Increment in on-time deliveries of mouldings to improve customer service of Fabricacion de Maquinas S.A. De C.V.

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Abstract

Customer service is one of the things companies have to be the most careful about and it involves many different aspects from prices, on-time deliveries, defects and other things. In other words the offer that a company makes to a client and therefore the reason why a client decides to work with a company. In this research paper our objective was to improve the deteriorated relationship between a supplier and its client by increasing the amount of on-time deliveries. We used the Lean Six Sigma methodology and DMAIC to give our research structure. This involved the use of different tools like R and R, Pareto diagrams, VSM, SMED, AMEF and other things. Through our analysis we found two main reasons why deliveries are late. The first one is the amount of time mouldings are in repairs because of defects and the second one is the amount of time that is lost in changeovers. To attack these two points we implemented tools like 5S, SMED and others and were able to improve on-time deliveries by 7%.

Keywords
Lean manufacturing; Six Sigma; On-time deliveries; Changeover

1. Pre-diagnosis

1.1 Description of the company

Fabricacion de Maquinas (FAMA) is a company that is part of the Vitro group. Their main market has been the metalworking industry in national and international levels for more than 70 years since the company first opened. Eventually when the glass industry started growing a necessity to produce glass bottles was born forcing Vitro to create bottling plants. These bottling plants needed mouldings to start production of glass bottles so FAMA started producing everything that is necessary to produce a glass bottle, but their main products are:

- blank mould
- blow mould

A blank mould is used to give the bottle a preform, called its blank shape and is used to measure the amount of glass that is necessary for a specific bottle. A blow mould is used to give the bottle its final shape and is used to do different printings on the bottle by the use of internal cuts in the moulding.
Currently FAMA produces these for many different important industries, for example:

- Beer industry
- Soda bottles
- Wine bottles
- Jar containers

1.2 Current situation

In 2015 the company Owens-Illinois bought the bottling plants of Vitro group turning into the main client of FAMA. Because of the relationship between FAMA and Vitro's bottling plants both companies agreed to keep working together, as long as FAMA is able to achieve good results in:

- On- time deliveries
- High quality products

In 2016 on-time deliveries were only of 56%, this deteriorated the relationship between FAMA and OI. In the next graph you can see the on-time deliveries for 2016:

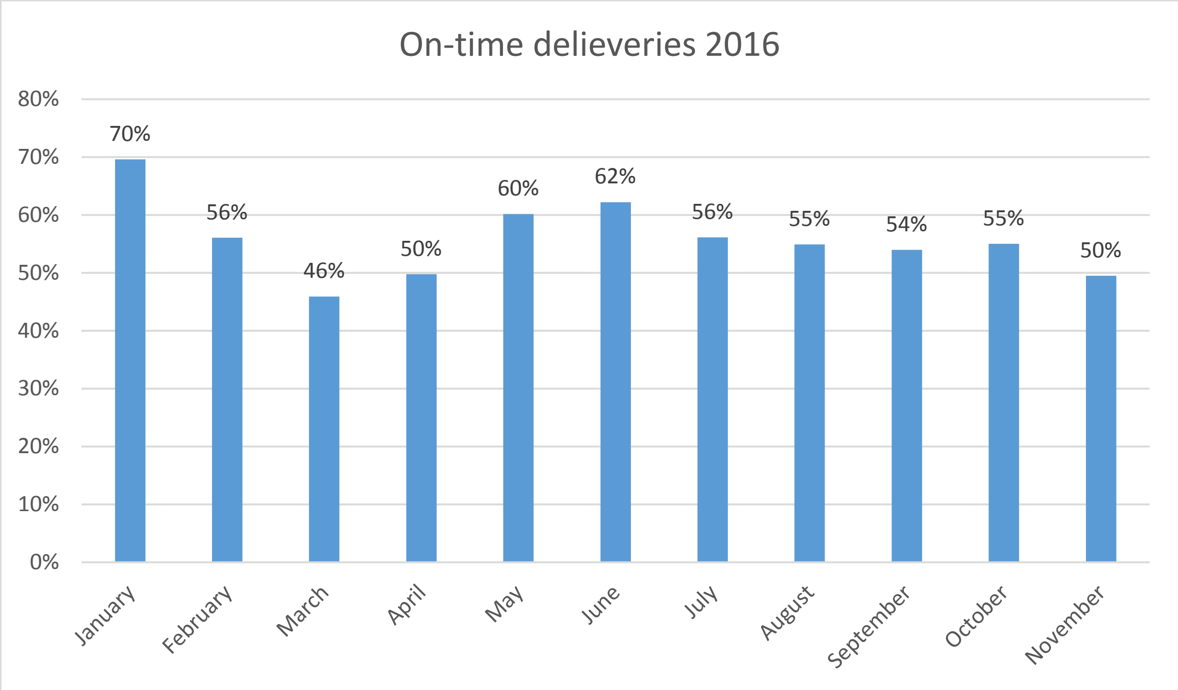


Figure 1. On time deliveries

As it can be seen on the graph on-time deliveries in 2016 were around 50-60%. Seeing that FAMA was unable to fulfill OI requirements on on-time deliveries OI decided to start looking for other suppliers.

1.3 Description of the problem

In March 2016 the company started supporting itself with other workshops to cover OI's demand but they started having problems with the quality of these. Because of this FAMA was forced to support the workshops sending them the raw materials and inspecting every moulding that the workshops sent.

Currently FAMA has an average monthly production of 2000 parts and the workshops can send 400 parts per month, this is not enough to fulfill OI average demand of 2800 parts per month. Because of this we realized we needed to increase the amount of parts that FAMA was able to produce, analyzing information from the company we realized FAMA had a high amount of defects.

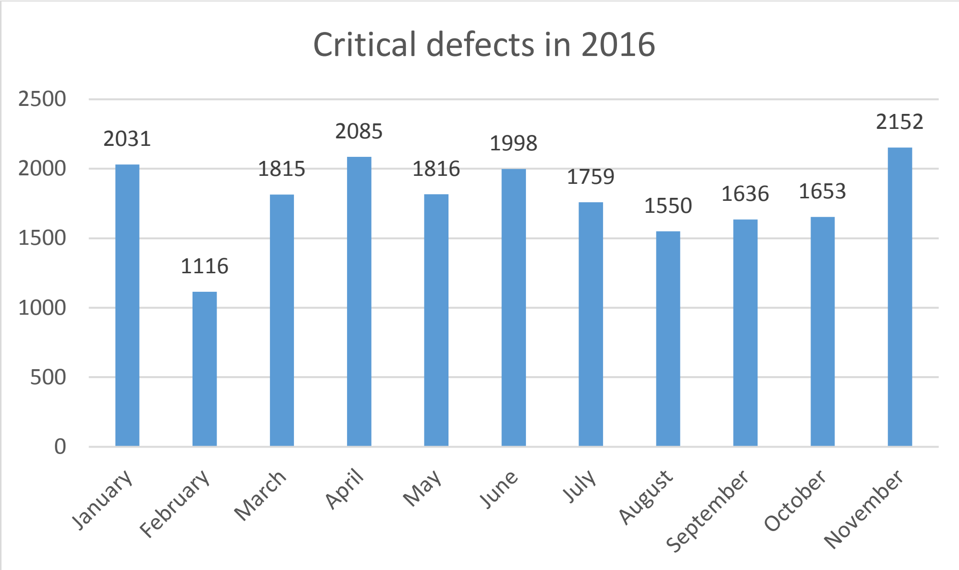


Figure 2 Critical defects

As it can be seen here the amount of defects from January to November was extremely high reaching a height of 2,152 defects in November before the project started.

1.4 Scope of the project

We decided to focus specifically on blow moulds, which are used to give the bottle its final shape in the production line "primeras operaciones".

1.5 DMAIC

We will be using DMAIC for this analysis, it consists of the next steps:

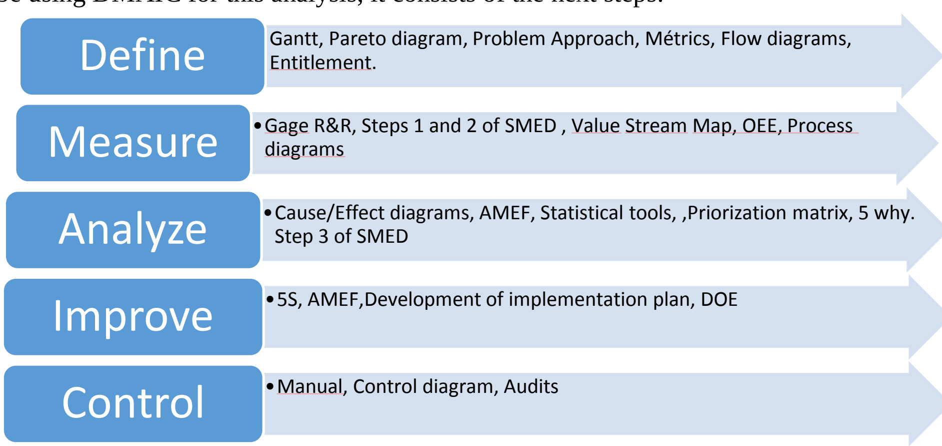


Figure 3 DMAIC steps

In each of these stages we used different tools to define the project, analyze the process, find the root causes, develop solutions and implement them.

1.6 General Objective

Increase on-time deliveries by 9%, going from 56% to 65%

2. Analysis

2.1 Value Stream Map

We decided to start analyzing the flows of materials to understand the process better. To do this we did the VSM and we started by defining families and sub-families using the most common products. Like we mentioned before we had already established that we were only going to be working with blow moulds so we looked into the information on all of the moulds that were sold in 2016. We found the best option was using the beer industry as a family and the bottle capacity of 300-600 ml as a subfamily.

We made a VSM of the family and the sub-family and we found that waiting times between stations were too long, analyzing the information more in depth we found that this is because of the many delays of the process.
We found that it takes too long for the machines to process a batch because of delays and that this is one of the main reasons why the waits between stations are so long for the batches. This also generates many problems for the company as it makes it much more difficult to plan the production since it is unknown how long it will take to do something. Using the theory of constraints, we looked for the machine that had the most inventory waiting to detect the bottleneck and we realized that the machines that generate these problems were mainly the first two machines in the process: assembly and exterior turning.

2.2 Process diagram

To analyze more in depth why the first two machines have so much inventory waiting we did a process diagram for each machine:

		Present		
	Summary	#	Time	Percentage
	Operation	6	0:29:43.80	30%
	Transportation	2	0:01:06.15	1%
	Inspection	2	0:01:55.00	2%
	Delays	1	1:05:33.22	67%
	Storage	1	0:00:12.01	0%
	Total	12	1:38:18.17	100%

Figure 4 Assembly diagram

		Present		
	Summary	#	Time	Percentage
	Operation	4	0:11:17.14	11%
	Transportation	2	0:01:21.75	1%
	Inspection	2	0:06:33.99	7%
	Delays	1	1:20:15.02	80%
	Storage	1	0:00:48.79	1%
	Total	10	1:40:16.69	100%

Figure 5 Exterior turning diagram

As you can see above, transport, inspections and storage take very little time, but delays make up most of the time analyzed. In this case the delays are the product changes and as you can see they are part of more than half the time it takes to make a mold so we decided to analyze the product changes more thoroughly.

2.3 SMED step 1, 2 and 3

To make a product change the operator looks for a program that has been previously worked similar to what he is about to produce. Once he has the program, he measures the first piece of the batch and compare the drawing, he uses a calculator to calculate how much should be lowered of each diameter and inputs this into the program.
Analyzing the activities carried out by the operators, we find that many of the activities they do internally (with the machine stopped) could be done externally (when the machine is running). What we found is that the workers spent a lot of time looking for the next batch or the tools they need to be able to perform the product change once the machine is no longer running.
Here you can see the results of our analysis for all machines:

Machine	Present state		Future State		Internal reduction
	Internally	**Externally**	**Internally**	**Externally**	
Assembly	**56%**	**44%**	**33%**	**67%**	**23%**
Exterior turning	**73%**	**27%**	**24%**	**76%**	**49%**
Welding preparation	**74%**	**26%**	**67%**	**33%**	**7%**
Plasma welding	**88%**	**12%**	**62%**	**38%**	**26%**
Average	**73%**	**27%**	**47%**	**54%**	**26%**

Table 1. SMED results

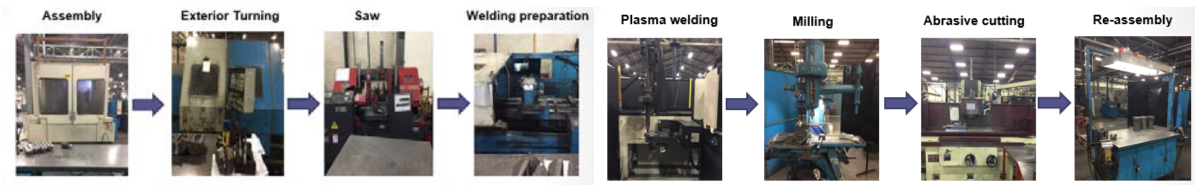
Since we had detected that the problem is not only the first two stations and that the cause of the delays is the product changes we proceed to analyze the urgent orders.

2.4 OEE

We knew we wanted to analyze the urgent orders and the machines more in depth individually so we decided to do an OEE to analyze the quality, availability and performance separately.

- Quality is the parts produced correctly.
- Availability is the planned process stops like lunch breaks and planned maintenance
- Finally performance is the comparison between the parts that should have been produced versus what was really produced.

Because we found that the problem was all of the machines during the SMED we included all the machines in this analysis. These are our results:



	Assembly	Exterior Turning	Saw	Welding Preparation	Plasma welding	Milling	Abrasive cutting	Re-assembly
Availability	70%	52%	62%	75%	85%	46%	56%	46%
Efficiency	77%	60%	92%	68%	97%	44%	94%	62%
Quality	61%	68%	95%	76%	68%	77%	83%	75%
OEE	33%	22%	54%	39%	56%	16%	44%	22%

Figure 6. OEE Results by station

We immediately noticed that the saw and re-assembly had extremely low efficiencies but when we analyzed this more in depth we realized this was correct because these two stations are a lot faster than the rest and because of this they spend a lot of time waiting for the other machines.

Analyzing the results we realized assembly, exterior turning, welding preparation and milling had low efficiency values. Milling has a low efficiency value because it is an extremely fast operation and could produce a lot more than it actually produces if it received more material. The other three machines are extremely complex CNC machines, we realized that the reason there efficiencies are so low is because they lose a lot of time because of their changeovers. This is because changeover times are very long and changeovers are very frequent because of urgent orders.

We analyzed the availability of all the machines and we found the saw, milling, abrasive cutting and re-assembly spend a lot of time with no people because there isn't enough work. On the other hand assembly, exterior turning and welding preparation are very limited because they are always running. The fact that they are always running plus the fact they are all extremely old causes them to stop working randomly causing a lot of lost time because of machine failures or corrective maintenance. This causes even more delays because these three machines are sequential and if one stops working it can cause the other machines to run out of materials.

Finally we found that the machines were generating a lot of defects but we didn't have an in depth analysis of the defects so we decided to analyze this more in depth using a pareto diagram.

2.5 Pareto diagram

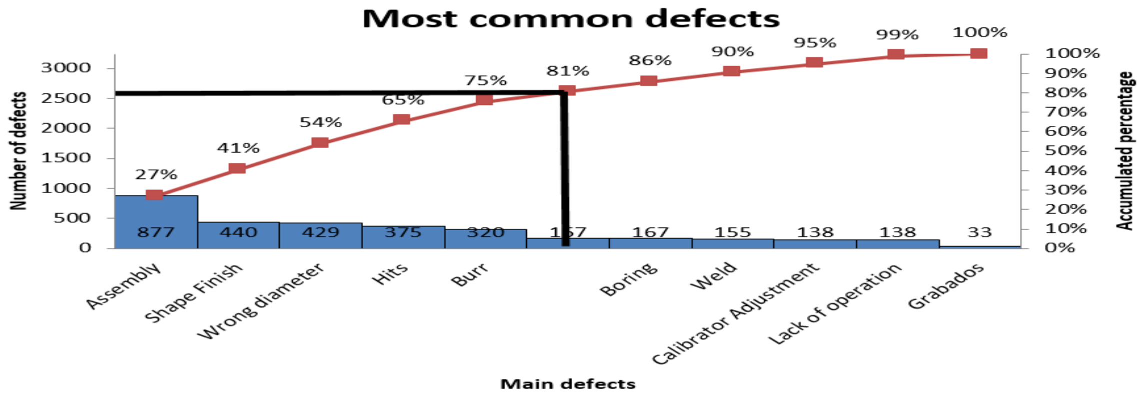


Figure 7. Most common defects

Analyzing the most common defects we found the defects of assembly, exterior form, incorrect diameter, hits and burr were the most common. We realized the exterior form and incorrect diameter could be caused by what we saw in the SMED so we decided to do a study on the method of measurement.

2.6 R y R

To do this study we thought about which machines measurements is absolutely critical and decided to focus on those. We found the critical parameters for each of these and asked two operators to do 10 measurements twice for each of these. These are the results:

R&R results	**Measurement system**	**Cause of the variation**	**What is going to be attacked**
Assembly	Unacceptable (70.16%)	Repeatability (64%)	Measurement system
Exterior Turning	Unacceptable (88%)	Repeatability (63%) and Reproducibility (62%)	Measurement system and operators
Welding preparation	Unacceptable (87%)	Repeatability (68%) and Reproducibility (53%)	Measurement system and operators
Plasma Welding	Unacceptable (100%)	Repeatability (73%) and Reproducibility (68%)	Measurement system and operators

Table 2. R&R results

As it can be seen in the table none of the four stations passed the test of the measurement system. We also found the cause of the variation of the four stations was both Repeatability and Reproducibility in all the stations except assembly. Because of this we found something had to be done about the measurement system and he operators.

2.7 Ishikawa

To do the ishikawa diagrams we got together everything we had seen in the plant and spoke to the operators to collect our findings. Once we had done this we corroborated this with the different departments to ensure if what we had found was correct. These are the results of our Ishikawa diagram:

- The focus of production is to produce mouldings without seeing the quality of the product
- There is no methodology to prevent and detect defects in the workstations.
- There is no policy to check and calibrate measurement instruments.
- The tools needed for each station aren’t standardized.
- There is no process to repair a mould with defects.
- Operators don’t care about the finished product.
- There is no standardized method for measuring
- There is a lack of a culture of order and cleanliness
- Supervisors do activities that shouldn’t be their responsibility
- There is no standard on the parameters to program a machine
- Machines are every old
- There are urgent orders that need to be processed immediately.

2.8 Root causes

Analyzing what we saw in the Ishikawa we found several root causes that repeated, taking this into consideration we put everything we found together and we found the six main root causes for the late deliveries:

- There is no methodology to prevent and detect defects in the stations.
- The policy for checking and calibrating measurement instruments is not implemented in the plant.
- There is no standardized measurement method in the production line
- There is no established place to put each work tool
- The activities or tools necessary for the changeovers aren't standardized
- The frequency of change of the cutting tool isn't standardized
-

2.10 Specific objectives

Our main project objective always was to increase on-time deliveries but the specific objectives changed several times as the project advanced and we found the root causes of the late deliveries. These are the final specific objectives for the project:

- Reduce the amount of defects in the production line "primeras operaciones" by 18%.
- Reduce the lost time because of changeovers by 10% in "primeras operaciones".
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2.11 Analysis conclusions

We analyzed the root causes and the effect they had over the specific objectives to separate the root causes based on the objective they affect and the impact they have over it. This is our result:

Root Causes	Impact on specific objective	Contribution in percentage points to the specific objective	Specific objectives
There is no methodology to prevent and detect defects in the stations.	50%	9.00	**Reduce the amount of defects in the production line "Primeras operaciones" by 18%**
The frequency of change of the cutting tool isn't standardized	20%	3.60	
The policy for checking and calibrating measurement instruments is not implemented in the plant.	17%	3.06	
There is no standardized measurement method in the production line	13%	2.34	
Total	100%	18.00	

Table 3. Analysis results

3. Design stage

In this stage we designed the formats and procedures necessary to attack the root causes we found in the previous stage. With this the intention is reducing the time it takes for batches to be released by quality by reducing the amount of defects and reducing the amount of time it takes for batches to complete their production process.

1. There is no methodology to prevent and detect defects in the stations..	2. The policy for checking and calibrating measurement instruments is not implemented in the plant	3. There is no standardized measurement method in the production line	4. There is no established place to put each work tool	5. The activities or tools necessary for the changeovers aren't standardized	6. The frequency of change of the cutting tool isn't standardized
• **Methodology to prevent and detect:** - Manual of operational (section I). - AMEF	• **Manual of operational (section II).** - Program of revisión and calibration. - Definition of actions and responsible. • **Internal audits.**	• **Manual of operational (section II).** - Guide to key parameters and instruments - Correct measurement method • **Internal audits.**	• **Standardization of tools required by work center** • **Manual de disciplinas Manual of operational (section III).** - Shift change process. - List of actions - Visual helps.	• **Manual of operational (section IV).** - Tool change process - Tool Guide.	• **Manual of operational (section V).** - Process of renovation of cutting tools.

Table 4. Root causes design

4. Implementation stage

This part consists in:

- Creation of a scoreboard:

Each of the metrics in this scoreboard comes from a different area, which is why we stablished a person of each area to gather all the information, and we decided that Alejandro Leal, from the Project's area, would be the one to collect the information and send the report to everyone involved.

Scoreboard		Amount of hours in changeover	Parts inspected with no defects	On-time delieveries	SOL grade
Week 1	April 3	376	63.3%	56.7%	79.4%
Week 2	April 10	374	67.0%	56.8%	82.7%
Week 3	April 17	365	71.1%	58.4%	82.8%
Week 4	April 24	360	74.3%	60.4%	84.0%

Table 5. Scoreboard

- Audits:

There were audits performed in several workstations, and they all passed the metrics test although the three most important stations for this test are: assembly, exterior turning and welding preparation. However, these 3 workstations were deducted points because they had tools that weren't in their correct place. The only station that did well in this part of the audit was exterior turning because at that point of the project we had dedicated a lot of time on this station.

- 5's

To implement 5's, we did the following actions:

- Sort: We selected the tools and the instruments needed for each work area, and took away all the tools that the station doesn't need or are damaged.
- Set in order: All the tools needed for the daily operation were identified and located on the work areas.
- Shine: We helped clean every work area and removed the burr and the dirt from the machines.
- Standardize: In the stations of exterior turning and welding preparation all the cutting tools were separated and those that are not used frequently were carried to the tools room. A Kanban system was implemented, using cards, to control the movement of these tools.
- Discipline: In order to keep the improvements in the long term, we created an internal audit program and an incentive system.

- Internal audits: We decided to apply weekly audits, where the process of measuring, calibrating and keeping everything in order are evaluated. We also tracked the progress of our project through an evaluation called SOL (Security, order and cleaning) that is already implemented monthly by FAMA.

- Measuring tools record update

We found a lot of measuring tools that needed to be calibrated, so we coordinate with the Projects, Security and Metrology areas to inspect all the instruments in all the work areas.
After the inspection, we found 22 out of 50 instruments that need to be calibrated immediately because their calibration was expired. Also, 9 instruments were found without a label and were also checked and labeled.

- Design of experiments

The goal of the experiment was to find the ideal parameters to run the machine, to maximize the lifetime of the cutting tools. After several tests, we found the following ideal parameters:

- 1000 RPM
- 50% speed
- 10 gallons of soluble

The original parameters that are normally used in the plant are these:

- 1,080 RPM
- 70% speed
- 7 gallons of soluble

With the original conditions, the cutting tool can work on 69 mouldings before it must be changed. With the new conditions that we found through the experiment the cutting tool can last 90 mouldings. With this information, we spoke with the operators to standardize the lifetime of this specific tool and now the operators know when they must change it.

- SMED

We compared the changeover times before the beginning of the project, during the project and also after the implementation was done, and we found better results when we helped the operators to do all the external activities (at the design stage).
There was a time reduction in the third stage of the project (implementation), as you can see in the following chart:

Work Area	**Analysis**	**Design**	**Implementation**	**Reduction percentage**
Assembly	01:05:34	00:48:14	**00:55:56**	15%
Saw	01:25:52	00:47:00	**00:58:30**	32%
Welding preparation	01:33:58	00:57:42	**01:05:03**	31%
Plasma welding	02:19:22	01:12:04	**01:35:15**	32%

Table 6. SMED results

- Manuals delivered:

Besides designing the operation manuals, we instructed all the operators on how to do several key things of their work. This was the most difficult part of the project because not only we needed to find the correct way of doing things but we also had to change the normal structure of thinking, break all the paradigms and eliminate all the wrong practices from the operators.

5. Conclusion

Now that we had done all this we updated the scoreboard with information from before we started implementing and from the first week of May to better evaluate the effects of the project. This is the new table:

Scoreboard		Amount of hours in changeover	Parts inspected with no defects	On-time delieveries	SOL grade
Before implementation		386	60.0%	56.0%	80.6%
Week 1	April 3	↑ 376	↑ 63.3%	↑ 56.7%	↓ 79.4%
Week 2	April 10	↑ 374	↑ 67.0%	↑ 56.8%	↑ 82.7%
Week 3	April 17	↑ 365	↑ 71.1%	↑ 58.4%	↑ 82.8%
Week 4	April 24	↑ 360	↑ 74.3%	↑ 60.4%	↑ 84.0%
Week 1	May 2	↑ 354	↑ 79.7%	↑ 63.1%	↑ 85.5%
Improvement		8.3%	19.7%	7.1%	4.9%
Expected project improvement		10%	18%	9%	10%

Table 7. Project Scoreboard

As it is shown on the scoreboard the implemented activities were able to increase the on-time deliveries by 7%, going from 56% to 63%. One of the main reasons why the project was not able to reach the goal proposed by the project is that the design of experiments has not been implemented yet but it will be implemented in the rest of the company basing itself on our experiment.

Also, the client service area was focused on delivering the orders that were delayed, neglecting the new orders. Because of this even with an important improvement in quality and productivity in the plant there is a gap between what the project achieved and what was expected at the beginning of the project.

Even though we were not able to get to the project goal we still gave the plant manuals with all of the implementations and the visual aids. One of the team members was also hired formally by the company ensuring the long term effects of our actions in the company.

We also decided to calculate the saving of the project and the cost that this brought to the company, we got to the conclusion that the project had a projected saving of 450 thousand pesos and a cost of 285 thousand pesos, the cost benefit this generates is 37%. This is extremely good because the projected cost benefit at the beginning of the project was of 30%. This shows that even if we didn't get to the on-time deliveries objective our project still had a very positive effect on the company.

Finally analyzing the improvements in on-time deliveries, defects and changeover times caused by our project we expect that the goal of 65 %(the projects main goal) will be reached by the middle of June. We also expect it to grow even more after this once our project is fully implemented.