A Small Business: An Operations and Production Application with Student Experience

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Abstract
The project provided a system view of the production processes, transactional and non-transactional flows, and standardized procedures for specific assembly steps, workstation design, and production line arrangement. Operation modifications are suggested to reduce labor requirements, cycle time, material movements, and reduce the safety concern and improved cost performance.

Keywords: Process Improvement, Time Motion, Value Stream Map

Introduction and Background
A small business which manufactures several different products had identified an issue with one of the assembly operations on their line. This presented an opportunity for a process improvement project that could be undertaken through a guided student experience. After preliminary review, the project was accepted and developed for a student experience. The crux of the project was identified as improving and reducing the level of manual work required for a specific assembly operation in the production of zippers. The primary focus of the project was improving and reducing the manual time required for producing double-end zippers. The manual assembly operation of attaching sliders to the double-end zippers also poses a long term concern of potential injury to the hand and wrist. Additionally, the project offered an opportunity to investigate and define opportunities for the entire assembly production line of the zipper.

Initial work focus was framed to improve and enhance the manual slider assembling operation. Within initial project work and understanding of the manufacturing process, a project scope expansion was agreed upon to envelop the full line. The new project scope provided process improvement opportunities for all the manufacturing processes involved for the production of the zipper. This excited the business, as the business is one of a very few U.S. owned and operated manufactures of zippers, which recognizes the need for increasing efficiency to maintain competitiveness. The project's goal was then modified to include a recommendation of improvements for the overall assembly process flow to reduce the throughput time for the Plastic Molded Line, and significantly, reduce the cycle time of the hand sliding process while alleviating the safety concern associated with the operators.

Various methods and techniques were employed to define and obtain results. Some of these are time motion studies, value stream mapping, work station standardization methods, material buffers, workflow optimization, and visual aids. The net to the small business is a potential savings of manual operations of 20%, significant reduction of throughput time, improved employee satisfaction, and the "basis" for future process improvements.

Understanding the Problem

The small business operates its Plastic Molded Line to produce the Army Combat assemble by hand Uniform Zipper (ACU). The zipper is unlike other products the company manufactures, the ACU zipper currently requires manual attachment of sliders to the chain of the zipper. The manual installation of the sliders is a major concern due to high labor costs and potential employee injury.

The ACU is produced in various colors and sizes. The colors are green, black, and camouflage and range from 19 to 26 inches in length. The life of the zipper begins with the production of tapes by looming machines at the business. Once the tape is finished, it is formed into chain. The chain is formed by attaching to the tape teeth or tracks for the sliders. The slider insertion permits assembly of the zipper. Figure 1 depicts the process steps for the ACU assembly line.

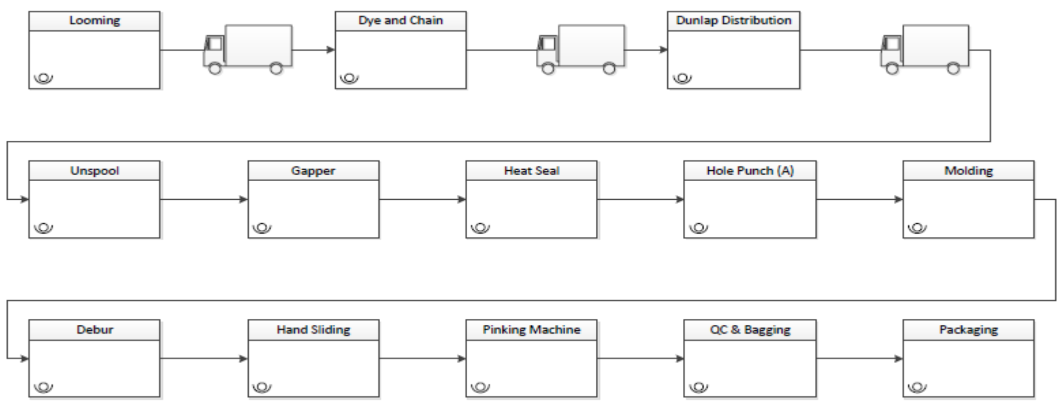


Figure 1 - Plastic Molded Line Process Flow

When the chain arrives, it is either stored in inventory or sent to the production line for initiating zipper manufacturing. The chain, sent to production, is staged in an area close to the Unspool. From that point is moves through the process line steps in a batch like method. The chain is collected and moved through the process steps in a container (as a batch). One container has capacity to contain enough continuous chain to produce as many as 450 zippers.

Prior to the Molding process the chain is separated into two respective parallel tapes is returner to the container and transported to the slider insertion and assembly process step. The slider assembly area encompasses 6 individual work tables for manually inserting the sliders on the tape. This process step is labor intensive and the initial and immediate focus of the project. Here, the sliders (one box end slider and one butterfly slider) are attached to one tape of the chain. Then, the other tape of the chain is attached to the sliders. Figure 2 depicts the two sliders. The container with the assembled zippers in a continuous chain is moves to cutting, packaged and boxing for shipment.

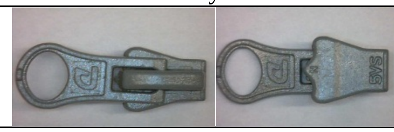
Box end slider	Butterfly slider
	

Figure 2 - Box end and Butterfly Sliders

Project Objective—Slider Insertion

The identification of improvements for slider insertions within the ACU line was separated into three elements. The first two are: Analysis of Current Process and Process Times and Organization and Standardizing Work Stations and Insertion Process. These elements using time motion studies and lean methodologies sought to establish an organized workplace that operates to standard work and serve as a model cell for future improvements. The current cycle times, process lead times and travel distance were identified. A target improvement of 20 % was sought through improvement in slider insertion procedure, organization and workstation standardization. The third element is investigated through the development of improved tools/ jig, and conceptual design for automation machinery.

Two Slider Process

The two slider insertion process is labor intensive, requiring team members to use both hands for completion. This process is costly, inefficient, and a safety concern. The process requires installation of the two sliders to one side of the chain tape by pulling each slider over the hook end, and then attaches the other side of the chain tape by guiding the end stop of the zipper through the installed sliders.

The purpose of improving this particular process is to reduce the cycle time and create better ergonomic working conditions for the team member. This will reduce labor costs and prevent the possibility of injury or carpal tunnel for the team member. Several tens of thousands ACU are manufactured per week. Cycle times recorded for seven team members. An average cycle time has been calculated for each of the team members, equation (1). To be consistent, 30 cycle times were recorded for each team member. Using the individual cycle times, a weighted average of all cycle times has been calculated to account for the most accurate average cycle time, equation (2).

$$C/T = \frac{\sum time}{30} \tag{1}$$

$$Avg = \frac{C/T_{TM1} + C/T_{TM2} + C/T_{TM3} + C/T_{TM4} + C/T_{TM5} + C/T_{TM6} + C/T_{TM7}}{7} \tag{2}$$

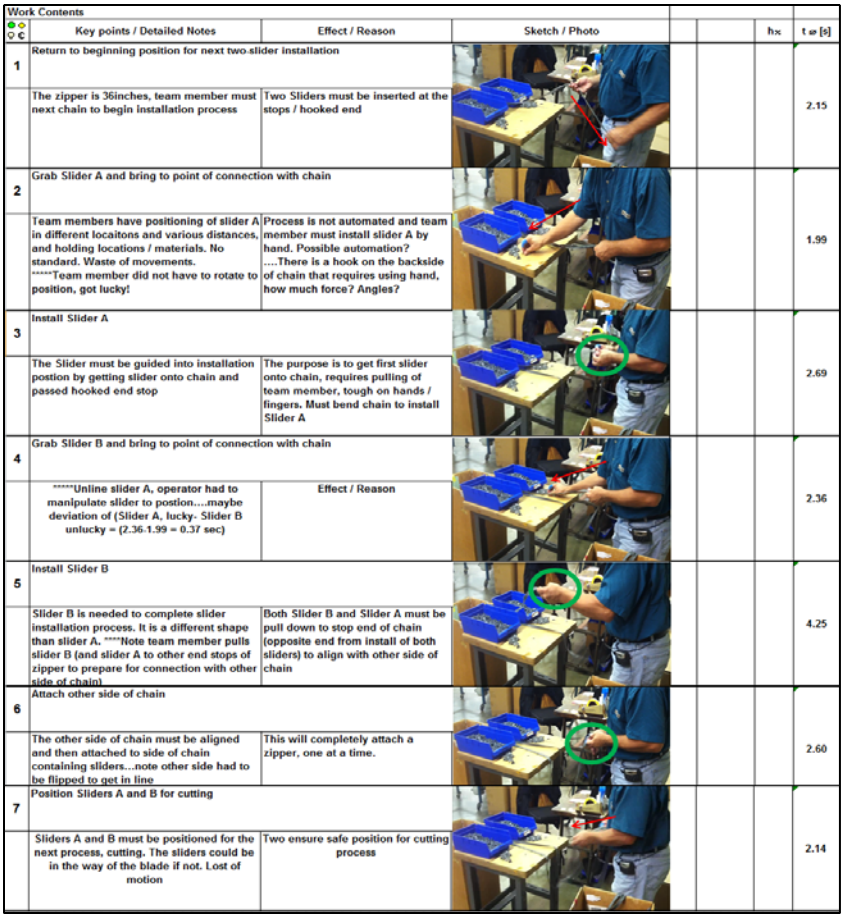
The weighted average of the cycle time is determined to be 21.93 seconds. This time can then be compared to the weekly average number of ACU zippers manufactured to show the labor hours associated with the current process, equation (3).

$$Labor\ Hours\ Per\ Week = \frac{(\text{average cycle time x weekly production})}{3600} \sim 200\ \text{hours per week} \tag{3}$$

The current process has many labor hours and the work elements are repetitive. This highlights the need to address the safety concern associated with the process. Many of the team members have sore fingers, hands, and wrists, and wear tape on his or her hands to prevent calluses or cuts due to the repetitive motion. Carpal tunnel is also a concern.

Methodology

The process was analyzed further by using time motion studies and an elemental breakdown of the process. This provides a fuller understanding of variables within the process and understanding opportunities for improvement. An example of a time motion study and elemental break down is show below in Figure 3.



Work Contents							
	Key points / Detailed Notes	Effect / Reason	Sketch / Photo			hx	t ø [s]
1	Return to beginning position for next two-slider installation						
	The zipper is 36inches, team member must next chain to begin installation process	Two Sliders must be inserted at the stops / hooked end					2.15
2	Grab Slider A and bring to point of connection with chain						
	Team members have positioning of slider A in different locaitons and various distances, and holding locations / materials. No standard. Waste of movements. *****Team member did not have to rotate to position, got lucky!	Process is not automated and team member must install slider A by hand. Possible automation? ....There is a hook on the backside of chain that requires using hand, how much force? Angles?					1.99
3	Install Slider A						
	The Slider must be guided into installation postion by getting slider onto chain and passed hooked end stop	The purpose is to get first slider onto chain, requires pulling of team member, tough on hands / fingers. Must bend chain to install Slider A					2.69
4	Grab Slider B and bring to point of connection with chain						
	*****Unline slider A, operator had to manipulate slider to postion....maybe deviation of (Slider A, lucky- Slider B unlucky = (2.36-1.99 = 0.37 sec)	Effect / Reason					2.36
5	Install Slider B						
	Slider B is needed to complete slider installation process. It is a different shape than slider A. ****Note team member pulls slider B (and slider A to other end stops of zipper to prepare for connection with other side of chain)	Both Slider B and Slider A must be pull down to stop end of chain (opposite end from install of both sliders) to align with other side of chain					4.25
6	Attach other side of chain						
	The other side of chain must be aligned and then attached to side of chain containing sliders...note other side had to be flipped to get in line	This will completely attach a zipper, one at a time.					2.60
7	Position Sliders A and B for cutting						
	Sliders A and B must be positioned for the next process, cutting. The sliders could be in the way of the blade if not. Lost of motion	Two ensure safe position for cutting process					2.14

Figure 3 - Example of Time Motion Study

The work is separated into value-add, non-value-add, and auxiliary work. The time motion studies help identify the types of work in the process, and make it easier to identify the non-value-add work. This type of work is considered to be manufacturing waste, or areas of opportunity for industry. Examples of non-value-add work include: transportation, inventory, motion or movements, waiting time, over processing, over production, and defects. The more this type of work can be reduced, the more value-add work, the work the customer is willing to pay for, can be created. Auxiliary work is work that must be performed by a team member, but can be reduced. For example, picking up a slider to install to the zipper is a type of auxiliary work. The closer the sliders are to the team member or the way they are orientated can be optimized for the installation.

Analysis and Results

Analyzing the time motion studies and elemental breakdowns for the process enables formulation and design of an organized standard workplace for the process. This organized standard workplace would be setup to reduce the amount of non-value-add work, and also serve for easy rotation among team members. It is estimated that with the use of a new tool/jig, the average weighted process cycle time can be reduced by 20% or greater. A reduction of 20% would reduce the average weighted cycle time to 17.5 seconds from the current 21.9 seconds and The weekly labor hours would be reduced to 150 hours from the previous 200 hours.

Moving forward, it is determined to be possible to semi-automate or automate the two hand sliding process. The benefits of automating the process include: reduction of labor costs, reduction of throughput time, reduction of footprint (space used on factory floor), increased productivity, and improved product flow along the ACU molded line. Currently, there are two proposed methods for semi-automating or automating the process. The first proposed method is to build upon the concepts derived in the tool/jig that is proposed for the organized standard workstation.

The first would occur after the molding process. The process would automatically align and attach sliders to the chain as the chain is being pulled by an electric motor. The second proposed method would be to redesign the current machines and process steps to incorporate the slider installation immediately prior to the molding process. Before the chain is molded, the sliders would be positioned for installation. This would require the redesign of the chain manipulation and modification of the current molding process.

Project Objective—Army Combat Uniform Molded Line, Value Stream Map

To provide a better understanding of the current molded line processes producing the ACU (Army Combat Uniform). An analysis of the processes is done with a (VSM) Value Stream Map, highlighting areas of opportunity within the system.

Purpose

The purpose of gathering data and analyzing the current processes is to establish a current condition or standard among these processes. Without a defined current condition, the basis for improvements cannot be established. It is important to know the amount of impact that changes to current processes will have on the overall improvement of the ACU molded line.

Methodology

The current processes will be presented using a value stream map. The value stream map provides a graphical representation of the processes and product flow by capturing detailed information corresponding to each process. Information for each process includes: cycle times, process lead times, travel distances, uptime, number of operators and more. The value stream map also highlights the difference between a push and pull type of manufacturing. Ideally, upstream processes should only produce what the downstream processes can produce creating a pull between the processes. A push environment produces product at each process regardless of whether or not the process downstream is ready to take on the products from upstream. A push environment creates lots of work in progress, and can this can be seen as inventory begins to pile up in between the processes. The value steam map gives an overall picture of the throughput time, cycle time, distance traveled, and process lead time of the ACU Molded Line. When completed, the current condition value stream map highlights areas of opportunity within the line for improvements to be made, such as bottle necks, unnecessary processes, misuses of resources, and more.

Analysis and Results

By reviewing the current information on the value stream map (information is still being collected), the project team has been able to identify four significant areas of opportunity within the ACU Molded Line. The project team feels confident that by addressing these four areas, a significant amount of improvement in overall productivity can be achieved. The first recommendation would be to establish a standardized buffer of inventory at the manufacturing facility in close proximity to the ACU Molded Line. The standardized buffer would ensure that the line would never run out of material to be processed and the travel distance to supply the line will be greatly reduced. The second improvement would be to rearrange the placement of the automated machines on the line to reduce travel distances, create a greater awareness of work in progress, and improve flow. This improvement would increase the amount of value-add work performed by the operator and decrease the amount of non-value-add and auxiliary work. Currently, the operator walks an estimated 2.27 miles per shift, and by rearranging the machines this number can be reduced. The third area of improvement is to optimize the bagging and packaging of the finished zippers. Currently, the team members travel long distances and double handle the finished zippers (walk 180 feet per box). The optimal packaging area would have all necessary materials in close proximity to the work area, and allow the team member to stage outgoing boxes in a timelier manner. The fourth area of improvement would shift the current “reactive” state of maintenance to a more “proactive” state. This would ensure that the machines are available for operation a higher percentage of time than the current state.

Summary of Results

The project was conducted through a series of plant visits, observations, and data collection. On the basis of this work, evaluation and analysis, the project consolidated findings into four elements based on ease and time for implementation. The result for each element follows.

- Standardized Procedures and Tools-Manual Process
  -Current metrics for average manual slider insertion time are minimum-13 seconds/assembler and maximum 34.5 seconds/assembler with an average of 22 seconds over all assemblers.

-Using the 22 sec/zipper assembly and several tens of thousands zippers/week, ~200 labor hours/week are utilized.
-Implementation of a standardize procedure for slider insertion, workspace organization, implementing a new chain feeder jig and a potentially new slider hold jig (currently under test & development).
- Estimated improvements are: 10% to 20% improvement on manual insertion equating to 17.7 seconds/assembler to ~50 labor hours per week saving.
-Reduce repetitive motion injury potential.
-Reduce fatigue of assemblers.

- Standardize Workstation
  -Development of a standard design workstation would ease and solidify the temporary nature of changes above. The station would include improved presentation of materials to the assembler to codify the gains.
  -Ease of people to move to or from any station provides flexibility for assignments.
  -Ease of workstation relocation to other plant sites enables possible improvements in material flows and handling
- ACU Material Management and Organization
  -Current situation and operations gives evidence to materials located in two plants necessitating travel time and production downtime. ACUM arrayed in a linear form-750 feet. Given current operation mode the person on shift operates and maintains the line requiring 750 travel feet every 30 minutes equates to 2.27 miles per shift. Packing and packaging prepares ~25 boxes/day at 45 pounds/box (Total: 1125 pounds/day) with each box traveling 180 feet. (Total box movement: .85 miles/day).
  -Suggested improvements are to establish a buffer zone for materials consumed (average weekly quantities) and surveyed periodically for replenishment. Rearrangement of ACUM for reduced travel time, improved machine operation and maintenance, and reduce material-in-process and non – productive activity.
  -Reconfiguration of the packing and packaging process step would reduce travel time, reduce box lifting, handling and movement, and improve material flow and connection with other process steps. Additional gains would be available floor space, less people fatigue, better utilization of people, improved work environment.
- Automation of 2 slider insertion offers two concepts with potential development, one being semi-automation and the second fully automated.
  -Concept 1: A machine using a concept variant of the slider hold from the manual process would be inserting following the molding process step. The chain would align through a holding jig (from above) causing deburring and placement for sliders insertion. Sliders would be picked and placed for chain pull through on one chain only. The parallel chains would move to an assembler for insertion of bottom pin, zipping, and cutting.

-Concept 2: A machine for insertion of 2 sliders prior to molding step requires redesign of the ACU process step immediately preceding molding of ACUM. The process step would combine slider insertion step followed by the molding process. Before chain is molded, sliders would be positioned for installation on the chain and opening the slot for molding. Once inserted the chain moves to molding. The concept would require modification of current molding process through mold rotation, roller adaption, and process timing sequencing.

-Both concepts would require additional time, experimentation, and prototyping to proof-of-concept.

Conclusions and Recommendations

As a result of the initial project request to examine manual insertion of the two slider process step, several improvements and adjustments were provided to the industry once the scope of the project was expanded to include the analysis of the two slider process and the process flow along the ACU line. The two slider process was determined to be a major bottle neck and problem area for the company. Recommendations of standard work procedures and organized workplace techniques were given, along with physical process improvement recommendations (ex: jig, containers, process aids, etc.). The early work and results led to an expanded and broader view of the assembly line. The results from these studies formed the basis for recommendations of: reconfiguring the assembly line for more effective coverage by team members and reduced travel, establishing a minimal staging area for assembly line materials and supplies to reduce line downtime, reducing work in progress by improved line balancing, and redo the layout and arrangement of the slider insertion process step and packing and packaging steps to reduce material movement, flow, and time consumed.

Footnote from Industry

The industry partner in this project elect to pause further developments based on their business considerations. It was noted that the results more than provide benefits to and beyond their expectations. The industry planned to move forward with four standardized workstations as test beds and incorporate the concepts of the advanced jig and chain feeds. Additionally, several pieces of new machinery were expected to be purchased, and upon arrival, a reconfiguration of the assembly would be considered and evaluated.

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