BUSINESS MANIAC VENTURES: USING THE DMAIC MODEL TO MANAGE MACHINE DEFECT

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ABSTRACT

HAMK UNIVERSITY OF APPLIED SCIENCES

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Subject of Bachelor's thesis Using the DMAIC Model to Manage Machine Defects

ABSTRACT

The aim of this project was to develop a system for identifying, documenting, analysing and fixing defects on a paint mixer and Sartorius scale using the DMAIC model. This would help to prevent defects on the machines; the number of breakdowns will be reduced; productivity increased; the useful life span of the mixer and the scales prolonged. It will provide clean and safe working conditions and zero accidents to personnel.

The thesis was commissioned by Business Maniac Ventures, Lagos State, Nigeria. In the autumn of 2011, Business Maniac Ventures decided to have a system to prevent breakdowns on the mixer and the Sartorius scale.

This work process was needed in Business Maniac Ventures because the company did not have a standard method for inspecting the mixer and the Sartorius scales for defects and fixing these defects. There were no documented evidences that reported defects would have been fixed. There were no records on the number of defects found and fixed on the equipment. Neither was there documented evidence of an analysis conducted before these defects were fixed nor some improvements were made on the equipment, the reason for these and no historic data to refer to as regards the deterioration of the equipment. There have also been recurring defects on the mixer.

At the beginning of the project, meetings were held with the technical manager and the business control manager of Business Maniac Ventures to determine the objectives of the project. The result of the thesis was a work process for managing machine defects. The work process stipulates what is to be done in the event of an abnormal condition on the equipment and the personnel responsible for the various actions.

Keywords Machine defects, Breakdown, Work Process, Lean Six Sigma.

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1 INTRODUCTION

The aim of this project was to develop a system for identifying, documenting, analysing and fixing defects on the paint mixing machines of Business Maniac Ventures in Lagos State, Nigeria using the DMAIC model. This would help to prevent defects on the machines; the number of breakdowns would be reduced, productivity increased, the useful life span of the mixer and the scales prolonged, clean and safe working conditions and zero accidents to personnel provided.

The case company, Business Maniac Ventures did not have a standard method for inspecting the mixer and the Sartorius scales for defects and fixing these defects. There were no documented evidences that reported defects would have been fixed. There were no records on the number of defects found and fixed on the equipment. Neither was there documented evidence of an analysis conducted before these defects were fixed nor some improvements were made on the equipment, the reason for these and no historic data to refer to as regards the deterioration of the equipment. There have also been recurring defects on the mixer.

2 ABOUT THE COMMISSIONING ORGANIZATION

2.1 Background of study

This thesis was carried out in the autumn of 2011 at Business Maniac paints division of Business Maniac Ventures, Lagos Nigeria. The company mixes auto-paints to customers' requirements and also provides car refurbishing.

The Business Maniac Paints sell different brands of auto paints both in wholesale and in retail. The retail sales generate more revenue for the company than the wholesale trade. The paints are usually mixed to customers' satisfaction.

Two main machines are used for the paint mixing operation. They are the Sartorius scale model PMA 7500 and the Dupont paint mixer SX E-4642 fillon. These devices are shown in Figures 1 and 2 respectively. Each machine has its own control panel and works independently. The Sartorius scale is used to measure the exact quantity of tint needed for the mixing operation while the paint mixer is used for the quick stirring of the tints to produce fine quality outer coat for automobiles. The mixer has the capacity to mix quantities as low as half a litre of paint to the exact attributes as described by the automobile manufacturer.

Figure1 Sartorius scale model PMA 7500

Figure 2 Dupont paint mixer SX E-4642 fillon

It is important that these machines are in good working condition so as to minimize errors in the paint-mixing process. A minor error in the measurement of the Sartorius scale will produce a different appearance from the required automobile colour. The stirrer of the fit mixing lid of the mixer (Figure 3) is also prone to contributing errors to the process. It often breaks down and it is the most important and delicate part of the mixer.

Figure 3 The fit mixing lid

There are also major potential hazards in the paint laboratory owing to the fact that there are low-voltage electrical cables connected to these devices as shown in Figure 4. There is always the possibility of liquid spilled on the floor. Hazards such as fall, trip, electrical shock etc could take place in the laboratory if proactive measures are not taken to prevent this.

Figure 4 The paint laboratory

There were no proactive measures taken to mitigate errors and danger from all these minor but delicate sources.

The main objective of this thesis was to develop a system to identify, document, analyze and fix the defects that might cause: errors in the production of good quality paint, breakdown of the equipment or render the paint laboratory unsafe for the employees.

The average turnover of Business Maniac ventures is 110 000 Euros per year, if the company were to lose one litre of auto-base and one litre of auto-cryl paints every business day due to rework, every year, the company would incur losses of 4534 Euros on auto-base and 5102 Euros on auto-cryl. This amounts to a minimum loss of 9636 Euro each year, which is about 8.6% of the company's turnover.

The DMAIC model was chosen for this project because it is easy to implement, it defines individual roles and responsibilities, makes the problem visible to all the personnel in the organisation and gives room to in-house improvements and modification.

Some other methods that could also be used are: autonomous maintenance (AM) and planning and scheduling (P&S). The implementation of AM requires a lot of training and preparation. This is not suitable for a small company like Business Maniac Ventures. The planning and scheduling method does not allow for total employee involvement. So the DMAIC model was preferred over the other methods. The DMAIC model is explained in more details in chapter 5.

2.2 Commissioning organisation

Business Maniac Ventures was established by Kunle Olaide on the 25th of May 1998 in a shop on 85, Bajulaye road, Somolu, Lagos State, Nigeria. It started with only two staff members- the technical manager, Kunle Olaide who knew very little about paints and paint products and a cashier, Bisi Oyewole. The first few months of the business was highly challenging. It seems as if the business would fail. Kunle was advised by families and friends to quite the business and start a grocery store but he was optimistic that there was going to be light at the end of the tunnel.

Today, Business maniac has three sections - Business Maniac Prints, Colour Language and Business Maniac Paints. Business Maniac Prints is a printing enterprise. Colour Language focuses on car refurbishing and house painting. Business Maniac Paints handles the sale of paints and painting accessories. Business Maniac Prints and Colour Language usually subcontract their printing and car refurbishing jobs to local printing presses and auto-refurbishing companies within Somolu town. Business Maniac is also involved in monitoring the process of these companies and in the decision-making regarding the subcontracted jobs in order to ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction. The company works with ISO 9001 but it is yet to obtain the certification.

Business Maniac is also one of the major sub-dealers of Dupont, Sikkens and Dyna paints in Nigeria.

Business Maniac Paints sell paints in whole sale and retail. Some of its products are: Sikkens autobase classic, autocryl plus, Dyna autobase, Dyna autocryl, Sikkens HS clear, P35 hardener, 123 clear, 123 hardener, reducer medium, degreaser, plastic primer, primer 680, kombi filler, Dupont clear, Dyna clear, Dyna hardener standard, Dyna hardener slow, Dyna thinner standard, Dyna extra slow thinner, Dyna primer, buffing control, wax etc.

The computerized mixing department of the Business Maniac Paints deals with mixing of autobase and autocryl paints to customers' specification and quantity. Each car colour is determined using the different car brands' standard colour charts. Different car brands have their own standard colour codes. The MIXIT 2 software is used to determine the exact quantities of paints and tints required to produce a perfect colour. These paints and tints are then transferred to the mixing unit which comprises a mixer and computer unit for the process control.

Mixing unit = control unit + mixer.

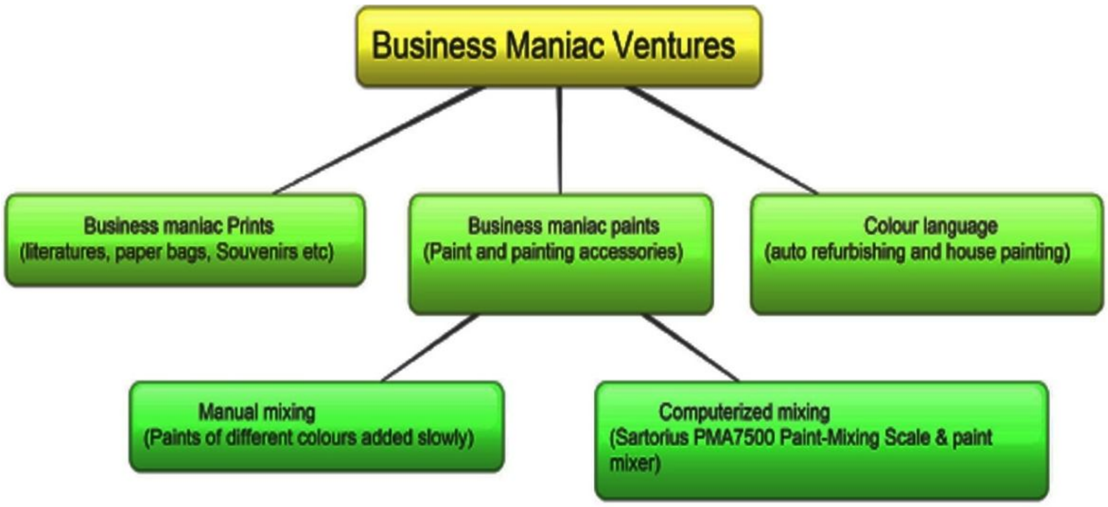


Figure 5 Segments of Business Maniac Ventures

2.2.1 Management of Business Maniac Ventures

Business Maniac Ventures is led by Kunle Olaide and his wife Catherine Olaide. Kunle Olaide decided to adopt the title of a technical manager due to his Christian faith claiming that the Holy Spirit is the CEO of the company. Kunle Olaide is the overall leader and the outsourcing manager. Catherine Olaide is the business control manager. There are two managers, six permanent staff and several local companies working for Business maniac. These six employees consist of a supervisor, four process operators and an admin staff who also does the job of a cashier.

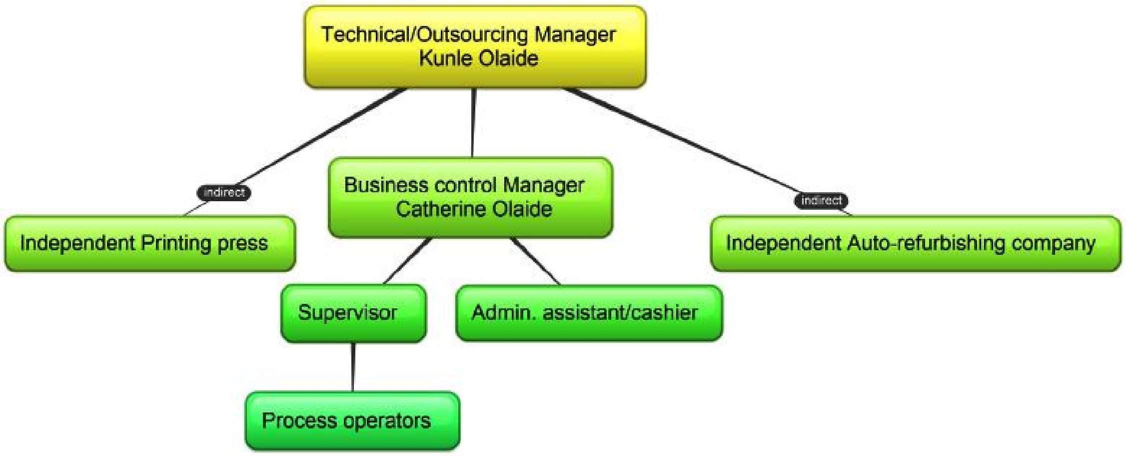


Figure 6 Organisational structure of Business Maniac Ventures

2.2.2 Business Maniac clients

The company's major clients are automobile refurbishing companies, oil servicing companies, paint retailers, painters, religious and social organizations, private individuals organizing events.

3 PROJECT OVERVIEW

3.1 The purpose of the study

The purpose of this study was to develop a system to prevent and fix machine defects on the mixing machines of Business Maniac Ventures. The lean six sigma tool – DMAIC model was chosen for this because it helps to highlight the role of individuals in the fight against machine defects and makes the team follow a systemic way of finding a lasting solution to a problem. The process is in this order:

- ✓ ***D - Defect identification*** *– to capture defects on the equipment by knowing the difference between normal and abnormal situations.*
- ✓ ***M - Defect tracking*** *– to measure the number of defects captured and fixed.*
- ✓ ***A - Defect analysis*** *– to know the main causes for these defects; finding a solution to them and providing a workable plan to fix them permanently.*

- ✓ ***I - Improvements** – to implement solutions to identified defects in order to maintain an ideal equipment condition.*
- ✓ ***C - Control** – to develop people's skills of identifying and correcting abnormal conditions. To make sure that the mitigating actions are implemented correctly in order to prevent future defects.*

The DMAIC process is closer explained in details in chapter 5.

3.2 Research questions

The main research question in this thesis was how to prevent defects on machines in the paint-mixing industry. This question raises lots of other issues that deal closely with defect prevention and management. These include questions such as:

1. How can machine defects be easily identified?
2. What are individual employee's roles in preventing defects on machines?
3. What are the quality tools that can be used for machine defect management?
4. How can the management be involved in the process of preventing defects on machines?

3.3 Research methodology

The qualitative research method was used in this thesis in the form of an analysis and interpretation of texts and interviews to discover meaningful patterns descriptive of a particular phenomenon.

The theory part contains materials gathered from professional literature, publications, internet articles, webinars, class lectures and work experience.

The technical manager of Business Maniac Ventures was also interviewed to collect the existing data on the current situation of the company.

3.4 Structure of study

The thesis starts by defining machine defects. These defects are classified into seven types in chapter four. The causes and effects of machine defects are also explained.

Chapter four ends with managing machine defects through DMAIC while chapter five looks closely at the defect management process using the DMAIC model and the defect management flow chart (Figure 8) explained in a tabular form.

Recommendations are given in the sixth chapter and conclusion forms the seventh chapter in this thesis.

4 MACHINE DEFECT DEFINITION FOR THIS PROJECT

4.1 Definition of machine defects

This chapter gives a general view on how machine defects were classified for the purpose of this project. This formed the basis for the work process that was designed to curb the existence of defects on the paint mixer and scales of the client company – Business Maniac Ventures.

The causes and effects of machine defects are also looked into here while the concluding part of the chapter contains information on how to prepare an organisation for a successful implementation of the DMAIC model to manage machine defects

The results of this project are not limited to the paint-mixing company. The process can be applied in several other organisations where lean manufacturing can be adopted for maximum profitability.

'**Defect**' stands for different things in different fields but they all leave a common footprint – **WASTE**! Either by slowing down the process, causing mix-up or causing damage.

To the reliability engineer, it is the root cause of the failure in the system. To the production planner, it is the reason for the delay in shipment. To the material planner, it is the cause of the out-of-stock. To the human resource manager, it is the cause of low morale in the organization. To the mechanical engineer, it is the knock in the engine. To the electrical engineer, it is the arc in the panel. To the civil engineer, it is the crack in the design. To the cashier, it is the cause of the overpayment. To the seamstress, it is the reason why the cloth didn't fit the client. To the driver, it is the reason why the car stopped in the middle of the road. etc.

A defect on a process machine is like the forerunner of a machine breakdown, personnel injury and environmental emission. It is anything that causes undesired behaviour, unkempt appearance and 'fire-fight' in any part of the machine. Defects are the root cause of all machine failures and breakdowns. Anything that impairs the whole or part of the functions of a machine and in some cases brings it to an abrupt shut down must be seen as a defect.

“The various X’s that are causing the Y to behave in an unacceptable manner” (Wheat, Mills & Carnell 2003, 31).

Boris (2006) described deterioration as the reduction in performance or reliability of equipment. This is also a machine defect.

On the 14th of July 2011, the author posted a question “what in your own words is a machine defect?” on the official Facebook page of the Institute of Industrial Engineers in order to get the views of industrial engineers and students on this matter. Machine defect was described as a condition that either affects the performance of the machine, the products from the machine or both the products and the machine itself. It negatively impacts the overall turnover of the company.

Defects have the ability of hiding themselves in the equipment but once they are there, they alter the reaction of the equipment and in most cases; they can be noticed by “just watching the process and logging anything that is unusual in the process” (Wheat, et al. 2003, 68).

4.2 Classification of machine defects

For the purpose of this project, machine defects were classified as:

1. Critical defects
2. Minor flaws
3. Unfulfilled base conditions
4. Unnecessary parts
5. Contamination sources
6. Hard to access
7. Organizational

Critical defects are conditions that impact the quality of the final products or the safety of the personnel. In the paint-mixing process, color-accuracy is very important. The goal is always to get the exact color as required by the customer, in cases where a customer wants to change the color of his/her car or as it is stipulated by the car manufacturer. Each car brand has a specific color brand chart. This chart indicates the mixture of tints required to get the exact color. If the functionality of the Sartorius scale or the mixer negatively affects the result of the process, this is considered a critical defect.

The object may come directly from the machines or other facilities such as the building, electrical gadgets, etc. If the safety device on the mixer fails or if it does not function as it is expected to, this should be considered as a critical defect.

Critical defects should be fixed immediately to avoid dissatisfied customers and unsafe working conditions.

Minor flaws are wear, cracking, chips, corrosion, smells, noise, heat etc. These can be commonly noticed around the mixer motor, stirrer and the Sartorius scale load cell etc.

Unfulfilled base condition this may occur if the machine and/or its environment are not clean, bolts and nuts are not tightened and moving parts are not lubricated properly. The total productive maintenance sees unfulfilled base condition as deterioration from the basic condition. Deterioration from the basic condition is the first step on the way to developing faults.

The further away we get, the higher the likelihood of a failure. This in most cases does not immediately stop the equipment from running. There is the likelihood to ignore it because it often starts off as minor irritations. The product quality may not be affected immediately, the whole system might still be working perfectly but in the nearest possible future, a failure will strike due to this. This can be very common with the stirrer of the mixer. It is possible to keep the mixer running with a partially loosened stirrer. It works fine for some time but after a while, disaster will surely strike due to the loosed stirrer.

Unnecessary parts are items that are not needed for the paint mixing process. These are considered waste. Examples are standby equipment, unnecessary spares, unused tools, idle parts etc. Some items may be considered as unnecessary at present but they may be needed in the future. There is no point keeping them around the process. They could cause mix-ups in the process. It is advisable that these items are stored away until they are needed. If something lies idle and just eating up the space, it should be considered as **“unnecessary”** It could be very costly to have mix-up in the paint-mixing process because it is an irreversible process.

Contamination sources also known as “source of infection” (Boris 2006, 16). These are leaks and contaminants from other sources. If during the mixing process, tints escape from the cans, there is a defect due to contamination source. If oil drips from the stirrer to the cans, there is a defect due to source of contamination. The effect is not what should be tackled but the source of this contamination. There is always the temptation to want to fix the effect while forgetting the cause of this effect. For example: there is a leak from the can of the mixer, most process operators may want to keep cleaning tints on the floor or around the can but the best way would be to fix the leaking point on the can. The source of contamination should be permanently fixed, not the effect. Fix the source and the effect is naturally taken care of.

Hard to access defects are as the name suggests, defects difficult to get to. Anything that makes an item difficult to clean, inspect, tighten, operate, lubricate, repair, or maintain is a “**hard to access defect**”. If anything causes an obstruction on the machine’s operation or maintenance, it should be considered as a **hard to access** or **hard to reach** defect.

Organizational defect – this is anything which impacts the team's ability to be effective e.g. the morale. This is for the leadership a problem. “At its best, leadership is about empowering people. Empowerment means that an individual or a team acts independently without being controlled, relying on the vision for guidance. Empowerment means trust, support, development and setting an example. Empowerment means unlocking people’s potential and energizing them.” (Sydänmaanlakka 2005, 120.)

Dialogue between management and employees is an essential part of implementing changes in any organization. (Wheat et al. 2003, 23)

4.3 Causes for machine defects

Generally, machine defects occur naturally or are forced to occur. Natural deteriorations occur due to operating years of a machine or due to aging. This is due to the wear and tear that occurs on rubbing surfaces, moving parts and landing zones. While the forced defects are due to “error in manufacture and measurement” (Hattangadi 2005, 3). It could be due to its **design, installation** or due to its **operation** and **maintenance**.

The design and installation defects are the machine defects that were created with the building and setting up of the machine. “These occur when design engineers fail to recognize certain natural phenomena or certain limitations of materials as well as operating conditions” (Hattangadi 2005, 3).

Operate and maintain defects are the machine defects that occur due to the activities of or on the machine.

According to Boris 2006, to maintain a basic condition, the machine must be clean inside and out. That is, the **accumulation of dirt** is one of the causes of machine defects. If we allow dirt to keep accumulating on the equipment, there is high chance that something would soon be out of place on the machine. The Sartorius scale would definitely malfunction when there is accumulation of dirt around the load cell. The mixer would soon become a scrap if it is not properly cleaned after each use.

Education and training – As the operators will be responsible for the machines, an accurate training session is required to explain how the machine works. They should know what to do to make the machine either behave normal or abnormal. This would help them recognize abnormal situations. It is also important that the employees and the management communicate with each other. The management may have the power to make changes, but most of the time the employees hold the real knowledge of the things that ought to be changed. A well trained operator knows the “why” the “what” and the “how” of the process. This would lead to recognizing and maintaining the basic condition of the machine.

Higher usage: When the equipment is subjected to such a condition that there is no planned shutdown for maintenance activity, “it is not uncommon to see an increase in the reported failure rate because higher usage causes additional failure exposure even if it had been powered on while not in use” (Herbert 2003, 17).

Variation - lack of a defined process standard is a common source of machine defects. It is very possible that the machine may sometimes be run at limits thereby causing the parts to begin to worn out. Also, if there is variation in the maintenance procedure, the maintenance exercise might become a damaging exercise on the machine. “Failure in early stages of the utilization period is usually due to variation in the manufacturing process” (Bo de Mare et al. 2009, 5).

Work flow – when the work flow is poorly designed, this could contribute to generation of defects in the system. A poor layout will give adequate room for mistakes in the operation and this could lead to defect due to misuse of equipment.

So, inadequate training or knowledge gap, un-standardized process, fatigue, bad layout and dirt are the major causes of machine defects.

4.4 Effects of machine defects

Machine defects will in most cases lead to breakdowns. The end result is unreliability, underperforming modules, drift, bypassed interlocks, dirty floor panels, oil and air leaks, and an invitation to a life of unscheduled breakdowns and quick fixes.

Safety: machine defects, if not curbed on time could result into injury to personnel, emission to the environment and loss of lives and properties.

On the 14th of March 2001, Petrobras oil rig in the Roncador field off the coast of Brazil sank with an estimated 9500 barrels of oil on board, killed ten members and fatally injured one member of the attending fire-fighting crew. This was caused by undetected error in the design of the oil rig. (Petrobras P-36 2001.)

Unutilized manpower – machine defects does not only affect the machine performance, it also affects the human resources in the industry. It makes valued talents to be focused on fire-fighting. It causes so much financial and capability losses to the company. Many resources that should have been channeled to more productive activities are dedicated to fixing failures. Some companies even have operators that are always idle and waiting for breakdowns to occur. This is a great loss to the organization. “A major goal of the productive maintenance (PM) pillar is to eliminate this need to watch. It should be possible to reduce breakdowns and stoppages and increase reliability by enough to allow the operator to be utilized in other areas and respond quickly in the event of an alarm”. (Boris 2006, 23.)

Machine defects also have impact on product quality, employee morale, manager-employee relationship, customer satisfaction, shipment, production planning, overhead cost, pricing and cost of spare parts. "Total manufacturing costs, quality and competitiveness are critical considerations of a manufacturing enterprise" (Pohjola 2010, lectures).

Company reputation – machine defect can negatively affect a company's reputation either by causing defective products to escape to the market or causing an event that would make the company known and associated with this negative event. An example was Petrobras oil rig. Today, the rig is more known for the incidence of its sinking and killing workers than for the purpose for which it was established.

4.5 Managing machine defects through DMAIC

Machine defects can never be completely eradicated throughout the life of the equipment but when these identified defects are fixed, the associated risks can be reduced and a long-lasting performance can be enjoyed throughout the life of the equipment.

How then can machine defects be managed?

In this thesis, the DMAIC tool was used to describe how machine defects can be managed.

DMAIC (pronounced as duh-MAY-ick) which is a lean six sigma problem solving tool is an acronym for determine, measure, analyze, improve and control. "It is a structured data based problem solving process" (George et al. 2003, 57). "The DMAIC framework insures that the problem is clearly stated and understood, that all relevant data is being used to analyze current performance and postulate improvement possibilities, and that the improvement is measured, audited and sustained" (Peter L. King, Lean Dynamics LLC, Institute of Industrial Engineers).

The DMAIC model is one of the most effective problem-solving methods ever used because it enables teams to use data to:

- ✓ Confirm the nature and extent of the problem
- ✓ Identify true causes of problems
- ✓ Find solutions that evidence shows are linked to the causes
- ✓ Establish procedures for maintaining the solutions even after the project is done

The DMAIC process makes the problem more visible to all and sundry in the organization making everyone to be involved in solving the problem. The standards of identifying and solving the problem are established. The decision made at every stage of the process is based on data. Things are done based on facts and not speculations or "how it has always been done" method.

The DMAIC tool uses collaboration techniques which include methods for sorting through, organizing, and prioritizing ideas in finding the solution to a problem. Though everyone is involved in finding the problem yet, it doesn't mean that everyone must be involved in the fixing exercise because "the experts of the process have always been and will always be the operators and no one can solve a problem faster than the people who do the work" (Wheat et al. 2003, 18).

The DMAIC tool becomes useless unless everyone especially the managers have a lean state of mind. What then is lean state of mind?

James P. Womack, the Founder and Chairman of the Lean Enterprise Institute, Inc. in one of his monthly publications, "Gemba walk with Jim Womack" described a lean manager as follows:

Firstly, the lean manager is a problem solver. This means going to see the actual situation, asking about the performance issue, seeking the root cause, and showing respect for lower-level managers and for colleagues at the same organizational level by asking hard questions until good answers emerge. Then an effective tool is used to efficiently solve the problem instead of some meaningless abstract analysis in some conference rooms behind the terminals of computer. Empty ritual is replaced with a rigorous thought process that engages employees and pulls forward their best abilities.

Secondly, the lean manager realizes that no manager at a higher level can or should solve a problem at a lower level. This is regarded as an abuse of lean tools. Instead, the higher-level manager can assign responsibility to a manager at a lower level to tackle the problem through a continuing dialogue, both with the higher-level manager and with everyone actually touching the process causing the problem.

Thirdly, the lean manager believes that all problem solving is about experimentation by means of Plan-Do-Check-Act. No one can know the answer before experiments are conducted and the many experiments that fail will yield valuable learning that can be applied to the next round of experiments.

Finally, the lean manager knows that no problem is ever solved forever. Whenever a countermeasure is applied, a potential problem has been introduced in the system. This is not bad. It is good, provided the critical, probing mind of the lean manager keeps on the case in pursuit of perfection.

The difference between the tradition manager and the lean manager is that, the traditional manager is usually passive, going through rituals and applying standard remedies to unique problems but the lean manager has a restless desire to continually rethink the organization's problems, probe their root causes, and lead experiments to find the best currently known countermeasures. When this lean mindset is coupled with the proper lean tools such as DMAIC, amazing things are continually possible, unprecedented results are achievable, barriers are bound to be broken, weaknesses become strength and threats become opportunities.

The DMAIC model can be applied in managing machine defects after lean mind set has been achieved across the organization. The process operator should be made to see himself as a lean manager of the process. He should seek to satisfy the need of the customers. He should realize that his job is to add value to the customers.

5 THE DEFECT MANAGEMENT PROCESS DEVELOPED FOR THIS PROJECT

The five basic steps of the DMAIC model were used to develop the defect management process as shown in figure 7. This explains what is done at every stage of the process.

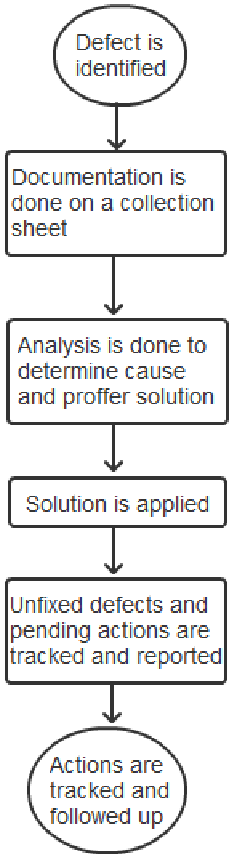


Figure 7 The defect management process steps

5.1 D - Define

The first step was to define:

- ✓ What would be regarded as defects on the machines – mixer and Sartorius scale. This was illustrated in details in section 4.2 and also indicated on the defect collection sheet under the caption: “Defect Type Descriptions” (Appendix 1)

✓ Individuals' responsibilities as shown in figure 8 below.

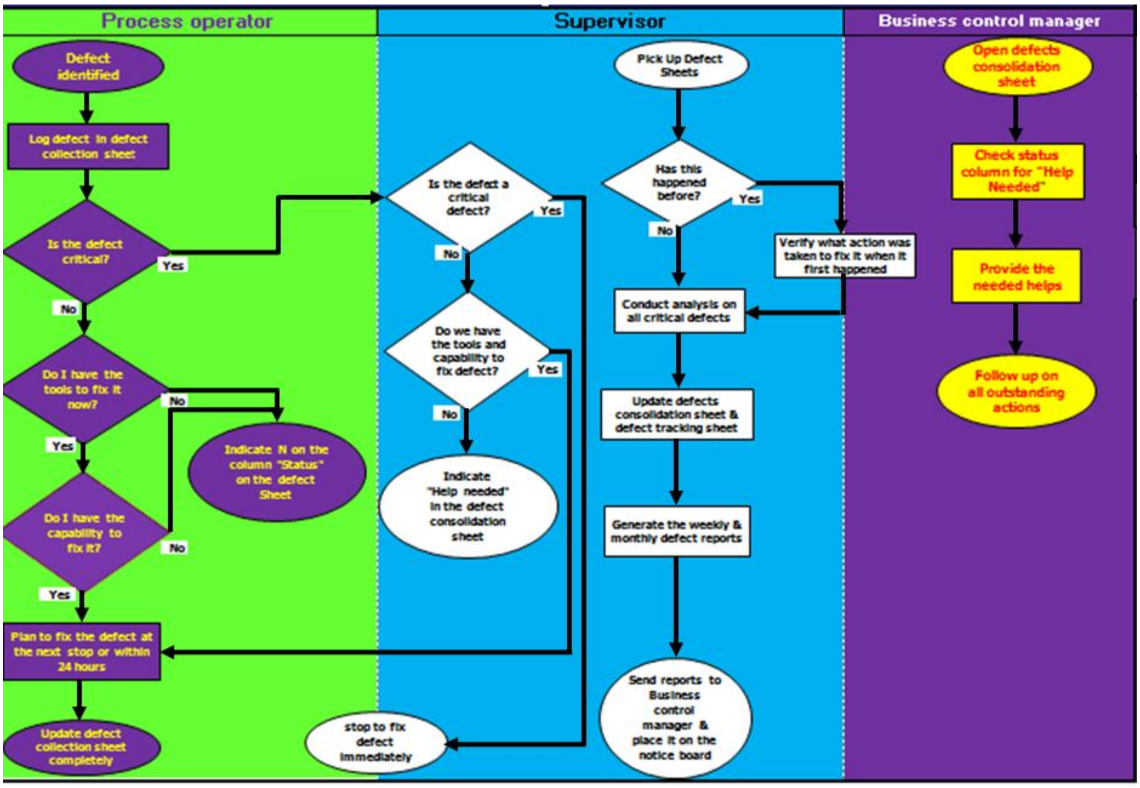


Figure 8 The defect management flow chart

In this process, it is very important to define what should be regarded as defects on the machines. This helps everyone to recognize defects at a glance and avoid capturing perceived defects. To do this, training across the organization is mandatory.

The training should focus on the following: **Understanding the process** – how does the machine work normally? When can it be said that everything is working properly? It is possible that shippable products are being produced while the machine is not working as it is supposed to, due to the presence of defects. The operators should be able to define the process. They should be able to recognize changes in the system. Is the sound normal? Is the movement sequential? Is the delay normal? Is the temperature ok? The process operator should understand and be able to explain the normal working mode of the machine and also the normal position of the parts on the machine. To understand the process, the normal versus the abnormal condition should be known.

General equipment safety – nothing we do is worth getting hurt for. Everyone in the organization should know how to relate with the machines in a safe manner. Operators should know how to carry out their responsibilities safely and others should know and understand their limits. The defined access they have on the production floor, the types of personal protective equipments needed for access into any part of the floor and the places they can't access.

This frequent training should not be limited to the process operators and technicians but should cut across the whole organization including the admin. The aim of the organization is to produce products that satisfy the need of customers. Every function in the organization should be aimed at creating value for the customers.

Since these trainings are on the job, it should have the following characteristics:

- ✓ It should not be 100 percent casual.
- ✓ The person taking the training should know what he is actually talking about.
- ✓ The trainer should have access to the appropriate training documentation and standards for the topic being covered.
- ✓ It should be straight to the point.
- ✓ It shouldn't be too theoretical.
- ✓ Employees should not trade their vacation or personal time for trainings.

Once the normal versus abnormal conditions are established, it would be easy to recognize defects on the machine. The first step is to recognize **loose, dirty and dry** on the machine i.e. the mixer and the scales**.** *That is, is the part that is supposed to be tight, loosed? It is a defect. Is the machine dirty? It is a defect! Are the moving parts lacking lubrication? That is a perfect defect!*

5.2 M - Measure

After a defined standard of defect classification has been achieved, a detailed documentation is needed (appendixes 1-6). The data of defects needs to be collected and understood before a meaningful analysis can be done and a proper solution proffered. This helps:

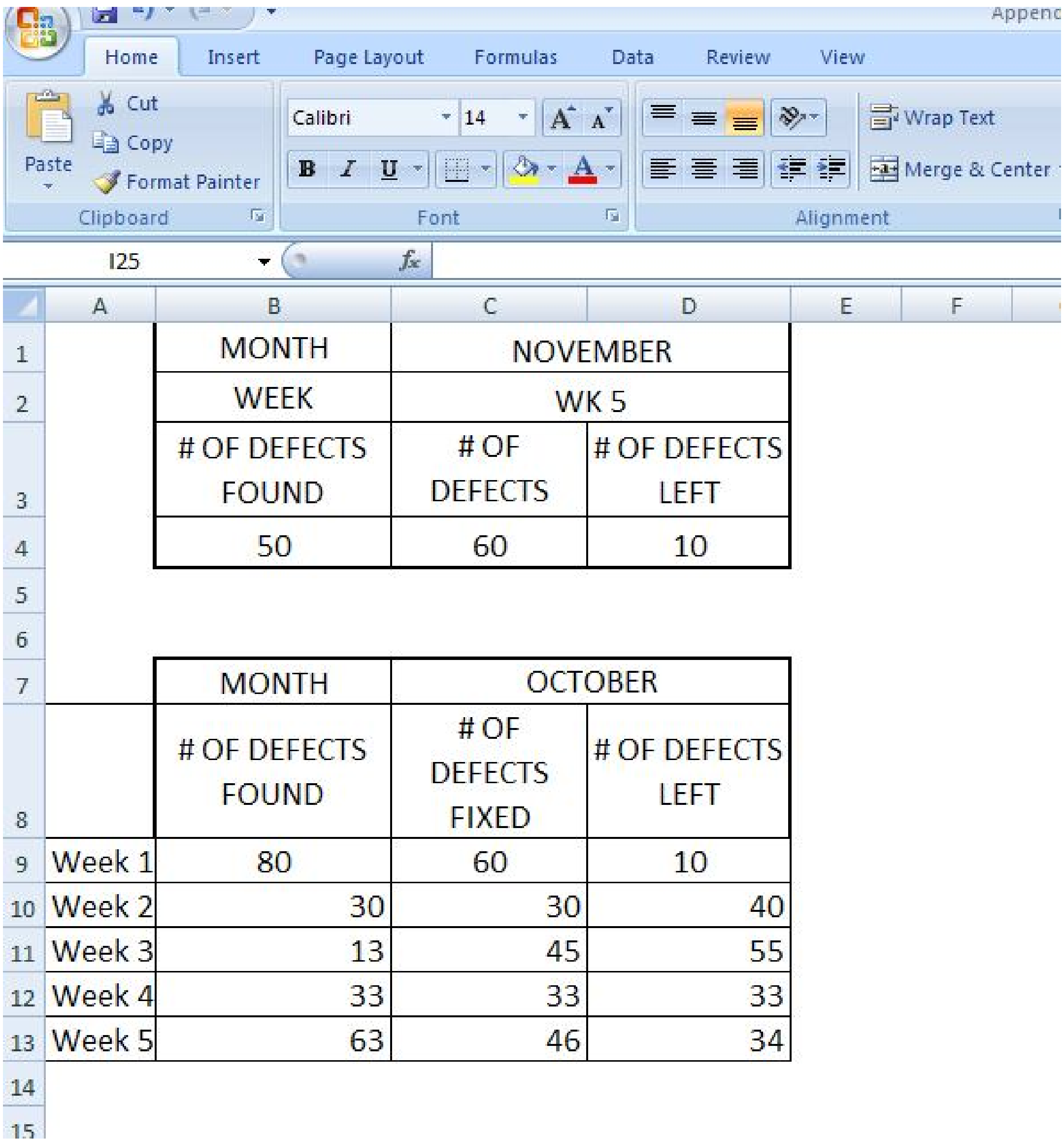
- ✓ To know the amount of defects in the system.
- ✓ To know the amount of unfixed defects in the system.
- ✓ To know the trend at which defects are generated in the system.
- ✓ To set a priority matrix for fixing defects.
- ✓ To reduce the frequency of scheduled inspection that should be embarked upon.
- ✓ To reduce the job of the maintenance team.
- ✓ To determine where a focus improvement process should be adopted.
- ✓ The management to know when the process needs help.

The defect collection sheet in appendix 1 is used at this stage to record the abnormal situation that was noticed; the frequency of occurrence is noted, the defect type description at the bottom of the sheet helps to guide anyone recording the situation to know how to classify the defect.

The defect consolidation worksheet (softcopy) in appendix 2 is used to collate all the data recorded on all the defect collection sheets in the paint laboratory. This helps to archive the records gathered on the field and also makes it easy to refer to them especially when trying to check if a defect has occurred before.

The tracking worksheet (softcopy) in appendix 3 is used to count the number of defects in the system. It helps to know the amount of defects that was found, fixed or left every week. The percentage of fixed defects is also indicated to know if the set goal of fixing a minimum of 85% of found defects per week is achieved or not.

The defect report data input worksheet shown in figure 9 is used to generate graphs to display the weekly and monthly defect situations at a glance (figures 10 and 11).



MONTH	NOVEMBER	
WEEK	WK 5	
# OF DEFECTS FOUND	# OF DEFECTS	# OF DEFECTS LEFT
50	60	10

	MONTH	OCTOBER	
	# OF DEFECTS FOUND	# OF DEFECTS FIXED	# OF DEFECTS LEFT
Week 1	80	60	10
Week 2	30	30	40
Week 3	13	45	55
Week 4	33	33	33
Week 5	63	46	34

Figure 9 The defect report data input worksheet (soft copy)

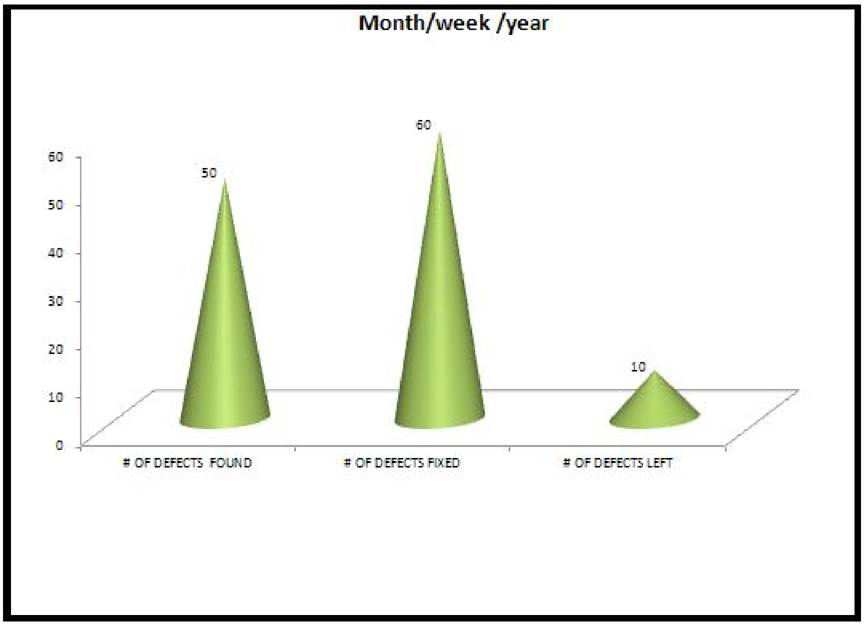


Figure 10 The weekly defect report

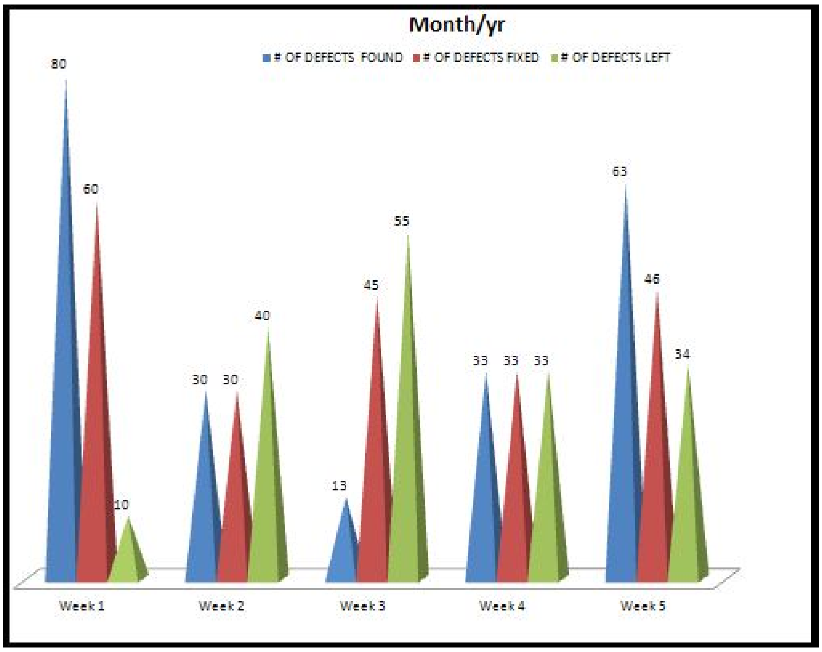


Figure 11 The monthly defect report

"Improper or incomplete collection of data is a fundamental error with an effect that may be magnified many times by subsequent action. Data may be collected in an ad hoc fashion by a quick scan, word of mouth, or even assumption. All of these methods yield unsatisfactory results. A more deliberate method is necessary". (Kenneth 2005, 78.)

In his book, Project quality management, Kenneth 2005, highlighted the tools for collecting project data and four tools for understanding the project data. These tools can also be used for collecting and understanding machine defects data. The check sheet, graphs, histograms, pareto charts, and scatter diagrams are used for collecting and understanding data. Data becomes useless if it is not understood. A good understanding of data helps to find the root cause to the problem.

A check sheet or a collection sheet as it is called in this project is a simple yet powerful tool for collecting data. Using a check sheet involves the following steps as highlighted by Kenneth 2005:

Define events and data. It is important to describe precisely what will be collected and to establish the boundaries of the collection effort. Failure to do this early and well may result in collecting the wrong data, not enough data, or irrelevant data. The business control manager in conjunction with the supervisor defines this to the other employees.

Decide who, what, when, where, how, and why. These aspects of the collection effort are essential to the ultimate success of the system. Determining who collects the data establishes responsibility. What data will be collected is determined by adding details to the definition of events and data in the previous step to prescribe the exact data elements. The "when" and "where" aspects determine the conditions under which the data will be collected. The "how" aspect describes the collection method and specific instructions for use.

Lastly, it is important to establish the reason for collecting the data (the why aspect) so that data collectors may understand the goal and may then respond appropriately to unexpected situations. This is the responsibility of the management. People need to know why they have to do something. Knowing the reason makes them commit to it. This can be done formally through training sessions and also informally in course of "off recording" discussions.

It is expedient that the collection sheet is designed in a clear and easy to use manner. Instructions and terms should be simple. Physical layout should facilitate easy navigation by users and should follow the logical order of the collection sequence of actions.

The above principles have been adopted in this project. On the collection sheet in appendix 1, the defect per specific area is captured under defect location. What is seen is documented. This could be unusual noise, unusual movement, loosed parts, accumulated dirt, wear, smell, unusual heat being generated etc as described in the column: defect type description.

It also includes the dates when the defect was found and when it was fixed and the person that saw the defect and the operator that fixed the defect. This will help to track improvements.

The type of defects column helps to set priority for fixing defects and the status helps to know the unfixed defects remaining in the system.

5.3 A - Analysis

After the defect list has been populated, a root-cause analysis would be conducted to find a lasting solution to the defect.

To conduct a meaningful root cause analysis, we need to understand perfectly how the system works but “merely understanding a process is not a sufficient basis for taking action. Action without analysis is limited to precedent, intuition, trial and error, or guesswork about what the boss wants. None of these approaches is likely to yield happy results. Analysis is necessary to determine the system interaction aspects of the process and cause-effect relationships” (Kenneth 2005, 115.) Analysis is the most critical part of the process. If a wrong analysis is done, it is very certain that a wrong solution will be proffered or the problem might just be compounded. A fourth-eye-check is always necessary to achieve a detailed analysis. In most cases, this may be someone from the management. A very helpful quality tool that is recommended in this project is the **Cause and effect diagram** (figure 9)**.**

If the same type of defect is being regularly captured, it is a sign that our analysis is not addressing the source of problem or the main cause of these defects have not been known.

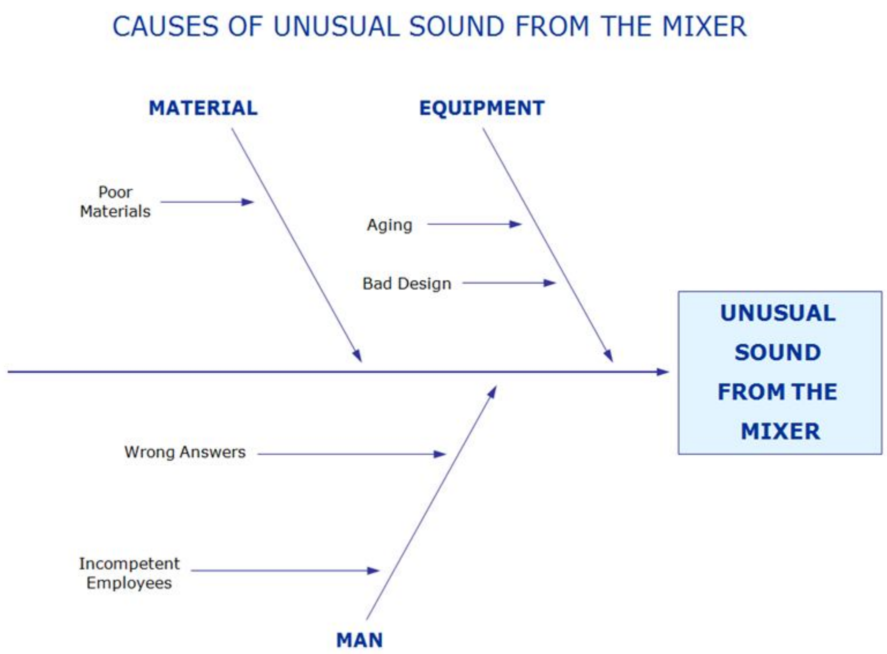


Figure 9 Cause and effect diagram

5.4 Developing cause and effect diagram

Cause and effect diagram: helps to identify, sort, and display possible causes of a specific problem or quality characteristic. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome. "Ishikawa diagram” was invented by Kaoru Ishikawa. It is also called fishbone because of the way it looks (figure 9)

Benefits of a cause and effect diagram:

- ✓ Helps to determine root causes.
- ✓ Encourages group participation.
- ✓ Uses an orderly, easy-to-read format.
- ✓ Indicates possible causes of variation.
- ✓ Increases process knowledge.
- ✓ Identifies areas of focus.

Below are detailed steps on how a cause and effect diagram can be developed in this project (figure 9).

Step 1: Identify and clearly define the outcome or effect to be analyzed - use operational definitions. This is what was noticed or seen as abnormal in the system. Make a clear and concise problem statement.

Step 2: Using a chart-pack positioned so that everyone can see it, draw the spine and create the effect box as shown in figure 9.

Step 3: Identify the main causes contributing to the effect being studied.

Some examples are:

- ✓ 3**M**s and **1P** - **m**ethods, **m**aterials, **m**achinery, and **p**eople
- ✓ 4**P**s - **p**olicies, **p**rocedures, **p**eople, and **p**lant
- ✓ 8**M**s (Manufacturing) - **M**achine (technology), **M**ethod (process), **M**aterial (Raw Material, Consumables and Information.), **M**an Power (physical work)/Mind Power (brain work): Kaizens, Suggestions **M**easurement (Inspection), **M**ilieu/Mother Nature (Environment) , **M**anagement/Money Power & **M**aintenance
- ✓ 8**P**s (Service industry) - **P**roduct=Service, **P**rice, **P**lace, **P**romotion/Entertainment, **P**eople(key person), **P**rocess, **P**hysical Evidence, **P**roductivity & Quality
- ✓ 4**S**s (service industry) – **S**urroundings, **S**uppliers, **S**ystems, **S**kills

Step 4: For each major branch, identify other specific factors which may be the causes of the effect.

Step 5: Identify increasingly more detailed levels of causes and continue organizing them under related causes or categories. You can do this by asking a series of why questions. Keep asking why until a main root cause is identified.

Step 6: - Identify root causes. Review the diagram and identify multiple occurrences of causes. Multiple occurrences indicate a root cause; that is, a single cause that has many instances of effect throughout the process.

Things to note in the process:

- ✓ Look for causes that appear repeatedly. These may represent root causes.
- ✓ Look for what you can measure in each cause so you can quantify the effects of any changes you make.
- ✓ Watch out for simple mistakes, bad training, misunderstandings and cover-ups. Attack the problem and not the people. *There are no bad people but bad habits.*
- ✓ Most importantly, identify and circle the causes that you can take action on.

5.5 I – Improve: Fix the defects through continuous improvement

In this type of industry where paints are mixed, the first step towards any meaningful improvement is the organization of the work place (5S's implementation). Put system in place to avoid mistake in the operation. Everything must have its own place and there should be a place for everything. "5S is a great tool for workplace organization. Just by removing clutter and becoming more organized, you eliminate a large portion of waste. Mistake proofing takes a holistic and customer oriented look at a process and points out areas of risk. Once you know the areas of risk, you can implement actions to mitigate risk." (Stephen, presentation 24.2.2009)

5S's implementation in the mixing room – the 5S's concept was a Japanese model which is: Seiri, Seiton, Seiso, Seiketsu and Shitsuke.

- ✓ Seiri means: organize, systemize, simplify or sort.
- ✓ Seiton means: Set, Systemize, Neatness or set in order.
- ✓ Seiso means: Scrub, Sweep, Clean or Shine
- ✓ Seiketsu means: Standardize, Regulate, Site-wide or Standardization
- ✓ Shitsuke means: Sustain, Embed, Self-discipline or Discipline.

"Whatever substitutes are selected, the bottom-line is that the five S's should combine to make a five-step formal program that introduces, implements, and maintains a clean, safe and clutter-free, and efficient site" (Boris 2006, 154).

For a successful implementation of this project, there is a need to have fixed positions for every apparatus and maintain a very clean environment in the paint laboratory. This will help to reduce the amount of defects that would be recorded and eliminate safety issues.

To implement 5S's in the mixing room:

- ✓ Adopt the "Plan Do Check and Act cycle".
- ✓ Plan the new layout and position of items
- ✓ Have a fixed position for the Sartorius scale and the mixing unit. These positions should be clearly marked and documented in the layout design.
- ✓ Determine a new fixed position for all the apparatus used for mixing. It is important to locate these apparatus very close to the Sartorius scale and the mixing unit.

- ✓ The computer should be located beside the Sartorius scale.
- ✓ Replace the existing chair with a rolling chair
- ✓ The log-book should have a fixed position that is reachable from an arm's length.
- ✓ Install a washing basin in the mixing room.
- ✓ Replace the wool rug with a plastic rug because it is easier and cheaper to clean spilled paint on a plastic rug than on a wool rug.
- ✓ Mark the racks on the mixing unit to indicate which paint should be mixed in each rack.
- ✓ Place a container of thinner on a marked position on the floor to clean-off spilled paint immediately.
- ✓ Unused paints and tints should be returned to storage immediately so as to avoid mix-ups
- ✓ Have a marked position for the trash bin.
- ✓ The toilet should always be clean so as to maintain good working condition and create good impression for the customers.
- ✓ Carry out the actions - Verify that the actions worked and make adjustments, if necessary.
- ✓ Think of simple inexpensive improvements. Think of using pencil to write in the space. Don't spent a decade and $12 Billion to develop a pen that can write in zero gravity, upside down, underwater, on almost any surface including glass and at temperatures ranging from below freezing to 300C. "Don't use an axe to kill a fly".(Nigerian adage) "The simpler the better" (Tuomela 2011, lectures)
- ✓ Start improvement on a small scale, validate, standardize before reapplication on a larger scale.
- ✓ Documents all your actions, *if it is not written, it is not done!*

5.6 C – Control to sustain the improvement

The control starts with checking the status of unfixed defects, providing the needed helps, reporting and tracking actions. (Appendix 6)

The supervisor sends the periodic reports to the business control manager and provides a copy for the other members of the organization. The business control manager monitors the agreed plans and implementations and provides supports and motivation for the team.

After we are done with making improvements, verifying and validating improvements and standardizing the improvements, measures should be put in place to sustain the improvements. These may include periodic audit of the defect management system. "Once you eliminate waste and become lean, implement controls to remain that way. A great control is a 5S audit…..Auditing is nothing more than periodically checking actual practice to standards. If they don't match, action must be taken under the leadership of management." (Stephen, presentation 24.2.2009)

5.7 **Table1** **Explanation of the defect management flow chart**

Flow Chart Explanation			
What	How	Who	When
Roles defined	Who does what is highlighted in this process. Individuals in the organization understand their roles and are given the necessary supports to function. This is highlighted in figure 8	Business control Manager	At the start of the process and continuously
Defect identified	Any activity on the machines is an opportunity to find defects. As such activities like cleaning, operation of the mixer and Sartorius scale. Typically, defects are found by the machine operators but can also be found by others. Defect finding is for everyone. The defect description on the collection sheet in appendix 1 helps to identify defects.	Process operator	Anytime
Log defects in the collection sheet; the frequency of occurrence is noted.	Defect sheets are available in a folder in the paint-mixing room. Everyone who picks up a defect sheet needs to fill in all the data required (good record keeping). Recording of defects should be simple and straight to the point. Check if the defect has occurred before. The collection sheet and the consolidation worksheet on appendixes 1 and 2 are used for this purpose	Process operator	Anytime
Track the number of defects	Prepare the defect reports. The figures are entered into the tracking worksheet in appendix 3 and then transferred to the defect report data input in appendix 4 to generate the weekly and monthly defect report graphs in appendixes 5 and 6.	Supervisor	Weekly/monthly
Analyze, fix and record the defects as fixed on the defect sheet and defect consolidation sheet	Analyze all critical defects to determine the root cause for the defect. In order to be able to understand if the defect can be fixed immediately or not, the person finding the defect should be clear on what is the action to be taken. Sometimes the immediate action will be a temporary solution, while the root-cause elimination will require a deeper analysis. The cause and effect diagram (figure 9) the problem analysis sheet (appendix 4) and the why why sheet (appendix 5) are used for this purpose.	Process operator/ Supervisor	After recording all the details on the defect list
Do we the tools and capability to fix it?	Determine if the needed tools to fix the defects are available and if there is enough capability to fix the defect. Where the team needs help, "HELP NEEDED" should be indicated on the defect consolidation sheet (appendix 2). The business control manager provides the help as soon as she can.	Supervisor/Business control manager	After recording the details on the defect consolidation sheet
Follow up on all outstanding actions	The process operators should always update the defect sheet after the defect has been fixed. The supervisor updates the defect consolidation sheet, sends the periodic reports to the business control manager and provides a copy for the other members of the organization. The business control manager monitors the agreed implementations and provides supports and motivation.	Process operator/Supervisor/ Business control manager	After recording the details on the defect consolidation sheet

In situations where the same types of defects are being capture regularly, it is a sign of problem with the root cause analysis. The procedure of analysis needs to be checked and the actions need to be thoroughly reviewed and a focused improvement needs to be adopted for total eradication of the recurring defect.

6 RECOMMENDATIONS

Using a DMAIC model to manage machine defects is an efficient method of improving product quality, workplace safety and productivity.

Periodic refresher training should be arranged for all employees. Seventy percent of problems are caused by inadequate skills or not enough knowledge with the staff. Refresher training should be on a need-to-have basis and not a nice-to-do basis. If the training does not add value to the overall objectives of the organization, then it is useless. Training should be well focused and practicable. On-the-job training should be well focused and not too casual. When an organization embarks upon adequate training of its employees, the return on investment is always very high though it may not be seen immediately because it is continuous. “A well-trained worker and a well-trained work force are more likely to produce products that conform to specifications. When the organization trains the worker to perform better, it incurs a one-time cost for the training and obtains cost savings from the reduced number of defects produced by the worker as a result of the training. The training pays the organization back…again, and again, and again.” (Kenneth 2005, 10.)

The system should be audited periodically in order to compare performance to plan. Audits have an associated cost, which may recur with every audit. The results of quality audits either show that the quality system is working or not working and must thus be improved. The audit should not be conducted to investigate who is not doing what he or she is supposed to do, but it should be conducted to improve the system and to make the life of the employees better in order to produce happy and loyal customers.

The system should not be a management tool for appraisal. It should not be used either to punish or to praise the workers. This will allow the operators to carry out their actions without fear.

7 CONCLUSION

Analyzing problems helps to get to the root cause of the problems. It engages everyone who is either directly or indirectly associated with the problem area. This helps to proffer meaningful and cost effective solutions. When a problem is well analyzed, the solution to the problem might just be a stone-throw away.

The implementation of this project has a significant value for Business Maniac Ventures. It was an eye opener to the organization. The way work is conducted with the company has improved.

This project could also be useful for other small and medium sized companies that are struggling with similar problems – machine defects.

Through this thesis process, I have gained more knowledge on the lean six sigma manufacturing system, improved my writing skills and the confidence to manage a production/manufacturing company and I am prepared to confront higher challenges in the near future.

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Appendix 1

DEFECT COLLECTION SHEET

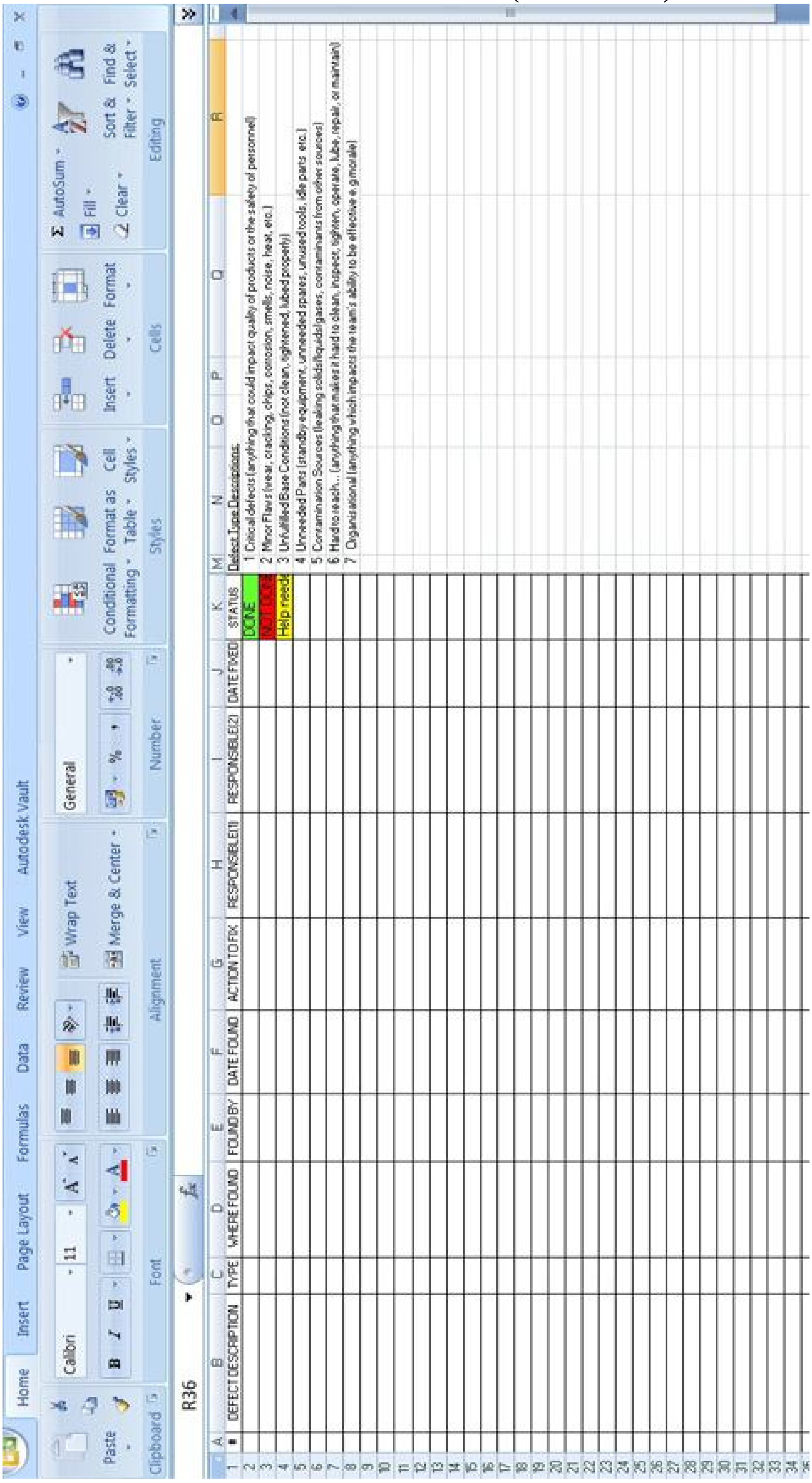
#	Defect location	What did you see?	Date found	Found by	Type of defect							What was done to fix it	Who to fix?	Fixed? Y/N	Fixed date	Status
					1	2	3	4	5	6	7					

Defect Type Descriptions:

1 Critical defects (anything that could impact quality of products or the safety of personnel)
2 Minor Flaws (wear, cracking, chips, corrosion, smells, noise, heat, etc.)
3 Unfulfilled Base Conditions (not clean, tightened, lubed properly)
4 Unneeded Parts (standby equipment, unneeded spares, unused tools, idle parts etc.)
5 Contamination Sources (leaking solids/liquids/gases, contaminants from other sources)
6 Hard to access... (anything that makes it hard to clean, inspect, tighten, operate, lube, repair, or maintain)
7 Organisational (anything which impacts the team's ability to be effective e.g morale)

Appendix 2

DEFECT CONSOLIDATION WORKSHEET (SOFT COPY)



Appendix 3

DEFECT TRACKING WORKSHEET (SOFT COPY)

	MONTH	WEEK	# OF DEFECTS FOUND	# OF DEFECTS FIXED	# OF DEFECTS LEFT	% DEFECT FIXED	# OF DEFECTS FOUND/DAY	# OF DEFECTS FIXED/DAY
2	OCT 11	1	49	45	20	92 %	8	8
3		2				#DIV/0!	0	0
4		3				#DIV/0!	0	0
5		4				#DIV/0!	0	0
6	NOV 11					#DIV/0!	0	0
7						#DIV/0!	0	0
8						#DIV/0!	0	0
9						#DIV/0!	0	0
10	DEC 11					#DIV/0!	0	0
11						#DIV/0!	0	0
12						#DIV/0!	0	0
13						#DIV/0!	0	0
14	JAN 12					#DIV/0!	0	0
15						#DIV/0!	0	0
16						#DIV/0!	0	0
17						#DIV/0!	0	0
18	FEB 12					#DIV/0!	0	0
19						#DIV/0!	0	0
20						#DIV/0!	0	0
21						#DIV/0!	0	0
22						#DIV/0!	0	0
23						#DIV/0!	0	0
24						#DIV/0!	0	0
25						#DIV/0!	0	0
26						#DIV/0!	0	0
27						#DIV/0!	0	0
28						#DIV/0!	0	0
29						#DIV/0!	0	0
30						#DIV/0!	0	0
31						#DIV/0!	0	0
32						#DIV/0!	0	0

Appendix 4

PROBLEM ANALYSIS SHEET

Problem Analysis (Getting to a Focused Problem Statement)
Initial Problem Statement:
1. What? Describe the phenomenon. What did you see?
2. Where? The Transformations/Work Points where critical defect is present:
3. Which? Final product/materials affected:
4. When? Start-up, Normal Operation; When did the problem start?
5. To Whom? Machine that was affected:
1. How? Circumstances of the loss; Failure Mode.
2. How Much? Magnitude: Number, frequency, amount... :
New Refocused Problem Statement: Evaluate the 5W-2H data and update your Problem Statement to be more focused

Appendix 5

ROOT CAUSE ANALYSIS SHEET

Problem	Why 1	Why 2	Why 3	Why 4	Why 5	Root Cause	ACTION	RESPONSIBLE	TARGET DATE

Appendix 6

MONTHLY ANALYSIS REPORT

Defect Analysis Report

JUNE 2011

Add Picture of the reporter

Graph of the Month defect data here!

Top 5 critical defects

Action plans

#	Actions	Responsible	Timing	Status
1				
2				
3				
4				
5				
6				
7				
8				