Process Optimization by Implementing Lean Six Sigma in an Optical Manufacturing Laboratory

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Abstract *— The Design Project intends to be implemented in an Optical Manufacturing Laboratory. This laboratory is located at Mayagüez with the purpose of distributing ophthalmic lenses to different optical centers around the island as well as different ophthalmologists in the west area. After some weeks of research investigation it has been noticed that the laboratory is resulting in scraps, work tools are not accessible, inventory is not well organized, and orders are not being delivered within the time period. In this project Lean Manufacturing tools as well as DMAIC and/or Six Sigma tools will be implemented along with some recommendations to help the laboratory improve its processes. Some of the Lean / Six Sigma tools used will be the Cause and Effect Diagram, Work Standardization, Pareto Chart, and the 5S Methodology. At the end of this project it is expected to be reduced by 0.7% (from 1.7%) the scraps manufactured, improve quality and overall efficiency.*

Key Terms *— laboratory, lean manufacturing, optical manufacturing, six sigma.*

PROBLEM STATEMENT

The whole process in the optical manufacturing laboratory needs improvement. Orders are not arriving within a 3 to 4 day period; the manufacturing process is resulting in scraps, the top four major scraps are related to the cutting machine which represent 15.60%, scratched lenses which represent 8.13%, incorrect data entry lenses which represent 8.13%, and the coating machine which represent 7.91%. Also quality inspection areas must be reinforced, work tools in the polishing and shining area are not adequately organized making it more difficult for the operator to complete the task. Finally, the inventory is not logically organized by lens type which affects in terms of space and accessibility.

LABORATORY PROCESS

The process in the laboratory starts with the order being received via fax. The person in charge of the area selects a tray identified with a number and color. The color is going to depend in which day of the week the fax is received. All their accounts are in Microsoft Excel program classified as internal (orders received from Sears Optical centers) or external (orders received from Ophthalmologists and/or other Optical centers). This same person goes to the corresponding account and enters the name of the patient, day, tray number, and color. The paper fax is placed in the tray and sent to the next person in charge of entering all the information in the Innovation Program. The information consists of the name of the patient, prescription, customer number, type of frame, and type of lenses. Finally, this information is printed and sent in the tray with the corresponding lenses to the first machine to begin the manufacturing process.

Figure 1 show the initial process described before.

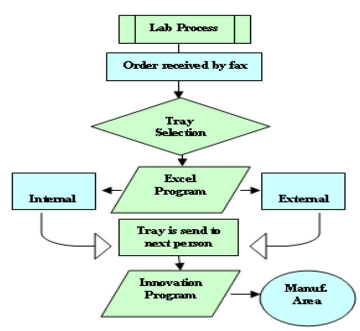

Figure 1

Lab Initial Process

MANUFACTURING PROCESS

The first step of the manufacturing process is the "blocking" machine where the technician enters the base of the lens. According to the base of the lens, the machine determines the block that is going to be used. Once the block is selected, the machine adheres the lens to this block by means of a wax.

The next machine, known as "generator" machine, measures the grossness of the lens's base and diameter and cuts it based on those dimensions next to be called sphere and cylinder respectively. A mold is selected with the same sphere and cylinder. The lens must fit the mold perfectly. There are a series of sandpaper. The black one is used to polish all types of lenses and eliminate any kind of marks left from the "generator" machine. The green one is used to polish only the polycarbonate lenses and the orange one is used to polish the plastic lenses.

Once the lenses are attached to the block and the sandpaper attached to the mold, they are both placed in the "polisher" machine which takes approximately 3 minutes. Once the lenses are polished they are placed in the "shining" machine using smoother sandpaper. Then they are separated from their respective blocks to be placed in the "lens washer".

The next step is the "coating" machine (only required for polycarbonate lenses) were lenses are first washed with a special water to eliminate all kind of statics and then sealed for UV rays purpose. Once the machine is over, the technician inspects the lens with a magnifying glass.

Finally, the "cut and assemble" machine cuts the lenses with the shape required to be finally placed in their frame.

Figure 2 shows the manufacturing process described before.

METHODOLOGY

DMAIC is a basic methodology described in Six Sigma [1]. It was used to optimize the processes in the laboratory.

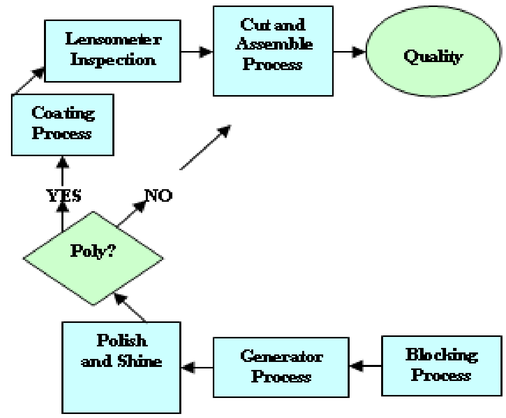

Figure 2

Manufacturing Process

Define Phase

The first thing that needs to be asked: What is the problem? As already mentioned the manufacturing process is resulting in scraps and orders are not arriving on time. Work tools are not adequately organized (making it more difficult for the operator to complete the task). Also inventory is not organized by lens type (making it more difficult for employees to identify the lens bases). Finally, quality inspection areas must be reinforced.

The second thing to do is to identify the focus of the process where it is going to be working at. The process starts with the orders received via fax. They have various sheets in Microsoft Excel with each one of their different accounts (internal and external). Once the fax is received they look for the corresponding account to enter the date, order number, patient name, color and number of the tray. The color of the tray is going to depend of the day in which the fax is received. This same person passes the tray to the next station, which is usually empty and worked by one of the operators of the manufacturing area. This person is in charge of looking for the corresponding lenses in storage to be scanned. Then enter the name of the patient, prescription, type of frame, type of lenses, etc. in a program called Innovation. This information is printed and sent in the tray to the first machine of the manufacturing process (Blocking Machine). Once the lenses go through the last machine (Cut and Assemble), they are placed in their respective frame. Finally, the tray goes to a cubicle identified with the name of the optical center or external accounts were the lenses are going to be sent.

The third thing to do is to establish the objectives for the project. The objective is to reduce scrap by 0.7 % (from 1.7%), reduce lead-time, organize inventory and workplace area, and improve quality and efficiency.

Measure Phase

Collect data for the year 2009 to identify the maximum defects occurred in the manufacturing process. Data from December 2008 to December 2009 shows that major scrap can be attributed to the cutting machine, scratched lenses, incorrect data entry, and coating machine.

It is really important to pay attention to employees' voice. A personal interview (like the one illustrated in Figure 3) was made to each one of the employees of the laboratory in relation to the scraps and the process. It provided a deeper understanding of what was happening and which were the things that had to be improved.

Personal Interview Questions

<u>Process</u>

1. What changes do you think can be made to improve the overall process?
2. Do you think that tasks are adequately distributed?
3. Do you think the inventory is logically organized?
4. Are you comfortable with your work tools?

<u>Scraps</u>

1. What do you think could be the major causes for the scraps related to the Cutting Machine?
2. What do you think could be the major causes for the scraps related to Scratched Lenses?
3. What do you think could be the major causes for the scraps related to Incorrect Data Entry?
4. What do you think could be the major causes for the scraps related to the Coating Machine?

Figure 3
Interview Questions

Analyze Phase

Pareto Chart was used to identify which part of the process was causing the majority of scrap or which were the top four. Make a root cause analysis of the top four defects (like the one illustrated in Figure 4) that occurred in the manufacturing process in terms of machinery, materials, methods, and technicians.

Figure 4 shows a Cause and Effect Diagram also known as Fishbone Diagram.

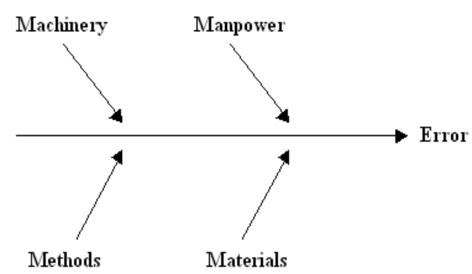

Figure 4
Cause and Effect Diagram

Improve Phase

Implementing 5s will involve:

1. Sort-Distinguish the necessary from the unnecessary.
2. Straighten- Arrange the necessary items in order for easy access.
3. Scrub- Clean workplace.
4. Standardize-Maintain the order and cleanliness.
5. Sustain-Train everyone to make it a work habit.

The 5s methodology is a system to reduce workplace waste and optimize productivity by maintaining an orderly workplace [2]. This methodology can be implemented in the inventory area. The inventory can be logically organized by lens type. The first shelf can have all the polycarbonate SV, FT-28, FT-35, progressive, and ellipse clear. The second shelf can have all the polycarbonate SV and FT-28 transition gray, polycarbonate SV and FT-28 transition brown, polycarbonate progressive transition gray and brown, polycarbonate progressive (Ellipse and Physio) transition brown. The third shelf can have trilogy SV and FT-28 clear, trilogy SV and FT-28 transition gray, trilogy progressive transition gray and brown, and polycarbonate polarized. In the fourth shelf all plastic SV and FT-28 clear, plastic Blended and High Index clear, plastic progressive (Image and Ellipse) clear, plastic Nu Polar. In the fifth shelf all the plastic SV and FT-28 transition gray and brown, plastic progressive transition gray and brown.

Another way of improvement would be the work standardization. Today in the laboratory the same operators are always in charge of the same machines. Because they only know how to run one in specific, training should be given in how to use each one of them. Once they are trained, they should be weekly rotated with a person making daily observations. Some operators may have shortcuts or ways to eliminate steps. These shortcuts can be evaluated and be followed by operators in the manufacturing area. Everyone can be trained based on these procedures [3]. This could bring benefits in terms of "takt time" and to keep the process operating smoothly.

Control Phase

To keep control of changes the SOP must be used and reinforced in each one of the operators. Those larger steps could be broken into smaller ones. Weekly or monthly metrics can be used to measure Lean success. Some of this metrics can be the process yield, data entry errors frequency, amount of calibrations delayed, and amount of training delayed. Also a checklist (like the one illustrated in Figure 5) can be done to be sure that 5S implementations and recommendations are being followed and maintained.

Figure 5 shows a possible example of a Checklist for the laboratory.

RESULTS

Pareto Chart from data collection for December 2008 to December 2009.

Figure 6 show the data collected from December 2008 to December 2009.

OPTICAL MANUFACTURING LABORATORY CHECKLIST

Date: ___________

Inspected by: ______________

RECOMMENDATIONS	DONE	NOT DONE
1.Machinery Preventive Maintenance		
2. Calibrations on date		
3. SOPs daily followed		
4. Lenses inspection before starting process		
5. Cleaning procedures before production day		
6. Tasks done in accordance of SOPs		
7. Data entry double verification		
8. Tasks distribution		
9. FIFO Method		
10. 5S Implementation at workplace area		
11. 5S Implementation at inventory area		
12. Analog timers		

Figure 5

Checklist

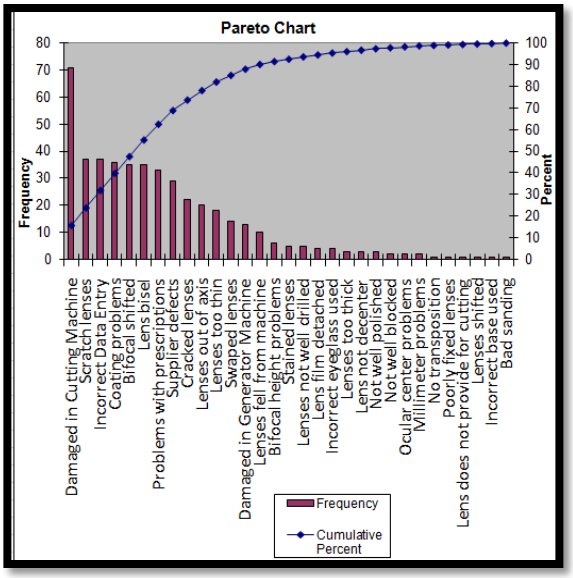

Figure 6

Pareto Chart

Top Four Major Scraps

The Cutting Machine is the number one defect in terms of the scraps manufactured. After making personal interviews to each one of the operators, calibration is one of the major causes for equipment breakdown, which at the same time can be directly related to electric dropdowns. These breakdowns can also be attributed to non-regular inspections because it is supposed to be done weekly and it is being done monthly. Also the operators are always running the same machines. This can make them more vulnerable to distractions. In terms of methods, they sometimes forget to push the data set button to reset the machine. They are not using the SOP as part of their daily basis processes.

Figure 7 shows the Fishbone Diagram for the Cutting Machine.

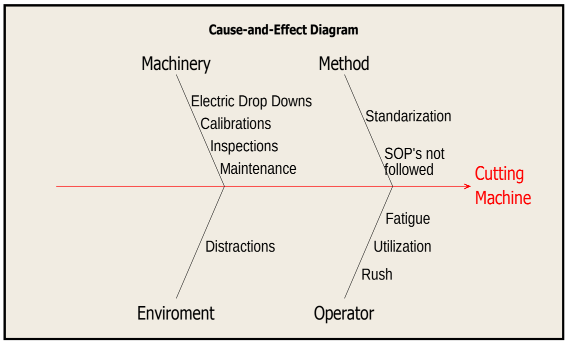

Figure 7

Cutting Machine

Scratched Lenses is the number two scrap. In terms of machinery, the lensometer could get lenses scratched if the operator does not use it appropriately. The same happens with the pencil used in the blocking machine. The drilling machine requires precision. The generator is usually used when the wax has not been completely cured. The environment also has a significant impact because just one particle in the paper tissue can get the lenses scratched. Also the scratches can be directly related to the supplier and to some methods used, like for example, when lenses are trying to be adapted to their respective frame.

Figure 8 shows the Fishbone Diagram for the Scratched Lenses.

The number three scrap is the incorrect data entry. This can be either at the laboratory or at the optical center. For example, in the optical center the employee enters the prescription and/or the type of lenses incorrectly. This can be attributed to lack of training, rush, and/or distractions. Therefore the order received via fax is incorrect. There might be also the case were the order received via fax is correct, but the person inside the laboratory copies the information incorrectly and selects the wrong base.

Figure 9 shows the Fishbone Diagram for the Incorrect Data Entry.

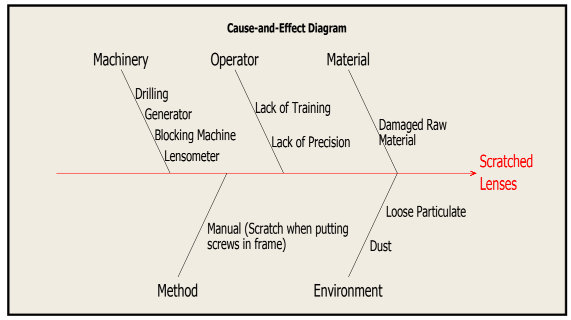

Figure 8

Scratched Lenses

The last from the top four is the coating machine. Equipment should be given the appropriate maintenance. If the "wash bowl" filter does not have sufficient water or the machine does not have sufficient coating, lenses can result in coating problems. Also operators must be sure of cleaning the lenses well before going through the coating process. On their way to this machine particles can be delivered.

Figure 10 shows the Fishbone Diagram for the Coating Machine.

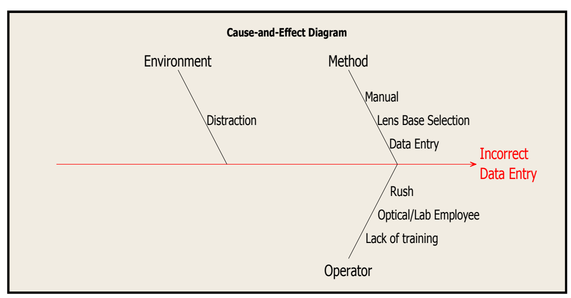

Figure 9

Incorrect Data Entry Lenses

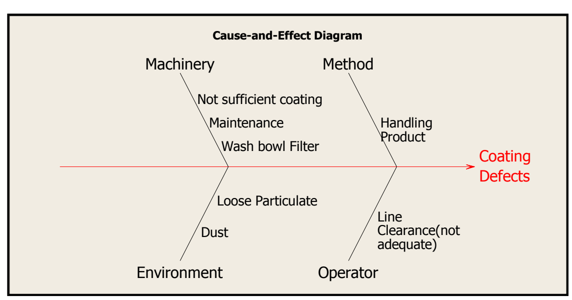

Figure 10

Coating Problems

RECOMMENDATIONS

Due to lack of time and money some recommendations were given to the administration. Here are some of the recommendations given for the top four mayor scraps, as well as for the process in general.

Scrap reduction recommendations

- To reduce scrap related to damage lenses in the Cutting Machine - A preventive maintenance and calibration program can be made in order to avoid calibration or breakdown issues. For example, a computer program with a warning alert of when machines should be calibrated. Also operators must be assigned to specific machines and establish work patterns and tasks to avoid distractions. Finally, training programs to provide refreshers of SOP.
- To reduce scrap related to Scratched Lenses - Lenses must be inspected when received from supplier; if they are damaged they should be returned. They can also implement cleaning practices before each production day to avoid particles in the air preventive maintenance.
- To reduce scrap related to Incorrect Data Entry - Second verification of data entered in the laboratory by a signature of the person in charge. But ideally all systems should be electronically to avoid manual entries.
- To reduce scrap related to Coating Machine - Daily verification can be made before starting the process to the water level on the "wash bowl" filter and coating amounts.

Process recommendations

Tasks can be distributed more efficiently. For example, the person at the front desk is in charge of accounts receivable, answering the phone, receive fax, give follow up to orders, invoicing, ordering special orders, filling in sheets for antireflective orders, match frames with its respective tray, as well as quality inspections. The laboratory does not have enough personnel because there are too much tasks for the small amount of employees. The data entry area is usually empty. One of the manufacturing operators works this area whenever it is possible. A recommendation would be to have a new employee to cover this area. Some of the responsibilities mentioned above can be delegated to this employee, like for example, ordering special orders, filling in sheets for antireflective orders, and matching frames with the respective trays, besides data entry and selecting the lenses. The operator can be now fully in charge of the manufacturing area and does not have to be at both places at the same time.

Some of the trays were tracked in the manufacturing area and they were not being processed in a logical order. For example, right now they place the trays one in the top of the other. The tray that is at the bottom should be the first to come in, but they always start with the one at the top. The idea would be to place some racks at each of the workstations to process the trays in order of arrival from bottom to top, as First In First Out (FIFO) Method. It would also be great to organize and make tools more accessible to the operators in each of the workstations, especially in the polishing and shining area. For example, place a tube on the wall over each one of the machines and identify each roll of sandpaper. The operator would only have to pull on the sandpaper needed in order to complete the job. Another good idea would be to train each operator on how to run each machine in order to keep them rotating at the manufacturing area. For example, during lunchtime (usually between 12:30 pm to 1:00 pm) the manufacturing area runs with only one or two operators in the same machines. While some are at lunch, two of them can be rotated every two weeks during this half-hour in order to keep the process running. Also it has been identified the polishing and shining area as the "bottleneck" of the process. This area consists of four machines, all in charge of one person. A good idea would be that once the operator next to him finishes all his work, he can help in this area to reduce the quantity of trays accumulated.

Between the first too machines, the lenses must be left 12 minutes for the wax to be cured. Most of the jobs are being processed earlier. A solution would be to place timers in each one of the trays to let them know when it is time. This would help in terms of reduction of scraps. Analog-manual-timers would be perfect. These timers are simple to use, easy to clean, good price, and good quality.

Finally, there are times in which some works are left aside because the frame has not arrived yet. These lenses are finished but they can't be placed at their respective frame yet. It would be good to make a cubicle for this type of works and name it "works not finished" or "work in process".

With the implementation of opportunities identified not only the quality of the product but the laboratory efficiency will increase.

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