar
    a. Start: When operator places ink traps on rack
    b. End: When operator places squeegee and flood bar on rack
4. Remove screen
    a. Start: When operator places squeegee and flood bar on rack
    b. End: When operator grabs ink removal spatula
5. Remove ink from screen
    a. Start: When operator grabs ink removal spatula
    b. End: When operator places screen on screen rack
6. Place screen on press
    a. Start: When operator places screen on screen rack
    b. End: When operator places screen on press
7. Remove pallet
    a. Start: When operator places screen on press
    b. End: When operator grabs trilock
8. Place trilock on
    a. Start: When operator grabs trilock

    b. End: When operator locks in trilock
9. Lock in screen
    a. Start: When operator locks in trilock
    b. End: When operator locks in screen
10. Remove trilock
    a. Start: When operator locks in screen
    b. End: When operator grabs the pallet
11. Place pallet on
    a. Start: When operator grabs the pallet
    b. End: When operator locks in the pallet
12. Attach squeegee and flood bars
    a. Start: When operator locks in the pallet
    b. End: When operator locks in squeegee and flood bar
13. Attach ink traps
    a. Start: When operator locks in squeegee and flood bar
    b. End: When operator locks in ink traps
14. Retrieve Ink
    a. Start: When operator locks in ink traps
    b. End: When operator stands by screen to add ink
15. Add ink
    a. Start: When operator stands by screen to add ink
    b. End: When operator places ink bucket on rack
16. Test print
    a. Start: When operator places ink bucket on rack
    b. End: When operator okays test print
17. Get design approved
    a. Start: When operator okays test print
    b. End: When operator gets tape to tape registry/When operator grabs new order shirt
18. Tape Registry (optional)
    a. Start: When operator gets tape to tape registry
    b. End: When operator tapes registry
19. Zero out counter
    a. Start: When operator tapes registry/When operator grabs new order shirt
    b. End: When operator places t-shirt on pallet

Designs

Old Design

Changeover Standard Operating Procedures		
Task	**Responsibility**	**Notes**
1. Wait count is good	Jesse	
2. Remove ink trap (s)	Jesse	
3. Remove squeegee(s) and Flood bar(s)	Jesse	
4. Remove screen (s)	Jesse	
5. Remove ink from screen (s)/squeegee (s)/ ink trap (s)	Jesse	During Actual Changeover
6. Place screen (s) on press	Jesse	Goes to back sometimes to retrieve screen (s)
7. Remove pallet	Jesse	
8. Place trilock on	Jesse	
9. Lock in screen (s)	Jesse	
10. Remove trilock	Jesse	
11. Replace pallet	Jesse	
12. Attach Squeegee (s) and flood bar (s)	Jesse	
13. Attach ink trap (s)	Jesse	
14. Retrieve ink	Jesse	
15. Add ink to screen (s)	Jesse	
16. Test Print	Jesse	Task requires test shirt to be obtained which is not nearby and under furnace conveyor
17. Get design approved	Jesse	Every design has to be verified even though specifications are on screen
18. Tape Registry (optional)	Jesse	
19. Zero out counter	Jesse	

New Design

Changeover Standard Operating Procedures		
Task	**Responsibility**	**Notes**
1. Wait count is good	Jesse	
2. Remove ink trap (s)	Utility	
3. Remove squeegee(s) and Flood bar(s)	Utility	
4. Remove screen (s)	Utility	
5. Remove ink from screen (s)/squeegee (s)/ ink trap (s)	Utility	Could be done during or after
6. Place screen (s) on press	Jesse	Screen will be staged by utility employee
7. Remove pallet	Jesse	
8. Place trilock on	Jesse	
9. Lock in screen (s)	Jesse	Utility could be by screen so Jesse does not have to walk around to lock screens ir
10. Remove trilock	Jesse	
11. Replace pallet	Jesse	
12. Attach Squeegee (s) and flood bar (s)	Jesse	Utility could help in this process
13. Attach ink trap (s)	Jesse	Utility could help in this process
14. Retrieve ink	Jesse	Ink will be stages by utility employee
15. Add ink to screen (s)	Jesse	Utility could help in this process
16. Test Print	Jesse	Test print shirts will be placed in a more assecible location near Jesse
17. Get design approved	Jesse	Design will only be approved if it does not have "no need for approval stamp" which goes on easy one to two color jobs with easy design placement
18. Tape Registry (optional)	Jesse	
19. Zero out counter	Jesse	
Means a change was made		