

Material Handling and Assembly Process Optimization using Value Stream Mapping

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ABSTRACT

The purpose of this project is to evaluate and optimize an assembly process for ergonomic and productivity considerations. Companies use lean manufacturing as a method for continuous improvement in order to increase throughput and for to reallocate resources for more important tasks. For this project, value stream mapping (VSM) was used to evaluate, analyze, and improve the ergonomic factors of an assembly process and to increasing throughput. With the use of VSM, researchers are able to see the areas of added value, non-added value, and bottlenecks. This project illustrates the implementation of VSM for the minimization of waste, by using the design method to restructure the process of assembly. The results show drastic improvement in assembly time and ergonomic workplace design, while providing a platform for a continuous improvement system.

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1. INTRODUCTION

The project problem that was addressed was a manual assembly process that has been used for over ten years. Noble Plastics is a product realization company out of Grand Chateau, Louisiana that specializes in automation and plastic injection molding. They manufacture parts for a twelve part, commercially used, flat floor mop called “the original Sh-Mop,” by ComsenTech, Inc. The components to the mop can be found in the Parts List in Table 1. The current process of the Sh-Mop’s part assembly is a manual procedure, which is time consuming and puts stress on operators during material handling. The need for a system evaluation and possible alternative assembly process is necessary to increase product throughput, solve ergonomic issues, and reallocate personnel to other duties. Noble Plastics uses lean manufacturing in their organizational operations making this tool a good fit for the company.

Noble Plastics is always attempting to improve their operations in order to maximize profits with the help of lean. Lean manufacturing is a continuous improvement philosophy that has a primary focus of eliminating waste in the form of nonvalue-added activities and striving for operational excellence [1]. The management practice was developed by Toyota after World War II in an attempt to rebuild the organization with the recent collapse of Japan’s manufacturing industry [2, 3]. From this philosophy came several tools that assist in the minimizing of resources because of Japan’s shortage of material, workers, and capital. They strive for continuous improvement, providing high productivity, and elimination of waste [4].

A tool coming from lean that assists in the visualization of the entire production process is called Value Stream Mapping (VSM). VSM represents information flow and material flow on a timeline in order to show added value and non-added value [5]. Despite some limitations with VSM reported during use in particularly complex production environments, small and medium sized systems can easily benefit from using this tool [6]. The VSM is able to represent, for this case, the entire assembly process of the original Sh-

Mop by collecting data to create a map of the current process. Once evaluated, bottlenecked, wasted time, and other limitations can be analyzed to create a more ideal process map that represents the future process. From there a redesign in process or other things may be added or subtracted in order to “fill the gap” to meet the future plan [7].

Assembly lines are typically made up of workstations with operators performing repetitive tasks with material flow traveling between each station or cell [8]. The process for the assembling of the original Sh-Mop is done in a cellular formation, similar to the traditional assembly lines. A traditional assembly process is one that has a single resource or worker assigned to a working cell in which monotonous assembly tasks are repeated. A flexible assembly line is one that can yield a higher efficiency rate by using automation to increase throughput [8]. The pros and cons of traditional and flexible assembly lines will be addressed later in this paper after all of the constraints have been identified. Furthermore, the collection of data will allow for an evaluation of ergonomic procedures.

2. METHODOLOGY

The methodology used for this project are based on the Japanese concept of Kaizen or continuous improvement ideology stemming from Lean philosophies. One of Lean’s main tools, Value Stream Mapping (VSM) is the primary methodology. It is used to represent the flow of materials and information, and the value flow through an individual process or an entire company [9]. This allows managers and operators to easily view bottlenecks and areas of waste by viewing value added and non-value added areas. The goal of using this tool is to take out the needless inventories or confine wasted steps [10]. VSM can be used to map out an entire company’s material and information flow from supplier to customer, or it can be used to map individual processes as it is used in this project. The importance of VSM is its ability to help better understand how the shop floor operates so that problem areas can be improved upon by developing more efficient methods, procedures, or work place designs. Because VSM is a continuous improvement tool, the process maps can and should be altered for improved quality throughout the life of the company. Another benefit of VSM is the effects it can have on costs. Shortening lead time can lead to monetary benefits [6].

There are four major steps to the creation process of VSM. The first step to VSM is to identify the process groups of the tasks being done. Identifying these processes and the tasks that comprise them, means gathering preliminary information such as which parts use common equipment and resources. This step is similar to creating a project scope in that an overview of the process is identified. In order for accurate data collection, the person or team collecting the VSM must make several visits to physically observe each process. The natural habits that the operators take should be documented, and the employees and operators should be interviewed. With researchers having fully evaluated the data from the process groups, the VSM can be drawn up to be as accurate as possible. [5], [9], [11]

The second step to VSM is identifying and creating the current flow in order to develop a value stream map of the current state of the full process. The information gathering and documenting of the process groups is used during this step to create the visual representation from supplier to customer. In order to identify the current flow there must be a deep understanding of the actual processes. Both the current and future value stream maps are created by using a collection of universal icons that depict the flow of value. The maps show the connection between orders from the customer to the sales or production department of the company being evaluated as well as the forecast and orders made to the material suppliers. From materials, the map shows travel to the warehouse, each inventory, and the travel through each process group until it reaches shipment to the customer. For each process group and inventory there is a data box to show the data collected on the process whether it is time or scrap rate. Under the map is a timeline that gives a visual representation of the value added or non-value added, such as time in inventory. Once the current value stream map is created it can be fully analyzed for improvement measures. [5], [9], [11]

The third step of VSM is establishing an improvement goal by creating the future state map. With the current VSM to analyze and use as a guide, problem areas with waste can easily be identified and potential solutions can be formulated. The potential solutions are laid out by altering the current map into ideal process groups to form the future map. By creating a future state map, researchers have a goal to help the team stay focused on improvement and remaining organized.

The fourth and last step to VSM is developing the plan to achieve the future state map by eliminating wasted time and altering operational procedures. In order for this to be done a wide variety area of tools can be used such as root-cause analysis; why, why, why method; or an engineering design process to add something to a process group. Because VSM is a continuous improvement tool, once the future state map is achieved another future state map can be created. [1], [7], [9]





3. VSM – DATA COLLECTION

For creating the VSM for this project, the process groups and the tasks that make them up must be identified and understood. Because this project's focus is on the problem of assembly ergonomics and process optimization, this value stream map will consider process groups to be individual stages of the assembly rather than encompassing every step that goes into the manufacturing of the original Sh-Mop. The entire assembly was studied, the operators were interviewed, and the production specialist was interviewed in order to collect the required data. An input/output process matrix was created to help identify the steps in the most accurate manner. So that the input/output process matrix can be understood as shown in Table 1, the part list in Table 2 shows and describes each component used in the full assembly.

Table 1. Input/ Output Matrix for Process Groups and Their Steps

Step	Input	Activity	Output
Fork/block Pre-Assembly			
1	Forks, blocks, locknuts, screws	Setup forks, blocks, locknuts, and machine screws	Organized materials
2	Fork, block	Pick up fork with one hand and block with the other hand and insert block between fork and match eyelets	Fork/block pre-assembly
3	Fork/block pre-assembly, machine screw	Insert machine screw through fork/block eyelets	Fork/block assembly less nut
4	Fork/block assembly less nut	Fasten locknut to machine screw by hand tightening	Fork/block assembly
5	Fork /block assembly	Place fork/block assembly 1 into inventory box 1	Stored assembly
6		Repeat step's 2 – 5 of Fork/block Assembly 1	Stored assembly
Fork/ block Assembly			
7	Stored assembly from step 6	Setup: move inventory box 1 to fork/block assembly 2 area; ready screwdriver and socket wrench	Positioning
8	Stored assembly	Pick up fork/block assembly 1 from inventory box 1	Positioning
9	Stored assembly, socket wrench	Position customized socket wrench onto locknut	Positioning
10	Stored assembly, socket wrench, screw driver	Position battery powered screw driver onto head of screw	Positioning
11	Stored assembly, socket wrench, screw driver	Tighten nut onto screw until the nut is pushed out of socket	Finished assembly
12	Finished assembly	Place for/block Assembly 2 into inventory box 2	Finished stored assembly
13		Repeat step's 2 – 6 of Fork/block Assembly 2	
Final Assembly			
14	Finished stored assembly, plastic rivets, foam base pads	Setup: Transport inventory cardboard box 2 to final assembly 2; prepare machine screws and locknuts, prepare plastic revets and foam base pads; turn on the automated base mold system	Positioning
15	Plastic rivets	Place plastic rivets into rivet holes on pneumatic assembly table	Positioning
16	Mop base	Take mop base from automated best mold system conveyor belt with left hand and place on pneumatic assembly table with bottom side up	Positioning
17	Foam base, mop base	With right hand grasp foam base pad and align rivet eyelets with eyelets on bottom side of mop base	Assembled foam/ mop base
18	Assembled foam/mop base	Flip mop base and foam base pad over onto grooved pneumatic assembly table	Positioning
19		Accurate pneumatic assembly table by pressing and holding button	
20	Assembled foam/mop base, finished stored assembly from step 12	While foam base pad and mop base are bant, align fork/block assembly 2 with eyelets on top side of mop base then release actuating button on pneumatic assembly table	Pre – assembled base
21	Pre- assembled base, screw, nut	Grab machine screw with right and lock nut with left hand; insert machine screw into mop base and fork/block eyelets	Assembled base
22	Assembled base	With right hand grasp battery powered screwdriver and drive the machine screw while holding the locknut with left hand until operator can feel machine screw come through the locknut	Final assembly
23	Final Assembly	Place final assembly into packaging box until fill with 20 final assemblies	Product ready to ship
24		Repeat step's 2-10	

Table 2. Part List

Part List		Picture
Part Name	Description	
Screw	#10-24x 1 1/7 slotted Philips, pan head machine screw	
Locknut	#10- 24 nylon inserted, zinc coated locknut	
Block	Polypropylene copolymer, injection molmed middle join of the mop that is between the base and the fork	
Fork	Polypropylene copolymer, injection molmed top join of the mop that is between the block and the mop handle	
Base	Polypropylene copolymer, injection molmed foundation of the mop	
Pad	Foam pad that is sucred to the bottom of the base	
Rivet	Plastic rivet yhat fastens the pad to the base	
Full Assembly		

3.1.1. Process Group Identification

The process groups that make up the assembly of the Sh-Mop are divided into three groups, two of which share resources and cells. The three process groups are fork and block pre-assembly, fork and block assembly, and final assembly which are represented in Table 1, followed by the tasks required for each assembly process group.

For the first process group, fork and block pre-assembly, the materials required are a fork, block, #10-24 nylon insert zinc coated locknut, and a #10-24 x 1 7/8 slotted phillips, pan head machine screw. After setting up the materials that go into the assembly, the operator can begin. In a process done completely by hand, the operator joins the fork and block to align the eyelets. The machine screw is then inserted through the eyelets. All materials are held in place by hand while the locknut is hand tightened to the screw. Once this task is complete the sub-assembled part is put into an inventory box, while other components undergo the first process group.

Process group two is driving the locknut onto the screw using a powered screw driver. The setup required for this task is simply gathering the inventory box from the first process group. The material used is a modified socket and battery powered, hand held power driver. The modification of the socket is a small pin welded into the center of the socket that allows the nut to fit around it. When the nut is set into the socket around the pin, the pin reaches approximately half the width of the nut. This allows the screw to be fastened onto the nut, but once the screw comes in contact with the pin, the nut extrudes off the socket. The steps required for this process group require the operator to pick up a tree from the inventory box, place the modified socket wrench and driver in position, and fasten the nut without over-tightening the assembly. Once these steps are complete the assembled tree is placed into a separate inventory box to await relocation to the full-assembly cell.

The third process group requires an operator to conduct the final assembly of the mop. Setup for this task to be completed requires the gathering and organization of six remaining components that make up the Sh-Mop. The number of each component depends on the intended number of full-assemblies. The components required are as follows: white plastic rivets, the gray foam pads, the plastic mop base, the tree assemblies, the #10-24 x 2 slotted phillips, pan head machine screw, and a #10-24 nylon insert, zinc coated locknut. For this process group the operator uses the assistance of a pneumatic table that bends the mop base and foam pad while actuating cylinders insert the rivets to fasten the two components together. The second step of the full-assembly process group, after setup, is to place the plastic rivets into the proper location on the pneumatic table.

The mop base is then taken from the conveyor and placed on the pneumatic work table with the bottom up. A foam pad is then placed onto the bottom of the mop base and the two components are flipped over and placed into position on the pneumatic table. With the right hand, the operator presses and holds the button that actuates the pneumatic table, which inserts the rivets and fastens the assembly. At this point the mop base and foam pad are fastened and bent upward, which makes room for the tree to be aligned with the eyelets of the mop base. This is done with the operator's left hand while the right hand is holding the actuating button. With the tree properly aligned the button is released and the parts elasticity returns the part to its normal shape. The 2-inch machine screw is inserted through the eyelets and the #24 nylon locknut is pushed into a hex head cavity on the mop base, made by the mold. This cavity allows the operator to apply a small force to the nut with their finger while using a power driver to tighten the screw and nut. After the fastening of the tree to the mop base the full assembly is complete and ready for packaging. The product is stacked vertically, into boxes that are later stacked onto pallets for shipment.

3.1.2. Time Study

As a requirement to construct the value stream map, a time study was completed during the data collection for the researchers to understand the material flow. The VSM uses the time during operation with the overall lead time in order to produce an increased potential improvement [12]. During this study, operators were asked to perform the tasks within each process group as they would normally. The importance of performing normally was stressed so as to acquire the most realistic time evaluation. The time study was done with a sample size of 50 parts per process per sample. Table 3 outlines the time study for each process group.

From a number of three samples, each having a sample size of 50 parts, the averages for each process group were calculated. Process group one had an average of 15.21 seconds per part. Process group two had an average of 12.03 seconds per part. And, process group three had an average of 30.98 seconds per part. Without constraints, the total assembly time came out to 58.22 seconds per part of just assembly time. It is important to understand that this total average assembly time in this table does not account for inventory or setup time. The setup time for each process group ranges from between 5 and 15 minutes depending on the amount of materials needed in each cell. Although some constraints were discovered during the data collection step, all of the constraints will be discussed after the current value stream map is created.

Table 3. Current Time Study

No.	Process Group Avg	Samples	Sample Size	Time (s)/Part
1	Avg fork/block Pre-Assembly	3	50	15.21
2	Avg fork/block Assembly	3	50	12.03
3	Avg Final Assembly	3	50	30.98
	Total Average Assembly Time – less Constraints			58.22

3.2. VSM–CURRENT MAP

Step two of the VSM is to identify the flow of materials at the current state in which it occurs. This requires on site data collection to demonstrate how each product component moves, as well as how the operators handle the product. With this step the value stream map of the current state can be created. The current VSM uses data collected in the previous step, which can be found in the time study and in the input/output matrix. The three process groups discussed, fork/block pre-assembly, fork/block assembly, and final assembly are shown on the current map in the order of operation. From there, each task is identified with the input the task brings, the activity or description of the task, and the output that is accomplished by the task. This information can be combined with a time study of each process group in order to complete the current value stream map. The VSM maps are made up of universal symbols to identify each part of the production [6, 12], or in this study, just the assembly. The current map in Figure 1 shows the materuak abd ubfirnatuib flow.

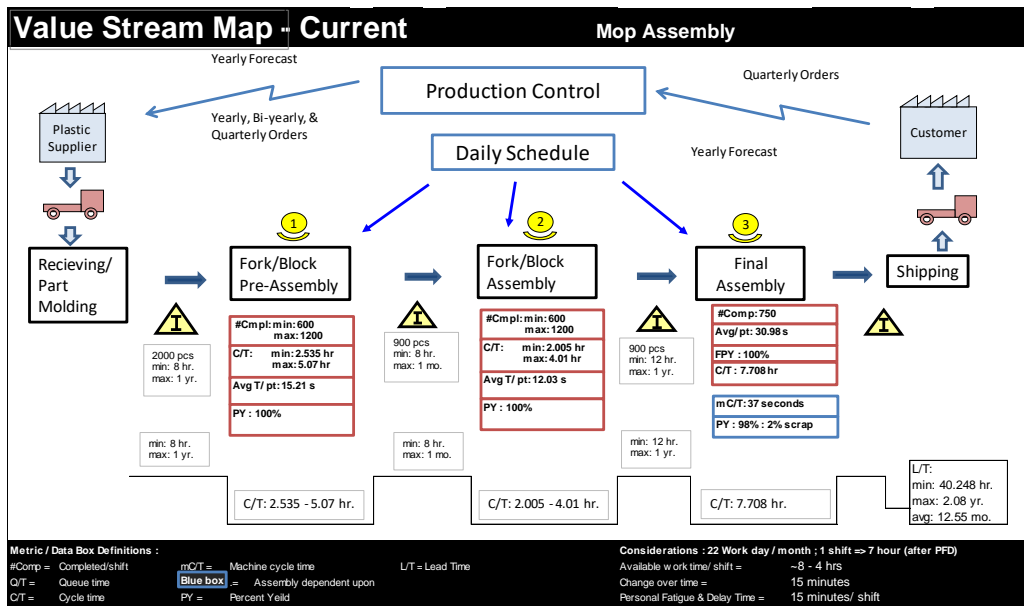


Figure 1. Input/ output matrix for process groups and their steps

3.3. VSM – FUTURE MAP

The future value stream map is similar to the current one, except that that it is a goal set to remain organized and to help stay focused on the long and short term vision. When using value stream mapping to improve a process, the team will always continue to create future value stream maps after each future map goal has been achieved [12]. This is part of the lean philosophy and continuous improvement. After evaluating the data collected and creating the current VSM map, the current map was used to evaluate the areas of constraint, areas of added value, and areas of non-added value [12]. This evaluation lead to the realization that the fork/block pre-assembly, in itself, was a constraint because of the wasted time of hand tightening each nut, inventorying the part, then coming back to tighten the parts.

The research conducted for this project found that many value stream map projects distinguish the inventory to be the primary non-value added step and thus attempt to minimize or eliminate inventory. This project, however, views the inventory of the fork/block assemblies as less of a waste due to particular production scheduling and customer order constraints that are in relation to the plastic injection molding machines schedule. A quarterly schedule for the Sh-Mops is given, yet it is not always feasible to run the injection molding machine in a quarterly fashion due to other, more consistent customer products. For this case, Noble Plastics is willing to inventory fork/block assemblies until the final assembly is scheduled. This way the injection molding machine and the six axis robot used are free to mold other products during the Sh-Mop production downtime.

The future VSM for the Sh-mop assembly Figure 2 eliminates the entire process group of pre-assembly. By completely taking out the pre-assembly process, the overall assembly time is drastically decreased. This process group can now be moved to the same cell as the final assembly, which was previously across the shop floor. Having the entire assembly performed in the same cell makes for less travel

time of product and a more stream lined system, and frees up area elsewhere on the shop floor. By eliminating the entire fork/block pre-assembly and combining the cells the cycle time is estimated to range from 2.02 to 4.403 hours. This makes the average part per time 13.21 seconds.

In addition to the time saved by combing the two processes, there is an entire inventory step that is eliminated that saves both time and shop floor space. After the new process group one, fork/ block assembly, the products should be inventoried for a lesser time due to the consolidation and streamlining of cells. The inventory time is estimated to be a minimum of 4.5 hours to a maximum of 6 months. Before the cells were brought together the fork/ block assembly and final assembly were rarely performed on the same day. Now, the inventory time can be minimized to 4.5 hours because the maximum time spent on fork/block assemblies is 4.403 hours. Thus, the final assembly can begin if the production schedule permits. With these changes to the VSM, the lead time changes from an average of 12.55 months to 9.03 months.

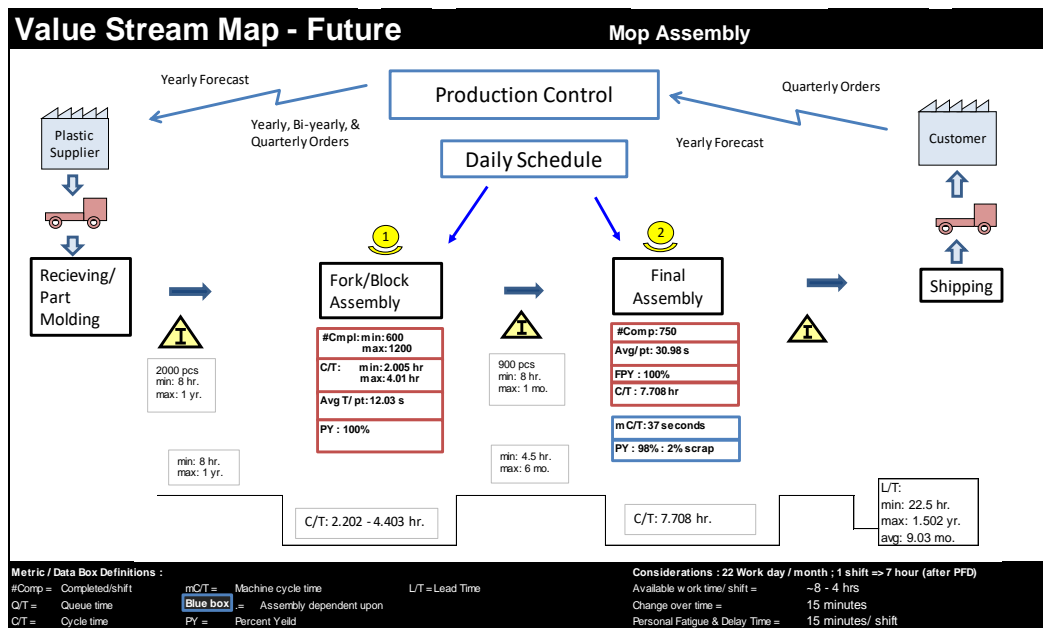


Figure 2. Input/output matrix for process groups and their steps

3.4. VSM – DESIGN

The last step for the value stream mapping process is to create designs, procedures, and/or new tasks that strive towards the goal of reaching the future VSM. In order to do this, an evaluation of the current and future map is performed to determine common problems that occur during the assembly. After observing and interviewing operators to find out the usual issues that can arise during the assembly process, a design or new procedure can be formed. In the case of the assembly of Sh-mop, the operators stated that hand fatigue was often an issue during the pre-assembly stage while forcing the block into the fork to match the eyelets. The tight fit between the two components is caused by the shrinkage of the material.

Another problem that often arose was the lack of agility when handing the fork and block during the fastening of the screw and nut. This is due to the fact that the left hand handles the socket wrench while the right hand operates the cordless power screw driver while leaving little stability to the fork and block. These two primary issues are ergonomic factors that need to be addressed. There are ergonomic concerns with the human factor regarding methods and tool design on a fundamental level. A poor working environment can cause operator stress or injury, as well as improper product assembly [13]. The agility problem affects both the fork/block pre-assembly and the fork/block assembly processes. In order to reach the goal of the future value stream map the entire pre-assembly process will be eliminated.

It was decided to create a fixture to help address the two problems stated above. The fixture design considers a concept developed by the Japanese for an error-free environment that helps the operator minimize defects that come with human error. Some of these errors addressed are forgetfulness, identification, inexperience, and inattentiveness. Furthermore, the design of this fixture helps to prevent incorrect installation by helping to eliminate obstructions that prevent correct assembly and part orientation during mating [13]. There have been many studies on the interests of ergonomic workplace design to help

minimize worker strain, assistive equipment, and general ergonomics in relation to product quality and assembly speed. When ergonomic factors are addressed and fixed the assembly speed and quality of the products are increased [14, 15, 16, 17].

For guidance and to help in the creation of an accurate, efficient design two processes were used, modeled from George E. Dieter and Linda C. Schmidt as they have it written in *Engineering Design*, fifth edition. The processes used are the engineering design process and product development process. The activities that make up the engineering design process are as follows: define problem, gather information, generate concept, evaluation of concept, produce architecture, configure design, create parametric design, and draw detailed design. From this the fixture was conceptualized and eventual drawn in SolidWorks as a more detailed design came about. The product development process as given by Dieter and Schmidt are as follows: planning, concept development, system-level design, detail design, testing and refinement, and production ramp-up [18]. The first four phases of the process were completed with the engineering design method. During the testing and refinement stages there were three prototypes created. The first was a rudimentary wood carving of the fixture. With the concept proving worth, the second prototype was printed using a 3D printer which served as a working prototype. With a few minor alterations, a CNC mill was used to cut the fixture out of an aluminum bar.

The design proposed for fixing the problem of reaching the future VSM is a fixture design to ease the assembly process. The fixture has grooved indentions, allowing for a snug fit of the fork and block as represented in Figure 3. This design allows for the eyelets to be aligned vertically. The working tool also has a modified socket fixed in to the base and fastened with a set screw. The first step for the operator is to place a nut into the modified socket. The fork is then placed into its proper groove on the fixture. The block can then easily be wedged between the fork to match the eyelets.

Having this type of fixture allows the operator to redirect the stress from their hands onto the fixture and components by wedging the pieces for alignment onto the body of the fixture. After the fork and block are positioned into the grooves of the fixture, the screw is inserted through the eyelets. This is easily held in place by the friction between the components. The final step of fork and block assembly is then to tighten the screw using a power screwdriver. Again, with the modified socket, the screw and nut cannot be over tightened. This grooved design can be replicated multiple times on the working tool for redundant assembly before the screw is fastened. For this instance, once all of the components are in place, a torque screwdriver hung via bungee cord can be used to drive the screw into place. This design accomplishes both goals of creating an ergonomically friendly process and eliminates the need for the fork/block pre-assembly



Figure 3. Aluminum fork and block assembly fixture

Furthermore, the fixture is easily manufactured using a computer numeric control (CNC) milling machine. The material selected to create the fixture is aluminum because of its abundance, cheap cost, and ease to work with. The fixture is cut from a 2-inch by 1.5-inch aluminum bar, costing approximately \$6.67 per foot. Because Noble Plastics owns and operates a CNC milling machine, the manufacturing of the fixture is at no out of house cost.

4. RESULTS

This project yielded positive results by meeting the two main objectives of optimizing the assembly of the Sh-Mop and creating an ergonomic working area with limited funds. Using the lean manufacturing tool of value stream mapping, the process groups were identified during the data collection step along with a time study to help determine whether the project would conclude with positive results regarding assembly process optimization. From the data, a current value stream map was created for the purpose of isolating the

value added and non-value added areas within the entire process from start to finish. A future map was then created to set an ideal, yet realistic situation that could optimize the process and help with material handling. This future value stream map was used as a guide to help to improve the process and to completely eliminate the process group of fork and block pre-assembly, which saves ample time and reduces the human physical stress involved with material handling.

After using the new assembly fixture, the operators reported favorable results that indicated a smoother assembly flow for the fork/ block assembly and a reduction in minor injury, such as hand sourness, from material handling. Furthermore, the time study that used the new process and assembly fixture, showed a drastic improvement in time which was used to assemble more forks and blocks, as well as to reassign employees to other products. As indicated in Table 4, there is a 69% improved time for the fork and block assembly. This improvement time does not factor in the non-added value of inventory between the original process groups of fork and block pre-assembly and fork and block assembly that were identified on the current value stream map. However, the total average lead times do account for both added value and non-added value steps like inventory time. Improvement for average lead time shows a 32.6% increase which is caused by the elimination of the first process group, fork and block pre-assembly, the inventory that followed, as well as a reduction in inventory by combining the two work cells. Although the final process group, full assembly, was not altered due to machine constraints, the overall improvement on the entire process was drastically increased.

Table 4. Current and Future State Comparison

	Original Data	New Data	Improvement (%)
Total Avg. Fork/ Block Assembly Time	27.24 seconds/ part	13.21 seconds/ part	69.37%
Total Avg. Lead Time	12.55 months	9.30 months	32.62%

5. CONCLUSION

The problems that this project addresses are both the ergonomic issue of material handling and time consuming task of assembling a 12-part assembly for “the original Sh-Mop.” By using the lean tool of Value Stream Mapping, the process is mapped for current and desired states for continuous improvement. This type of mapping allows for the visualization of the value added and non-value added tasks within the entire process. The steps involved for the creation of the current VSM start with data collection. In order to optimize the process, it must be fully understood which requires in person data collection. From this data, a current map of the process groups could be created that links the supplier, production, and customer together.

The process groups identified were fork and block pre-assembly, fork and block assembly, and full assembly. The data and current map that was formed for the assembly process at Noble Plastics indicated several constraints. The data indicated that there is a yearly forecast of material from which approximately 4,320 Sh-Mop’s are ordered per quarter. With these staggered orders, the production and assembly of the components are spread throughout the year. The sum of the total assembly time for an entire year is less than a month. Because the assembly of the Sh-Mop is so infrequent there was budgetary limitations that prevented the investment of automation equipment. Furthermore, research indicated that the assembly automation equipment needed is task particular, thus Noble Plastics would not be able to reallocate its resources during the 11 months of down time.

With these constraints discovered from the current state and the confines of a budget in mind, a future value stream map was created to formulate a goal of improvement towards the process. This future VSM required the elimination of the task group of fork and block pre-assembly, the inventory that followed, and a shortening of inventory time that was created by combining the two work cells. In order to meet the future VSM, a design for a fixture and new tasks were created that achieve the desired state. This state saves time during assembly and creates an ergonomic assembly process that has been met with the assembly fixture that assists operators in the fork and block assembly. It also shrinks the inventory time by shortening one step and eliminating another.

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