Increase Productivity in a Manufacturing Department of a Medical Devices Manufacturing Company Using Six Sigma Methodology

Yazmín Morales López
Manufacturing Engineering

José A. Pesante, Ph.D.
Industrial Engineering Department
Polytechnic University of Puerto Rico

ABSTRACT

Productivity is a very important metric because is the way to make sure that we optimize our resources and time. Is the way to measure if we are manufacturing as expected (as per time standards) and with the required resources (people). In this project, the Six Sigma Methodology was used to obtain an increase of at least 50% in the productivity of this manufacturing department in a medical devices manufacturing company. Six Sigma has a key methodology: DMAIC. DMAIC is used to improve an existing business process. Consists in Define, Measure, Analyze, Improve and Control. In this article you will find the results obtained after the implementation of productivity metric and the use of DMAIC as the correct methodology for improvements.

PROBLEM STATEMENT

At this moment in this manufacturing department does not exist a metric to measure productivity. Productivity is a very important metric because is the way to make sure that we optimize our resources and time. Is the way to measure if we are manufacturing as expected (as per time standards) and with the required resources (people). Productivity in economics refers to measures of output from production processes, per unit of input [1]. Labor productivity, for example, is typically measured as a ratio of output per labor-hour, an input. Productivity may be conceived of as a measure of the technical or engineering efficiency of production. As such quantitative measures of input, and sometimes output, are emphasized.

OBJECTIVES

The objective of this project is to obtain an increase in productivity by 50% from the baseline of 42 units per person (UPP). This productivity improvement represents also an estimated savings of $100K for this manufacturing department.

CONTRIBUTIONS

Some of the contributions of this project are the following:

- Output Increase.
- Comply with the customer shipping dates maintaining under control the back orders.
- Identification of the major offenders of productivity.
- Scrap reduction opportunities.
- Setup reduction opportunities.
- Layout opportunities.
- Cost savings.
- Depends on the demand, the output increase have a direct impact on the manpower needs.

BACKGROUND

Productivity is the ratio of what is produced to what is required to produce. Productivity is the measure on production efficiency [2].

In most manufacturing plants, productivity is one of the most important metric and has the way to measure it. In this medical device company, there is no way to measure productivity and the management wants to know if the manpower is working efficiently.

Exists different ways of how we can eliminate waste in manufacturing in order to obtain productivity improvements. In order to achieve different goals and reduce waste, we can use KPI's in the manufacturing shop floor. Key Performance Indicators (KPI's) can be viewed from two perspectives: the lean manufacturing perspective of waste elimination and the corporate perspective of achieving strategic goals. A KPI is a measure that helps and supports achieving a critical goal of the organizations. Measure is important for the manufacturing floor because is the way to expose, quantify and visualize the waste. Lean manufacturing eliminate all activities that do not add value for your customer. The seven major forms of waste in the manufacturing process are:

- Overproduction
- Idle Time
- Unnecessary transportation
- Over-processing
- Inventory
- Unnecessary motion
- Scrap/defects

Definitively, eliminating these wastes will have a direct impact and improvement in productivity.

Visual KPI's had motivated the operators to greatly exceed the expected output. Getting information to the manufacturing floor in real- time drives productivity.

KPI's have specific indicators to drive a specific improvement. Some KPI's used to improve productivity are: Run rate, pieces per labor hour, total effective equipment productivity, units per person (UPP) and overall equipment effectiveness.

An important thing to consider is that the leadership is critical for the success of the goals. They need to work with a strategy deployment that involves creating goals at the top-most level and cascading them through all layers of the company. A good KPI should involve all the team: top management, intermediate management and the people on the shop floor.

The ideal set of KPI of the company will be strongly aligned with the company's strategic objectives and highly actionable by the plant floor personnel.

To obtain an increase in productivity, I used the Six Sigma Methodology. Six Sigma is a set of practices originally developed by Motorola to systematically improve processes by eliminating defects [3]. A defect is defined as nonconformity of a product or service to its specifications.

While the particulars of the methodology were originally formulated by Bill Smith at Motorola in 1986, Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects. Like its predecessors, Six Sigma asserts the following:

- Continuous effort to reduce variation in process outputs is the key to business success.
- Manufacturing and business processes can be measured, analyzed, improved and controlled.
- Succeeding at achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

The term "Six Sigma" refers to the ability of highly capable processes to produce output within specification. In particular, processes that operate with six sigma quality produce at defect levels below 3.4 defects per one million opportunities (DPMO). Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma has a key methodology: DMAIC. DMAIC is used to improve an existing business process and consists in:

- *Define:* Identify opportunities for improvement
- *Measure:* Measure the actual status of the process
- *Analyze:* Identify root causes of the problem
- *Improve:* Implement solutions
- *Control:* Establish controls to avoid re-occurrence

METHODOLOGY

The Six Sigma Methodology (DMAIC) was used in order to increase productivity. Below you will find all the DMAIC stages and the details of each one [4] (Figure 1):

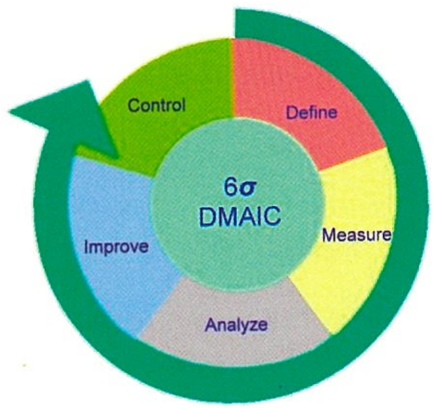


Figure 1: *Six sigma: DMAIC methodology stages*

DEFINE

The Define stage consists in the following:

- Problem Definition.
- Q-Diagram: Questions diagram used to drive the search of data. The questions will go from general to specific.
- Project Charter: summary of the project. Shows the problem statement, CTQ, objective, financial impact, customer impact, scope of the project and the team members.
- Translate the Voice of Customers to the Critical to Quality of the process: The Voice of Customer is essential to understand the customer needs. The voice of customer help us to: Identify critical parts of the process or product, Define critical requirements to Quality (CTQ Tree), Decide areas to be focus for the improvement efforts.
- General Image of the process: SIPOC (Suppliers, inputs, process, outputs and customers).
- Process Map: Visual presentation of the process flow. Helps to identify bottle necks, redundancy, key points for decision making, roles and responsibilities.

MEASURE

The Measure stage consists in the following:

- Data Collection of the actual process; including variability (different shifts, different production lines, different products).
- Operational definition for productivity.
- Name of Key performance Indicator (KPI).
- Detail image of the process: Value stream map.
- Actual status of the process using different statistical tools: Graphical Summary, Box Plots, sampling strategy.

ANALYZE

The Analyze stage consists in the following:

- Use the process data to identify the factors of the process (X's) that affect the productivity (Y's).
- Cause and Effect Diagram- Fishbone.
- Analysis of the data using different tools: Multi-Vari Charts, Box Plots, Individual Moving Range Chart (I-MR).

IMPROVE

The objective of the Improve stage is making the changes in the X's of the process to obtain productivity improvements. The Improve stage consists in the following:

- Documentation of solutions.
- Plan for the implementation of solutions.
- Metric Status.

CONTROL

The Control stage consists in the following:

- Control Plan: To install mechanisms to prevent the reoccurrence of the problems. To sustain the results with the savings acquired.

- Change in procedures.
- Training evidence.

RESULTS

Below you will find the details of the actions and results of all the DMAIC stages. Each stage was completed using different tools that were the key in the analysis.

DEFINE

At the beginning of the project, this manufacturing department did not have a metric to measure productivity. For a manufacturing department is important to know if they have the correct manpower and that those people are productive.

Improve the productivity of this manufacturing department, also improve the manufacturing output and the department cost.

Some questions during the define stage are:

- How to measure productivity?
- What are the productivity major offenders?
- What productivity offenders can be quickly minimized?
- What is the problem in this manufacturing department?
- What is the project scope?
- When the problem started?
- What are the benefits of the productivity improvements?
- What is the actual status in terms of productivity?
- Where the production department is losing production time?

The Figure 2, translate the Voice of Customers to the Critical to Quality of the process. In this project the critical to quality is the increase of productivity by 50%.

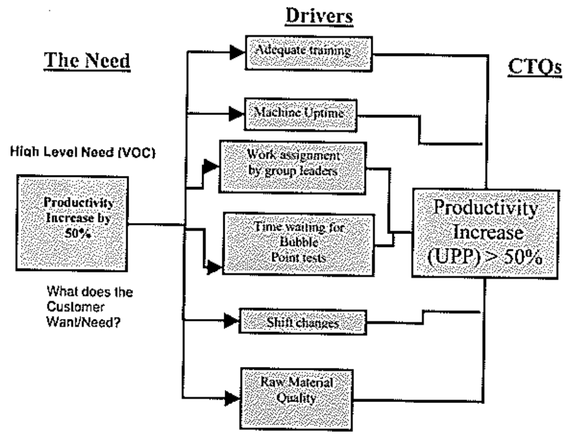


Figure 2: VOC-CTQ Tree

The SIPOC (Figure 3) is created in order to have a general view of the process. For the SIPOC diagram the suppliers and the inputs are the following:

- Raw material warehouse: material
- HR department: training
- Maintenance department: machines and spare parts
- Engineering: procedures

We need material inspected and accepted, trained personnel, machines and spare parts in good shape and ready to use. Also the correct procedures available and updated in order to obtain the expected output (units produced). The customers wants product on time and with the expected quality.

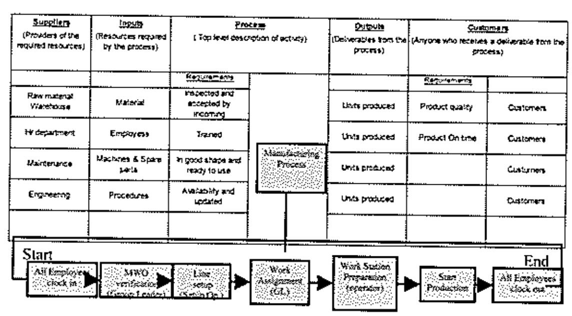


Figure 3: SIPOC Diagram

MEASURE

Some questions during the measure stage are:

- Is there any productivity metric at this moment?
- What data should be collected?
- What measurement method is used?
- How to get the data?
- Is the measurement system good?
- How much time is waste in non-value added activities?

During this stage, the operational definition for productivity was established. The productivity metric used was Units per person (UPP).

UPP Definition = Units completed/ Heads

- Heads = (Persons x worked hours clocked in) / (Hours available per shift).
- Heads = Operators, Setup's, Group Leaders, Material Handlers and Manufacturing Inspectors.
- Units completed at corrugating, end capping and packaging operations.

During the measure, a process/activity based map was completed in order to have a detail image of the process. This activity based map included the details different operations performed by personnel with different responsibilities. The map also included the waiting times and showed the value and non value added operations (see Figure 4). The data showed that the group leader spent fifth teen minutes in the schedule verification and work assignment to the operators. The setup operator spent thirty five minutes more for the documentation and parameters verifications and the production of the fourteen samples units. At the end the manufacturing personnel have to wait eighty five minutes for the testing results, before starting production. The waiting for testing is the major offender of the waiting time.

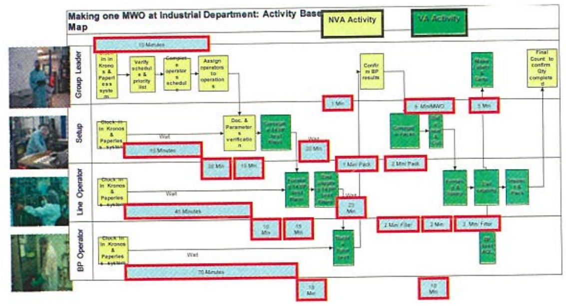
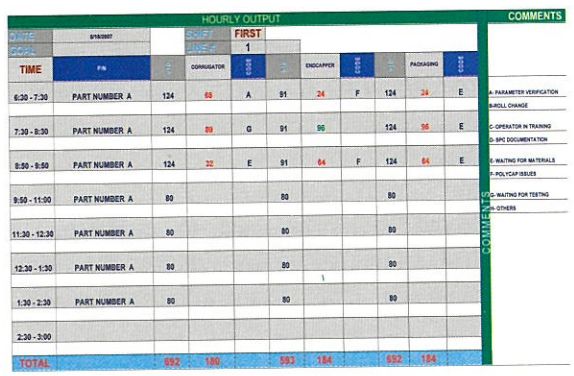


Figure 4: *Process/Activity based map*

Part of the sampling strategy for the measure stage included the output monitoring per hour. A board was implemented to monitoring he output completed at different stages of the line comparing the result against the standard per hour. This board was a visual aid to all the manufacturing floor of the line performance. The board included the output in red if the line was no achieving the expected result and in green if the output is as expected. Also have the details of the issues founded that were impacting the expected result. The purpose of the board was not only to collect the output data, was also to have a visual indicator for taking immediately actions in order to avoid downtime. See an example of the board below in the Figure 5.



TIME	P/N		CORRUGATOR	CODE		ENDCAPPER	CODE		PACKAGING	CODE
6:30 - 7:30	PART NUMBER A	124	68	A	91	24	F	124	24	E
7:30 - 8:30	PART NUMBER A	124	80	G	91	96		124	96	E
8:50 - 9:50	PART NUMBER A	124	32	E	91	64	F	124	64	E
9:50 - 11:00	PART NUMBER A	80			80			80		
11:30 - 12:30	PART NUMBER A	80			80			80		
12:30 - 1:30	PART NUMBER A	80			80			80		
1:30 - 2:30	PART NUMBER A	80			80			80		
2:30 - 3:00										
TOTAL		692	180		593	184		692	184	

Figure 5: *Hourly Output Monitoring Board*

After some weeks of data collection, other opportunities in terms of downtime were founded. The hourly monitoring board had data of downtime reasons that was used for the analysis and the search of improvements. The Table 1 below has the actions taken for downtime in order to obtain some productivity improvements.

Table 1: Findings and Actions for Downtime Improvements

Findings	Actions
Downtime during shift start	Supervisors to identify issues & offenders. Take action immediately. Improve "handshake" between shifts.
Downtime associated to breaks y lunch	Evaluation of "continuous running" for critical operations.
Downtime associated to "wait" for testing	Procedure evaluation for other alternatives.
Downtime associated to machine startup	Maintenance personnel will be in charge of turn on the machines.
Define Group Leader role and responsibilities	Work Sampling.
Downtime associated to setup's	Evaluate setup logistic.

ANALYZE

Some questions during the analyze stage are:

- How can we analyze the productivity at this manufacturing department?
- What factors affect the output?
- Can we implement fast changes for inputs?
- What is the critical part of the process?
- Which shift or Production lines are affected?
- The changes will have a direct impact in my output?

Collected data was used to establish the baseline of Units per person (UPP). The data established that 42 UPP is the baseline. In this stage also the standard UPP was calculated. The data analyzed to established standard UPP was the following:

- Standard Headcount- Demand of the last 12 months(weighted average), run time (standards per operation), uptime, yield and available time per day
- Standard UPP = Daily output (based in weighted average demand) / Standard headcount

A graphical summary was completed in order to analyze the standard UPP (see Figure 6). The average was 48 UPP. In order to obtain a 50% of improvement, they need to move from the baseline (42UPP) to 63 UPP.

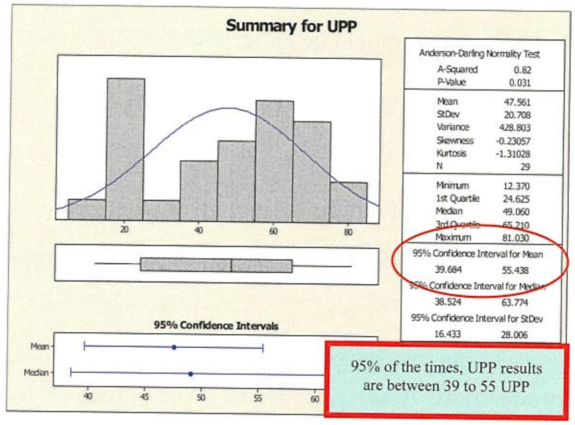


Figure 6: *Graphical Summary: Standard UPP*

In order to analyze all the possible causes that were affecting that the UPP were not achieved, a cause and effect diagram (see Figure 7) was completed. The areas to focus after the fishbone analysis were:

- Personnel- work assignment by the group leaders to the operators
- Methods- waiting for testing

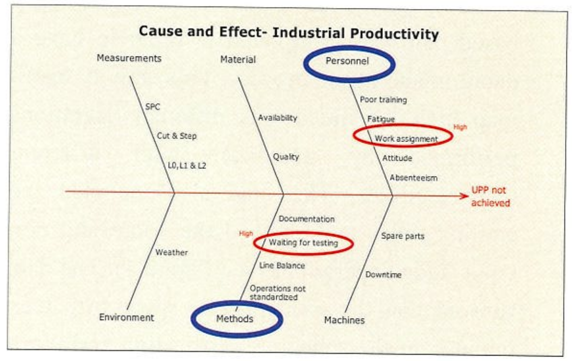


Figure 7: *Cause and Effect Diagram*

At this stage, we had a month of UPP data from the different shifts to analyze. Tools like box plots and multi-vari were completed in order to found variability and trending. The data on the box plot showed that the first shift complete more units per person than the second and the third shift (see Figure 8). The take away from the multi-vari, as per

Figure 9, was that the Friday has a significant difference in terms of UPP for all shifts.

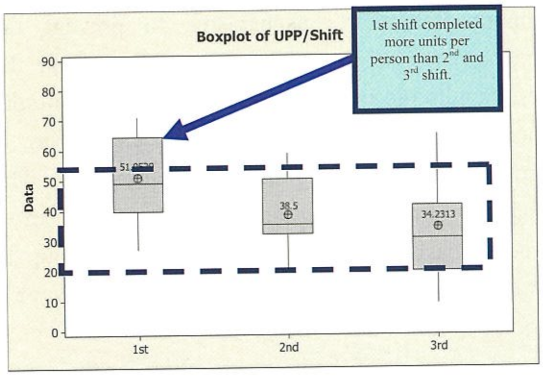


Figure 8: *Box Plot-UPP per shift*

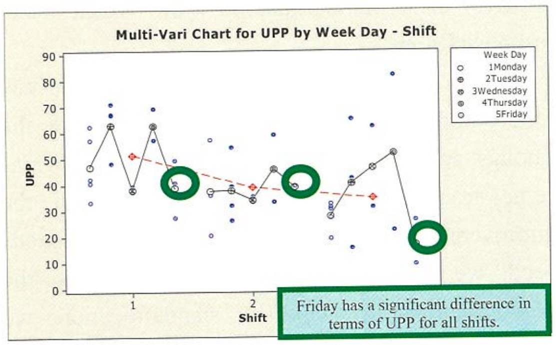


Figure 9: *Multi-Vari Chart-UPP per day/shift*

To finalize the analyze stage, after one month of data collection, some actions were implemented. All actions will have a positive impact on productivity. The table below (Table 2) has the details of the actions implemented.

Table 2: *Findings & Actions- Productivity Improvement*

Findings	Actions	Increase in time
Downtime during shift start	Overlapping between shifts. Machines will be continuous running.	30 min/ shift
Downtime associated to "wait" for testing	Change in procedure	1 hour / shift
Downtime associated to machine startup	Work Sampling completed	3 hours on Sundays (3rd shift)
Define Group Leader role and responsibilities		N/A

IMPROVE

In this stage, we had the data collected and analyzed and we are ready to implement solutions.

After the work sampling of the group leaders roles and responsibilities, we found some opportunities that have a positive contribution on productivity. Basically we found that we had two positions as group leaders (Technical Group Leader and Line Working Group Leader) that had similar roles. The table below (Table 3) included the changes of responsibilities of the technical group leaders that will be part of other position responsibilities. Those changes represented a reduction of four group leaders.

Table 3: *Changes on Group Leader Roles & Responsibilities*

Responsibilities	Proposed Changes
Verify priorities and assign work to setup's	Line working group leader will be in charge
Verify schedule and change in priorities if necessary	Line working group leader will be in charge
Coordination of material dispatch	Warehouse person will have access to view the schedule on line in order to coordinate the material dispatch.
Support in machines problems	Maintenance person assign and physically located in manufacturing
Material Transactions	Line working group leader or material handler will be in charge
Documentation review and signs	Line working group leader or setup will be in charge
Complete some specific setup's	Training to all the setup's operators
Work orders for maintenance department	Maintenance person assign and physically located in manufacturing
Complete setup's information (Data)	Line working group leader will be in charge
Document output per hour (Boards)	Line working group leader will be in charge

Other actions implemented during this improve stage are the following:

- Hourly Monitoring as per operation standards

- Special shift for the machines setup to avoid downtime
- Change in procedure: Waiting time for testing at the beginning of shift
- Roles and Responsibilities changes
- Manpower calculation: based on UPP
- Elimination of Technical Group Leaders: Maintenance technicians assumed technical roles
- Technical Group leaders are now Working Group Leaders: They were part of the Group Leaders reduction analysis
- Group Leader Job Description revised and approved to standardized responsibilities
- UPP metric- Weekly reporting on Site Operations Weekly Meeting

After the implementation of those actions, we can see a big improvement in productivity. The UPP improvements represent a 75%. The productivity goes from 42 to 75 units per person. The following chart (Figure 10) is an Individual Moving Range for UPP that demonstrate the improvement.

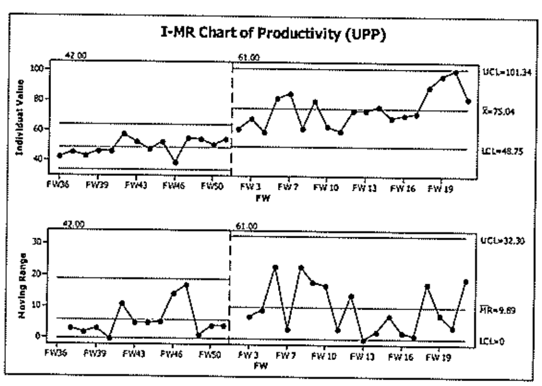


Figure 10: Individual Moving Range for UPP

CONTROL

The control stage consists in the implementation of mechanisms to prevent the reoccurrence of the problems and to sustain the results with the savings acquired. The hourly output monitoring was implemented officially in a procedure and is continuously monitored. The manufacturing supervisor have to report in a weekly basis the UPP to the operations group in order to maintain the focus in the goal and have a good explanation if the goal is not achieved.

As a result of the work sampling for the group leader position, the job description was revised to reflect the standardization of roles and responsibilities.

All the controls mentioned before was the key for sustain the results. At the end of the project, the savings achieved were of $113,280. The savings came from the personnel reduction. With the improvement of 75% in UPP, based on demands need, we reduced 24 operators. Also, with the group leader responsibilities standardization, we reduced 4 group leaders. The Figure 11 showed the summary of the strategies, actions and solutions from each stage.

CONCLUSIONS

Using the DMAIC methodology, you have the opportunity to make all the questions and go through an organize process using different tools for the finding of the solutions. DMAIC allows you to find permanent solutions and real improvements in this case with excellent economic results. After the implementation of the productivity metric, units per person (UPP), we obtained a 75% of improvement in UPP. This improvement represented a reduction of 24 operators and 4 group leaders based on the demand and $113,280 in savings. As you can see, using the appropriate tools we can achieved more that expected.

Measure is important for the manufacturing floor because is the way to expose, quantify and visualize the waste. Now this medical device manufacturing company has the way to measure the output implemented in a procedure and the way to confirm if they are productive.

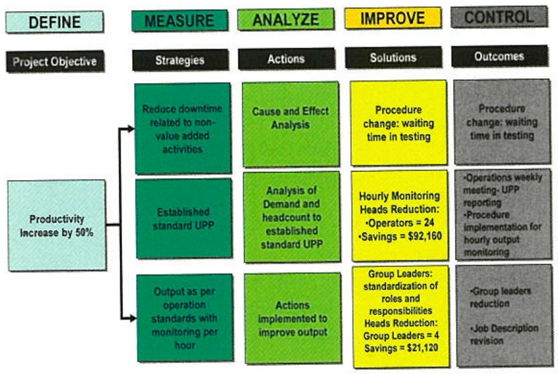


Figure 11: *Summary*

REFERENCES

[1] Productivity, retrieved September 11, 2008, from http://en.wikipedia.org/wiki/Productivity

[2] Vorne, R. (2007), "KPI's from a Lean perspective: Achieve goals, reduce waste", *Plant Engineering*, Jul 2007, Vol.61 Issue 7, p49-52.

[3] Six Sigma, retrieved January 27, 2008, from http://en.wikipedia.org/wiki/DMAIC

[4] DMAIC, retrieved October 13, 2008, from http://exa.com.tw/exa/chinese/image/dmaic.jpg

Yazmín Morales se graduó del programa de Maestría en Ingeniería de Manufactura, en la colación de grados de 2009. La señora Morales posee un grado de bachillerato en Ingeniería Industrial y sus intereses en investigación van alineados al área de Procesos Farmacéuticos.