University of Khartoum
Faculty of Engineering
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Application of “Lean six sigma” Methodology to Improve Quality in COLDAIR Factory

A thesis submitted in partial fulfillment of the requirements for the degree of B.Sc. in Mechanical Engineering

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DEDICATION

We dedicate this research with much love and appreciation;

For all the candles which are always burning to light our way, our lovely mothers.

For our fathers who have always been there for us and from whom we can learn and depend on forever.

For the roses which are making our life more beauty, our brothers and sisters.

For our family, friends, teachers and colleagues
And for everyone that we love.
ACKNOWLEDGEMENTS

At first we thank Allah for his mercy,

We wish to express our deepest gratitude and appreciation for our supervisor Ustaz. Widatalla Alamin Abdullah for his patience and continuous guidance, advice and supervision throughout the course of this work.

And special thanks to the management and staff of COLDAIR Factory for their cooperating and assistance and supplying us with all information that we needed.
Abstract

The main objective of this research is the application of Lean Six Sigma which is a methodology that relies on a collaborative team effort to improve performance by systematically removing waste, to improve the quality in the plastic section of COLDAIR Factory. And its methodology is “Define, Measure, Analyze, Improve and Control”.

The first chapter of research gives general information about Lean Six Sigma and related terms preparing the readers to get overall view.

In second chapter Lean Six Sigma methodology has been discussed scientifically in details, also two case studies that applied “DMAIC” have been written.

The third chapter shows a brief information about COLDAIR Factory and the plastic section. Then the “DMAIC” has been discussed and applied in the plastic section, so the problems were “Defined”, “Measured” what was measurable, “Analyzed” the causes of defects, “Improved” the current situation, and finally “Controlled” the improvement to sustain and maintain the results.

The fourth chapter of the project shows the results at which that the overall equipment effectiveness was improved from “34.75%” to “54.8%” using Lean Six Sigma methodology. The main problems was Heating up, Tools change and Air Drop Down Time and they have been reduced. Also some recommendations have been written to the company, and then all references in this project were picked out.
الملخص

الهدف الرئيسي لهذا البحث هو تطبيق منهجية "6 سيجما قليلة الهدر" في تحسين الجودة لقسم البلاستيكيك في مصنع كولدير، وذلك باستخدام طريقة التعرف والقياس والتحليل والتحسين والضبط. طريقة "6 سيجما قليلة الهدر" هي منهجية تعتمد على الجهود المتضمنة للفرق لتحسين الأداء وذلك بإزالة الهدر.

الفصل الأول لهذا البحث يعطي معلومات عامة عن "6 سيجما قليلة الهدر" والمصطلحات المرتبطة بها، ليعد القراء لأخذ نظرة عامة عن المشروع.

في الفصل الثاني تم مناقشة هذه المنهجية و"6 سيجما" بطريقة علمية وبالتفصيل لجعل القراء أكثر فهماً للمشروع، ووضع دراستان سابقتان استخدمتا نفس المنهجية المستخدمة في هذا البحث.

يوضح الفصل الثالث معلومات مختصرة عن مصنع كولدير وعن قسم البلاستيكيك، وتم مناقشة وتطبيق منهجية التعرف والقياس والتحليل والتحسين والضبط في قسم البلاستيكيك في مصنع كولدير، فُهمت المشاكل الموجودة، وقريب ما يمكن قياسه، وحلت الأسباب والعوامل، فتحسن الوضع الحالي، وتم توطيد ضبط التحسين الذي جرى والنتائج المتحصل عليها.

الفصل الرابع هذا المشروع يوضح النتائج وأن الفعالية الكلية للمعدات تحسنت من "34.75%" إلى "54.8%" باستخدام منهجية "6 سيجما قليلة الهدر"، والمشاكل الأساسية تتمثل في الوقت الضائع في تسخين القوالب وتغيير الأدوات وانخفاض ضغط الهواء مما مثلمتها. أيضاً تم كتابة بعض النصائح للشركة.

ثم وُضعت جميع المراجع التي استخدمت في هذا المشروع.
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<th>Description</th>
</tr>
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<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>QC</td>
<td>Quality control</td>
</tr>
<tr>
<td>DPMO</td>
<td>defects per million opportunities</td>
</tr>
<tr>
<td>O.E.E.</td>
<td>Overall equipment effectiveness</td>
</tr>
<tr>
<td>KPI</td>
<td>key performance indicator</td>
</tr>
<tr>
<td>FMEA</td>
<td>Failure Modes and Effects Analysis</td>
</tr>
<tr>
<td>DT</td>
<td>Down Time</td>
</tr>
<tr>
<td>MCs</td>
<td>Machines</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operation Procedure</td>
</tr>
</tbody>
</table>
CHAPTER 1
1.1 Introduction:

1.1.1 Total Quality Management [1]:

Total Quality Management “TQM” is an approach to management of an organization that integrates the needs of customers with a deep understanding of: the technical details, Costs and Human resource relationship. It has four main components: quality planning, quality control (QC), quality assurance and quality improvement.

Quality management is focused not only on product and service quality, but also on the means to achieve it. Quality management, therefore, uses quality assurance and control of processes as well as products to achieve more consistent quality.

Quality Improvement can be distinguished from Quality Control in that Quality Improvement is the purposeful change of a process to improve the reliability of achieving outcome.

Quality Assurance is the planned or systematic actions necessary to provide enough confidence that a product or service will satisfy the given requirements.

Quality Control is the ongoing effort to maintain the integrity of a process to accomplish the reliability of achieving an outcome.

1.1.2 Notable approaches to Quality Control [2]:

There is a tendency for individual consultants and organizations to name their own unique approaches to quality control, a few of these have ended up in widespread use:

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Approximate year of first use</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical quality control (SQC)</td>
<td>1930s</td>
<td>The application of statistical methods (specifically control charts and acceptance sampling) to quality control.</td>
</tr>
<tr>
<td>Total quality control (TQC)</td>
<td>1956</td>
<td>Popularized by Armand V. Feigenbaum in a Harvard Business Review article and book of the same name. Stresses involvement of departments in addition to production (e.g., accounting, design, finance, human resources, marketing, purchasing, sales).</td>
</tr>
</tbody>
</table>
Statistical process control (SPC) 1960s The use of control charts to monitor an individual industrial process and feedback performance to the operators responsible for that process. Inspired by control systems.

Company-wide quality control (CWQC) 1968 Japanese-style total quality control.

Total Quality Management (TQM) 1985 Quality movement originating in the United States Department of Defense that uses (in part) the techniques of statistical quality control to drive continuous organizational improvement.

Six Sigma (6σ) 1986 Statistical quality control applied to business strategy. Originated by Motorola.

| TABLE 1-1 |

1.1.3 Six Sigma [3]:

Six Sigma is a set of strategies, techniques, and tools for process improvement. It was developed by Motorola in 1981. Six Sigma became famous when Jack Welch made it central to his successful business strategy at General Electric in 1995. Today, it is used in many industrial sectors.

The term "Six Sigma" comes from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO).

Six Sigma's implicit goal is to improve all processes, but not to the 3.4 DPMO level necessarily. Organizations need to determine an appropriate sigma level for each of their most important processes and strive to achieve these. As a result of this goal, it is incumbent on management of the organization to prioritize areas of improvement.

Six Sigma is a registered service mark and trademark of Motorola Inc. As of 2006 Motorola reported over US $17Billion in savings from Six Sigma. Other early adopters of Six Sigma who achieved well-publicized success include Honeywell (previously known
as AlliedSignal) and General Electric, where Jack Welch introduced the method. By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality.

The International Organization for Standards (ISO) has published ISO 13053:2011 defining the six sigma process.

### 1.1.4 Lean Six Sigma

Lean Manufacturing is an operational system that maximizes Value Added and eliminates Waste in all processes throughout the Value Stream.

In recent years, some practitioners have combined Six Sigma ideas with lean manufacturing to create a methodology named “Lean Six Sigma”. The Lean Six Sigma methodology views lean manufacturing, which addresses process flow and waste issues, and Six Sigma, with its focus on variation and design, as complementary disciplines aimed at promoting “business and operational excellence”. Companies such as GE, Verizon, GENPACT, IBM and Sandia National Laboratories use Lean Six Sigma to focus transformation efforts not just on efficiency but also on growth. It serves as a foundation for innovation throughout the organization, from manufacturing and software development to sales and service delivery functions.

Lean Six Sigma is a methodology that relies on a collaborative team effort to improve performance by systematically removing waste; combining lean manufacturing / lean enterprise and Six Sigma to eliminate the eight kinds of waste, they spell TIM WOODS (Transport, Inventory, Motion, Waiting, Over production, Over processing, Defects, Skills).

The Lean Six Sigma concepts were first published in a book titled Lean Six Sigma: Combining Six Sigma with Lean Speed by Michael George and Robert Lawrence Jr. in 2002. Lean Six Sigma utilizes the “DMAIC” phases similar to that of Six Sigma. The Lean Six Sigma projects comprise the Lean’s waste elimination projects and the Six Sigma projects based on the critical to quality characteristics.

The “DMAIC” toolkit of Lean Six Sigma comprises all the Lean and Six Sigma tools. The training for Lean Six Sigma is provided through the belt based training system similar to that of Six Sigma. The belt personnel are designated as white belts, yellow belts, green belts, black belts and master black belts, similar to karate. For each of these belt levels skill sets are available that describe which of the overall Lean Six Sigma tools are expected to be part at a certain Belt level. These skill sets provide a detailed description of the learning elements that a participant will have acquired after completing a training program.

The level upon which these learning elements may be applied is also described. The skill sets reflect elements from Six Sigma, Lean and other process improvement methods like the theory of constraints (TOC) and total productive maintenance (TPM).
1.1.5 Overall equipment effectiveness (O.E.E.) [5]:

Overall equipment effectiveness (O.E.E.) is a hierarchy of metrics developed by Seiichi Nakajima in the 1960s to evaluate how effectively a manufacturing operation is utilized. If for example the cycle time is reduced, the OEE will increase, i.e. more product is produced for less resource.

OEE measurement is also commonly used as a key performance indicator (KPI) in conjunction with lean manufacturing efforts to provide an indicator of success. OEE breaks the performance of a manufacturing unit into three separate but measurable components: Availability, Performance, and Quality.

Each component points to an aspect of the process that can be targeted for improvement. OEE may be applied to any individual Work Center, or rolled up to Department or Plant levels. This tool also allows for drilling down for very specific analysis, such as a particular Part Number, Shift, or any of several other parameters.

It is unlikely that any manufacturing process can run at 100% OEE. Many manufacturers benchmark their industry to set a challenging target; 85% is common.

The Availability portion of the OEE Metric represents the percentage of scheduled time that the operation is available to operate. The Availability Metric is a pure measurement of Uptime that is designed to exclude the effects of Quality, Performance, and Unscheduled Downtime Events. The losses due to wasted availability are called availability losses.

The Performance portion of the OEE Metric (also known as process rate) represents the speed at which the Work Center runs as a percentage of its designed speed. The Performance Metric is a pure measurement of speed that is designed to exclude the effects of Quality and Availability. The losses due to wasted performance are also often called speed losses. In practice it is often difficult to determine speed losses, and a common approach is to merely assign the remaining unknown losses as speed losses.

The Quality portion of the OEE Metric represents the Good Units produced as a percentage of the Total Units Started. The Quality Metric is a pure measurement of Process Yield that is designed to exclude the effects of Availability and Performance. The losses due to defects and rework are called quality losses.
1.2 Details of the project:

1.2.1 Problem statement:

There was some problems in the quality and productivity of the “plastic” section in COLDAIR Factory, these problems were appeared when the O.E.E. (Overall equipment effectiveness) which is an indicator to the success of a manufacturing process was calculated, and based on data from Jul-2014 to Dec-2014 the O.E.E. was 34.75% when the international standard value is “85%”.

1.2.2 Objectives:

The objective of this project is to improve the quality by increasing the O.E.E. from 34.75% to be double “69.5%” at the end of June-2015.
1.2.3 Methodology:

The methodology used in this project is Six Sigma project methodology "DMAIC".

![DMAIC Roadmap](image)

1.2.4 Project Plan:

Deadlines for each Phase:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Starting</th>
<th>Ending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define</td>
<td>3 week in Jan.</td>
<td>2 week in Feb.</td>
</tr>
<tr>
<td>Measure</td>
<td>3 week in March.</td>
<td>1 week in April.</td>
</tr>
<tr>
<td>Analyze</td>
<td>2 week in April.</td>
<td>3 week in April.</td>
</tr>
<tr>
<td>Improve</td>
<td>4 week in April.</td>
<td>1 week in May.</td>
</tr>
<tr>
<td>Control</td>
<td>2 week in May.</td>
<td>2 week in June.</td>
</tr>
</tbody>
</table>

TABLE 1-3
1.2.5 **Scope:**

This project will be implemented in the "plastic" section of COLDAIR Factory.
2.1 Six sigma [6]:

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes.

The term Six Sigma originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a sigma rating indicating its yield or the percentage of defect-free products it creates. A six sigma process is one in which 99.9999998% of the products manufactured are statistically expected to be free of defects (0.002 defective parts/million), this defect level corresponds to only a 4.5 sigma level. Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a by-word for the management and engineering practices used to achieve it.

<table>
<thead>
<tr>
<th>Sigma</th>
<th>Defects</th>
<th>Yield</th>
<th>DPMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69.1%</td>
<td>30.9%</td>
<td>691,462</td>
</tr>
<tr>
<td>2</td>
<td>30.8%</td>
<td>69.1%</td>
<td>308,538</td>
</tr>
<tr>
<td>3</td>
<td>6.7%</td>
<td>93.3%</td>
<td>66,807</td>
</tr>
<tr>
<td>4</td>
<td>0.62%</td>
<td>99.38%</td>
<td>6,210</td>
</tr>
<tr>
<td>5</td>
<td>0.02%</td>
<td>99.977%</td>
<td>233</td>
</tr>
<tr>
<td>6</td>
<td>0.0003%</td>
<td>99.9997%</td>
<td>3.4</td>
</tr>
</tbody>
</table>

TABLE 2-1

Features that set Six Sigma apart from previous quality improvement initiatives include:
- A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project.
- An increased emphasis on strong and passionate management leadership and support.
- A special infrastructure of "Champions", "Master Black Belts", "Black Belts", "Green Belts", etc. to lead and implement the Six Sigma approach.
- A clear commitment to making decisions on the basis of verifiable data and statistical methods, rather than assumptions and guesswork.
2.2 Methods used in Six sigma projects [7]:

According to “Vinay T. Belagala”, a famous Marketing Analyst, Six Sigma projects follow two project methodologies inspired by Deming’s “Plan-Do-Check-Act” Cycle. These methodologies, composed of five phases each, bear the acronyms “DMAIC” and “DMADV”.
• DMAIC is used for projects aimed at improving an existing business process.
• DMADV is used for projects aimed at creating new product or process designs.

2.2.1 DMAIC [8]:

The DMAIC project methodology has five phases:
• Define the system, the voice of the customer, and the project goals, specifically.

• Measure key aspects of the current process and collect relevant data.

• Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.

• Improve or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.

• Control the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

Some organizations add a Recognize step at the beginning, which is to recognize the right problem to work on, thus yielding an RDMAIC methodology.
2.3 Lean manufacturing [4]:-

Lean manufacturing, lean enterprise, or lean production, often simply, "Lean", is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for.

In these difficult financial times organizations need to be looking for every opportunity to reduce costs and become more competitive. Fortunately a methodology, known as Lean Six Sigma, exists that can help us achieve this end.

Lean Six Sigma has been shown to significantly reduce costs by speeding up the flow of materials and information through processes as well as improving the quality of the products produced by the process. Organizations have successfully used Lean Six Sigma around the world to significantly improve a wide variety of processes in many different cultures.

Lean Six Sigma is designed to help you learn how to identify ways to improve efficiency within your business processes in order to provide a higher level of productivity with the staff and with the products.

The main target of every company is to generate Profit:

![Profit Diagram](image)

FIGURE 2-1
2.4 Seven Quality Tools [9]:

7 Quality Tools are seven tools that used to improve the processes, the next figure shows these tools:

![The 7 Quality Tools for Process Improvements](image1)

FIGURE 2-2

2.4.1 Fishbone Diagram [9]:

The fishbone diagram is a cause-and-effect diagram that can be used to identify the potential (or actual) cause(s) for a performance problem. Fishbone diagrams provide a structure for a group’s discussion around the potential causes of the problem.

![Fishbone Diagram](image2)

FIGURE 2-3
2.4.2 Pareto Chart [9]:

A Pareto chart is a bar and line chart that displays data in a hierarchical order identifying where any given problem occurs most frequently.

The objective of a Pareto chart is to identify the 20% of the places that account for 80% of the problem. Pareto identified that problems are not evenly distributed, and there is commonly an 80:20 rule (the data won’t be exactly 80:20).

A Pareto chart will enable resources to be targeted at the 20% of the wards with 80% of the problem resulting in the greatest gains for quality improvement.

The bars display the number of events per area of interest. The line displays the cumulative % of events, i.e. the percentage of each bar added onto the next together. So the bigger numbers will have a greater percentage impact.

2.5 Failure Modes and Effects Analysis [10]:-

Failure Modes and Effects Analysis (FMEA) is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures, in order to identify the parts of the process that are most in need of change.

2.6 Eight Wastes of Lean [11]:-

An easy way to describe the wastes, they spell TIM WOODS.

- T – Transport: Moving people, products & information.
- I – Inventory: Storing parts, pieces, documentation ahead of requirements.
- M – Motion: Bending, turning, reaching, and lifting.
- W – Waiting: For parts, information, instructions, equipment.
- O – Over production: Making more than what is immediately required.
- O – Over processing: Tighter tolerances or higher grade materials than are necessary.
- D – Defects: Rework, scrap, incorrect documentation.
- S – Skills: Under-utilizing capabilities, delegating tasks with inadequate training.

2.7 Five S [12]:-

5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.

The 5S pillars, Sort, Set in Order, Shine, Standardize, and Sustain. That provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment.
2.8 **Five Whys**[^13]:

5 Whys is an iterative question-asking technique used to explore the cause and effect relationships underlying a particular problem. The primary goal of the technique is to determine the root cause of a defect or problem by repeating the question “Why?”. Each question forms the basis of the next question. The "5" in the name derives from an empirical observation on the number of iterations typically required to resolve the problem.

The method provides no hard and fast rules about what lines of questions to explore, or how long to continue the search for additional root causes. Thus, even when the method is closely followed, the outcome still depends upon the knowledge and persistence of the people involved.

![Diagram of Five Whys Process](source: Example Image)

**FIGURE 2-4**

2.9 **previous studies used “Lean Six Sigma”:**

2.9.1 **Using Lean Six Sigma to Improve Call Center Operations**[^14]:

Employees knew that the service in their third-party call center had deteriorated in recent years. Their job was to handle queries from independent business owners about financial services offered by the call center’s client. As in many call centers, the job was considered highly stressful because of expected response times and resolution.

Initially, no one at the call center knew exactly how bad the problem was – all they knew was that the client was considering canceling the contract. While certain data were collected (time that representatives were available to answer calls, hold time, etc.), there were no data connected to the goals of resolving 75 percent of the inquiries the first time around (first-call resolution) and 90 percent of inquiries within five days (five-day resolution). Furthermore, unknown to the call center, a key decision maker at the client was taking data on how many calls she received each week from people who were -
unable to get answers from the call center. The number of these so called escalated calls had grown to a mean of 15 per week.

When faced with this kind of problem, many companies just lay off staff in an attempt to increase productivity of the remaining group, hire more staff without solving the underlying problem or try to improve results by forcing people to be on the phone more. This company took a different tack: They turned to a “Lean Six Sigma” expert for help with the goal of improving performance to a level that the client would find acceptable, and thereby assuring renewal of the contract.

**Actions:**

To better meet the needs of the process, the work unit decided to:

Split the team into two sections: Part of the staff would only take calls, and the rest would do the research to resolve the issues.

Representatives would rotate through the two groups, with daily metrics designed for success, collected individually and reported in a central location. Significant drops in first-call resolution now immediately trigger follow-up action.

Have the IT “Information Technology” staff set up the computer system to use an unused field in the screens to capture research information and notes, leading to the ability to monitor not only the issues needing research, but also the age of those issues.

Forward any calls that were not resolved within four days to management for action.

**Results:**

Within weeks, the first-call resolution rate rose to from 50 percent to 90 percent and the five-day resolution rate rose from 62 percent to 98 percent. Equally important, the secret escalated calls metric that the client was keeping on how many calls she got per week dropped from 15 per week to less than 1 per month.

### 2.9.2 Application of Lean Six Sigma to Libraries (Jaykar library at Pune University India)

Jayakar Library started to implement applications of Six Sigma process in 2007. After explaining the concept to all as to what Six Sigma means, its scope was explained to all i.e. the difficulties that come up daily to the library and the readers were noted down. Thereafter, assessment i.e. as to how many definite difficulties and which section of the library is need to improve is decided and discussed with staff and requested them to came up with ideas and solutions to solve the difficulties and solutions were obtained in the meet and planning in phased manner was work out to implement the solutions to improve the system and order was given to staff for implementation. For research being a study and as researcher was not working in Jayakar Library, the work of suggestions -
and helped in reducing the difficulties that came up. When DMAIC process was started 86 difficulties from all divisions came up after discussion with readers and employees.

These difficulties were divided in 3 groups:
1. In the context of quality.
2. In the context of management.
3. In the context of other departments.

Such types of difficulties are narrated below:
While preparing the ‘Reference’ list, many mistakes were noticed and they were nearly 20%. In this context after discussing with employees and respected persons in library, these difficulties, have been reduced, and came to- 10%. Therefore, there was control on the reader’s time saving which was wasted in finding the information required by them. Similarly, because of accuracy of information it was difficult to search and made available to readers and since readers were asking for the same information again and again, employees’ time was also wasted. Moreover, there was control on facing the anger on all matters of the readers.

While searching the catalogue of the books in the library those 40% of the difficulties that arises, after providing solutions to these difficulties, they were reduced to 20%. It was brought to the notice of the employees as to how and how many mistakes took place while cataloguing the documents. There was control on mistakes that would emerge. While doing so, the difficulties did not diminish all at once, but there was successes in reducing these difficulties slowly and steadily in 1 and 1/2 years, and as books are properly shelved to their proper places as per classification scheme adopted by the library so that they were easily available to readers.

Soft Skill & 5s Audit - Training to employees in Jayakar Library in Soft Skill & 5s Audit have been provided to update their knowledge and improve their spoken ability. This has definitely beneficial to all.

While issuing books as per demand of the readers from reference division the percentage of giving wrong books was 10%. That also is being reduced. Since selection of experts in this subject in the reference division is made, the efforts are being made to give guidance to new class and to accomplish the demand of the readers according to their desire.
3.1 A brief notes about Coldair Engineering Company Limited:

The company began in 1935 to repair a small broken refrigerator.

In 1941 it became a Workshop in the name of “Dar-Eltabreed”.

In 1952 it moved to the industrial area in Khartoum and established the first factory for the production of air conditioners in Sudan and water coolers, refrigerators for bananas and fruits.

In 1959, the company opened a showroom and administrative office on “Zubayr Basha” Street in Khartoum to exercise its marketing of refrigerators (Leonard) in Sudan in addition to its products.

In 1960 the factory at the industrial area in Khartoum moved to the current location at the industrial area in Khartoum North, where the production of household refrigerators as well as air coolers (air conditioners) and water coolers and refrigerators for bananas and fruits.

In 2004 the company started to produce refrigerators “Deep-freezers”.

The products offered by the company:

1\ refrigerators in the following sizes (8,10,12,14) feet.

2\ refrigerators “Deep-freezers” in the following sizes (10,12,14) feet.

3\ air coolers (air conditioners) 3000 to 4000 Btu/hr that was requested to its efficiency.

4\ Water Coolers sizes (15,20,25) gallons to serve schools, factories, companies, clubs, etc.

5\ commercial refrigerators for shops and supermarkets and cafeterias.

The company provides maintenance and spares by a team of skilled technicians and specialists with original spares parts and high efficiency.

COLDAIR products based on more than 40 years of experience and quality, with good prices and 5 years of warranty service under conditions of normal use.
3.2 Plastic section:

- Starts at: main store material supply.
- Ends at: assembling line.

![Diagram showing material flow from main store material supply to assembling line.]

**FIGURE 3-1**

3.3 Methodology:

The project methodology “DMAIC” is a logical and structured approach to problem solving and process improvement, which has five phases:

3.3.1 Define:

This phase was focused on defining the specific goals to achieve outcomes, consistent with customers’ demand and business strategy. Also described the problem quantifiably and the underlying process to determine how performance would be measured.

Voice of the customer (VOC) is a term used in business and Information Technology refers to a process or program designed to capture customers' preferences and opinions, analyze them to gain new business insights, and then share them to create meaningful change.
The Customer of the Project is the Production Line. The voice of the customer is shown by the next table:

### Voice of Customer

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Who is the customer?</th>
<th>What customer said (Voice of Customer)</th>
<th>What is the need?</th>
<th>When is the need felt?</th>
<th>Where is the need felt?</th>
<th>Why is the need felt?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plastic section</td>
<td>The plastic section MCs OEE 34% and it is very low when comparing with world class (85%)</td>
<td>improve the OEE plastic section MCs</td>
<td>By the end of Dec. 2014</td>
<td>Plastic section Machines</td>
<td>The plastic section MCs OEE 34% and it is very low when comparing with world class (85%)</td>
</tr>
</tbody>
</table>

TABLE 3-1

In this project, data have been collected for the previous six months of the project start (since July, 2014). The data have been collected to all section’s machines which are six machines. The next tables shows these data:

1. **Machine: GIESS 1 (cycle time 4.5 minutes/unit):**

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14CF CABINET LINER - FORMED</td>
<td>10</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>12CF CABINET LINER - FORMED</td>
<td>225</td>
<td>38</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>10CF CABINET LINER - FORMED</td>
<td>256</td>
<td>9</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>10SD/14DD DOOR LINER – FORMING</td>
<td>3300</td>
<td>66</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>10SD CABIENT LINER – FORMING</td>
<td>572</td>
<td>10</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>12SD CABIENT LINER – FORMING</td>
<td>4313</td>
<td>58</td>
<td>315</td>
<td></td>
</tr>
<tr>
<td>12SD DOOR LINER – FORMING</td>
<td>3679</td>
<td>89</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>12/14DD CF FREEZER DOOR LINER</td>
<td>90</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12DD CABINET LINER - FORMED</td>
<td>148</td>
<td>7</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>12/14DD SKD DOOR LINER - FORMED</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10DD SKD DOOR LINER - FORMED</td>
<td>466</td>
<td>35</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>10/12DD SKD FREEZER DOOR LINER</td>
<td>1906</td>
<td>70</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>14DD SKD DOOR LINER - FORMED</td>
<td>770</td>
<td>28</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>12/14DD SKD CABIENT LINER - FORMED</td>
<td>47</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10DD SKD CABIENT LINER - FORMED</td>
<td>111</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td>1211</td>
<td>576</td>
</tr>
</tbody>
</table>

TABLE 3-2
### Machine: GIESS 2 (cycle time 4.5 minutes/unit):

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14CF CHEST FREEZER CABINET LINER</td>
<td>68</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>14CF DOOR LINER CHEST FREEZER</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10SD/14DD DOOR LINER - FORMING</td>
<td>378</td>
<td>20</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>14SD DOOR LINER - FORMING</td>
<td>1197</td>
<td>17</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>10SD CABINET LINER - FORMING</td>
<td>3099</td>
<td>34</td>
<td>188</td>
<td></td>
</tr>
<tr>
<td>12SD CABINET LINER - FORMING</td>
<td>2645</td>
<td>43</td>
<td>228</td>
<td></td>
</tr>
<tr>
<td>12SD DOOR LINER - FORMING</td>
<td>2942</td>
<td>38</td>
<td>157</td>
<td></td>
</tr>
<tr>
<td>14SD CABINET LINER - FORMING</td>
<td>1363</td>
<td>17</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>14DD CABINET LINER - FORMED</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12/14DD SKD DOOR LINER - FORMED</td>
<td>2186</td>
<td>38</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>10DD SKD DOOR LINER - FORMED</td>
<td>224</td>
<td>9</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>12/14DD SKD CABINET LINER</td>
<td>1884</td>
<td>32</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>10DD SKD CABINET LINER - FORMED</td>
<td>594</td>
<td>39</td>
<td>36</td>
<td></td>
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<tr>
<td><strong>Total:</strong></td>
<td><strong>1033</strong></td>
<td><strong>590</strong></td>
<td>1033</td>
<td>590</td>
</tr>
</tbody>
</table>

### Machine: BM BIRAGHI 125 (cycle time 6.5 minutes/unit):

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/10/14/12CF DOOR HANDLE BASE</td>
<td>940</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>8/10/14/12CF DOOR HANDLE COVER</td>
<td>940</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>DRIP TRAY TOP FLAPPER – WHITE</td>
<td>11078</td>
<td>6</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>SWITCH BOX – FORMING</td>
<td>8416</td>
<td>2</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>DOOR LOCK COVER – FORMING</td>
<td>8339</td>
<td>10</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>MOBILE LOCK COVER FOR REF.</td>
<td>3200</td>
<td>0</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>DOOR ANGULAR RIGHT – FOR NEW REF.</td>
<td>20597</td>
<td>0</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>DOOR ANGULAR LEFT – FOR NEW REF.</td>
<td>20597</td>
<td>0</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>398</strong></td>
<td><strong>16</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**TABLE 3-3**

**TABLE 3-4**
### 4. Machine: BM BIRAGHI 720 NEW (cycle time 0.9 minutes/unit):

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVAPORATOR FRAME – FORMING</td>
<td>2713</td>
<td>23</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>EVAPORATOR DOOR PANEL (COVER)</td>
<td>3120</td>
<td>23</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>EVAPORATOR DOOR MOULDING</td>
<td>3748</td>
<td>8</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>DRIP TRAY TOP – FOR NEW REF.</td>
<td>6240</td>
<td>50</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>EGG RAIL – FOR NEW REF.</td>
<td>8014</td>
<td>17</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>BOTTLE RAIL – FOR NEW REF.</td>
<td>3722</td>
<td>24</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>DIRY DOOR – FOR NEW REF.</td>
<td>7540</td>
<td>39</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>PLINTH – FOR NEW REF.</td>
<td>12559</td>
<td>71</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>CRISPER PAN – FOR NEW REF.</td>
<td>8753</td>
<td>63</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>CRISPER PAN TOP – FOR NEW REF.</td>
<td>3224</td>
<td>29</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>651</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**TABLE 3-5**

### 5. Machine: BM BIRAGHI 720 OLD (cycle time 0.9 minutes/unit):

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total Time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVAPORATOR FRAME-FORMING</td>
<td>9421</td>
<td>117</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>EVAPORATOR DOOR PANEL (COVER)</td>
<td>8649</td>
<td>105</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>EVAPORATOR DOOR MOULDING-FORMING</td>
<td>6679</td>
<td>62</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>DRIP TRAY TOP-FOR NEW REF.</td>
<td>5104</td>
<td>65</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>EGG RAIL-FOR NEW REF.</td>
<td>27274</td>
<td>135</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>BOTTLE RAIL-FOR NEW REF.</td>
<td>8784</td>
<td>96</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>DIRY DOOR-FOR NEW REF.</td>
<td>5420</td>
<td>29</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>CRISPER PAN TOP-FOR NEW REF.</td>
<td>8512</td>
<td>153</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>746</strong></td>
<td><strong>83</strong></td>
</tr>
</tbody>
</table>

**TABLE 3-6**
6. Machine: BM BIRAGHI 100 (cycle time 0.65 minutes/unit):

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Produced</th>
<th>Scrap</th>
<th>Total Time (h)</th>
<th>D.T (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIAL CLAMP-FORMING</td>
<td>6425</td>
<td></td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>LOCK PLATE FOR REF &amp; CHEST FREE</td>
<td>2400</td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>LOCK SUPPORT FOR REF &amp; CHEST FR</td>
<td>2200</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>LOCK BOTTOM FOR CHEST FREEZER</td>
<td>1900</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>8/10/12/14 CF DOOR HANDLE BASE-N</td>
<td>4506</td>
<td></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>8/10/12/14 CF DOOR HANDLE COVER-</td>
<td>4506</td>
<td>20</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>SWITCH BOX-FORMING</td>
<td>2920</td>
<td>3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>THERMOSTAT BOX-FORMING</td>
<td>13870</td>
<td>15</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>CONTROL KNOB FOR NEW REF.</td>
<td>10152</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>DOOR LOCK SUPPORT-FORMING</td>
<td>11351</td>
<td>2</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>LAMP COVER-FOR NEW REF.</td>
<td>9066</td>
<td>8</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>HANDLE BASE – FOR NEW REF.</td>
<td>8304</td>
<td>4</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>HANDLE COVER – FOR NEW REF.</td>
<td>6614</td>
<td>4</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>DOOR LOCK COVER – FORMING</td>
<td>3196</td>
<td>3</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>SUCTION PIPE PASSAGE-FORMING</td>
<td>13242</td>
<td>68</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>MOBILE LOCK COVER FOR REF.</td>
<td>6542</td>
<td></td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Total:                             | 632      | 22    |                |         |

TABLE 3-7
**Down time Summary Report:**

**Section: Plastic**

<table>
<thead>
<tr>
<th>Machine</th>
<th>Downtime Type</th>
<th>hr</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIESS 1</td>
<td>Mechanic</td>
<td>36</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Air Drop</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>NEC POWER OFF</td>
<td>49</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Tools Change</td>
<td>92</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>296</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>STOCKTAking</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>Other</td>
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<td>0</td>
</tr>
<tr>
<td>GIESS 2</td>
<td>Mechanic</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>26</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Air Drop</td>
<td>78</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>NEC POWER OFF</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Tools Change</td>
<td>98</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>281</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>STOCKTAking</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>BM BIRAGHI 100</td>
<td>Tools Change</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>BM BIRAGHI 720 OLD</td>
<td>Mechanic</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>NEC POWER OFF</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Tools Change</td>
<td>67</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>BM BIRAGHI 125</td>
<td>Tools Change</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>BM BIRAGHI 720 NEW</td>
<td>Mechanic</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>NEC POWER OFF</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Tools Change</td>
<td>81</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Heating Up</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**TABLE 3-8**
Then we calculate the Overall Equipment Effectiveness (O.E.E.) for all section's machines, which consists of:

1 - Availability percentage (A%).
2 - Performance percentage (P%).
3 - Quality percentage (Q%).

The world class maximum O.E.E. is 85%, so we always try to reach near this percentage.

1- Availability (A):

1\ We have two shifts in day (for six days in week):

Day shift = 10 hr

Night shift = 12 hr

So the total day shift time = 10 + 12 = 22 hr

Total day shift time = 22 * 60 = 1320 minutes

2\ Planned Down-time (minutes):

We always try to reduce this time, but we can’t eliminate it.

DT ≡ Down-time.

3\ Run time (minutes):

Run time is the time which the engine must be run in.

Run time = total shift – planned DT

4\ unplanned Down-Time:

We always try to eliminate this time.
5\ Net operating time:
Net operating time is the real working (Running) time for the engine.
Net operating time = Run time - unplanned DT

6\ Availability percentage (A%):

\[ A\% = \frac{\text{Net operating time}}{\text{Run time}} \times 100\% \]

2- Performance (P):

1\ Process amount:
Process amount is the total units produced.

2\ Lead time:
Lead time is the time for producing one unit. We design the engine according to the design lead time.

3\ Performance percentage (P%):

\[ P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} \times 100\% \]

3- Quality (Q):

1/ Scrap:
Scrap is the total rejected units.

2\ Quality percentage (Q%):

\[ Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) \times 100\% \]

\[ O.E.E. = A\% \times P\% \times Q\% \]
Calculations:

\[ a \equiv \text{Total shift time.} \]
\[ b \equiv \text{Total Planned DT.} \]
\[ c \equiv \text{Total Run time.} \]
\[ d \equiv \text{unplanned DT.} \]
\[ e \equiv \text{Net operating time.} \]
\[ g \equiv \text{Process amount.} \]
\[ h \equiv \text{Lead time.} \]
\[ j \equiv \text{Total scrap.} \]

We have 6 month (from 1\textsuperscript{st} July to 31\textsuperscript{st} December), so the total days is 184 day, and the total working days is 158 day (26 Fridays).

Total shift time = 1320 \times 158 = 208560 \text{ minutes}

Planned DT for each day = 2.5 hr = 2.5 \times 60 = 150 \text{ minutes}

Total Planned DT = 150 \times 158 = 23700 \text{ minutes}

Run time = total shift – planned DT
\[ c = a - b = 208560 - 23700 = 184860 \text{ minutes} \]

1\textsuperscript{st} For Machine: GIESS 1:

Process amount = total produced = 15903 units

Total scrap = 455 units

Total unplanned DT = 576 hr = 576\times60 \text{ min} = 34560 \text{ minutes}
1- **Availability:**

\[ c = 184860 \text{ minutes} \]
\[ d = 34560 \text{ minutes} \]

Net operating time = Run time - unplanned DT

\[ e = c - d = 184860 - 34560 = 150300 \text{ minutes} \]

\[ A\% = \frac{\text{Net operating time}}{\text{Run time}} \times 100\% \]

\[ A\% = \frac{e}{c} = \frac{150300}{184860} \times 100\% = 81.30\% \]

2- **Performance:**

Process amount = total produced = 15903 units

Lead time = 4.5 minutes/unit

\[ P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} \times 100\% \]

\[ P\% = \frac{h \times g}{e} = \frac{4.5 \times 15903}{150300} \times 100\% = 47.61\% \]

3- **Quality:**

Total scrap = 455 units

\[ Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) \times 100\% \]

\[ Q\% = 1 - \frac{j}{g} = 1 - \frac{455}{15903} \times 100\% = 97.14\% \]

\[ O.E.E. = A\% \times P\% \times Q\% \]

\[ O.E.E. = 81.30\% \times 47.61\% \times 97.14\% = 37.60\% \]
2\ For Machine: GIESS 2:

Process amount = total produced = 16614 units

Total scrap = 292 units

Total unplanned DT = 576 hr = 590 \times 60 \text{ min} = 35400 \text{ minutes}

1- Availability:

\( c = 184860 \text{ minutes} \)

\( d = 35400 \text{ minutes} \)

Net operating time = Run time - unplanned DT

\( e = c - d = 184860 - 35400 = 149460 \text{ minutes} \)

\[
A\% = \frac{\text{Net operating time}}{\text{Run time}} \times 100\%
\]

\[
A\% = \frac{e}{c} = \frac{149460}{184860} \times 100\% = 80.85\%
\]

2- Performance:

Process amount = total produced = 16614 units

Lead time = 4.5 minutes/unit

\[
P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} \times 100\%
\]

\[
P\% = \frac{h \times g}{e} = \frac{4.5 \times 16614}{149460} \times 100\% = 50.02\%
\]

3- Quality:

Total scrap = 455 units

\[
Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) \times 100\%
\]

\[
Q\% = 1 - \frac{j}{g} = 1 - \frac{292}{16614} \times 100\% = 98.24\%
\]

\[
O.E.E. = A\% \times P\% \times Q\%
\]

\[
O.E.E. = 80.85\% \times 50.02\% \times 98.24\% = 39.73\%
\]
3. For Machine: BM BIRAGHI 125:

Process amount = total produced = 74107 units
Total scrap = 22 units
Total unplanned DT = 16 hr = 16*60 min = 960 minutes

1. Availability:
c = 184860 minutes
d = 960 minutes
Net operating time = Run time - unplanned DT
e = c - d = 184860 - 960 = 183900 minutes

\[
A\% = \frac{\text{Net operating time}}{\text{Run time}} * 100\%
\]

\[
A\% = \frac{e}{c} = \frac{183900}{184860} * 100\% = 99.48\%
\]

2. Performance:
Process amount = total produced = 15903 units
Lead time = 6.5 minutes/unit

\[
P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} * 100\%
\]

\[
P\% = \frac{h \times g}{e} = \frac{0.65 \times 74107}{183900} * 100\% = 26.19\%
\]

3. Quality:
Total scrap = 22 units

\[
Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) * 100\%
\]

\[
Q\% = 1 - \frac{j}{g} = 1 - \frac{22}{74107} * 100\% = 99.97\%
\]

\[
O.E.E. = A\% \times P\% \times Q\%
\]

\[
O.E.E. = 99.48\% \times 26.19\% \times 99.97\% = 26.04\%
\]
4. **For Machine: BM BIRAGHI 720 NEW:**

Process amount = total produced = 95633 units

Total scrap = 347 units

Total unplanned DT = 100 hr = 100*60 min = 6000 minutes

**1- Availability:**

c = 184860 minutes

d = 6000 minutes

Net operating time = Run time - unplanned DT

e = c - d = 184860 - 6000 = 178860 minutes

\[
A\% = \frac{\text{Net operating time}}{\text{Run time}} \times 100%
\]

\[
A\% = \frac{e}{c} = \frac{178860}{184860} \times 100\% = 96.75\%
\]

**2- Performance:**

Process amount = total produced = 59633 units

Lead time = 0.9 minutes/unit

\[
P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} \times 100\%
\]

\[
P\% = \frac{h \times g}{e} = \frac{0.9 \times 59633}{178860} \times 100\% = 30.01\%
\]

**3- Quality:**

Total scrap = 347 units

\[
Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) \times 100\%
\]

\[
Q\% = 1 - \frac{j}{g} = 1 - \frac{347}{59633} \times 100\% = 99.42\%
\]

\[O.E.E. = A\% \times P\% \times Q\%\]

\[O.E.E. = 96.75\% \times 30.01\% \times 99.42\% = 28.87\%\]
5\ For Machine: BM BIRAGHI 720 OLD:

Process amount = total produced = 80043 units

Total scrap = 762 units

Total unplanned DT = 83 hr = 83*60 min = 4980 minutes

1- Availability:
c = 184860 minutes
d = 4980 minutes

Net operating time = Run time - unplanned DT
e = c – d = 184860 – 4980 = 179880 minutes

\[ A\% = \frac{\text{Net operating time}}{\text{Run time}} \times 100\% \]

\[ A\% = \frac{e}{c} = \frac{179880}{184860} \times 100\% = 97.31\% \]

2- Performance:
Process amount = total produced = 80043 units

Lead time = 0.9 minutes/unit

\[ P\% = \frac{\text{Lead time} \times \text{Process amount}}{\text{Net operating time}} \times 100\% \]

\[ P\% = \frac{h \times g}{e} = \frac{0.9 \times 80043}{179880} \times 100\% = 40.05\% \]

3- Quality:
Total scrap = 762 units

\[ Q\% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) \times 100\% \]

\[ Q\% = 1 - \frac{j}{g} = 1 - \frac{762}{80043} \times 100\% = 99.05\% \]

\[ O.E.E. = A\% \times P\% \times Q\% \]

\[ O.E.E. = 97.31\% \times 40.05\% \times 99.05\% = 38.60\% \]
For Machine: BM BIRAGHI 100:

Process amount = total produced = 107194 units
Total scrap = 129 units
Total unplanned DT = 2 hr = 22*60 min = 1320 minutes

1- Availability:
c = 184860 minutes
d = 1320 minutes
Net operating time = Run time - unplanned DT
e = c – d = 184860 – 1320 = 183540 minutes

\[ A% = \frac{\text{Net operating time}}{\text{Run time}} * 100\% \]

\[ A% = \frac{e}{c} = \frac{183540}{184860} * 100\% = 99.29\% \]

2- Performance:
Process amount = total produced = 107194 units
Lead time = 0.65 minutes/unit

\[ P% = \frac{\text{Lead time} * \text{Process amount}}{\text{Net operating time}} * 100\% \]

\[ P% = \frac{h * g}{e} = \frac{0.65 * 107194}{183540} * 100\% = 37.96\% \]

3- Quality:
Total scrap = 129 units

\[ Q% = (1 - \frac{\text{Scrap}}{\text{Process amount}}) * 100\% \]

\[ Q% = 1 - \frac{j}{g} = 1 - \frac{129}{107194} * 100\% = 99.88\% \]

\[ O.E.E. = A% * P% * Q% \]

\[ O.E.E. = 99.29\% * 37.96\% * 99.88\% = 37.65\% \]
For all six machines:

\[
O.E.E. = \frac{\sum_{i=1}^{6} O.E.E_i}{6}
\]

\[
O.E.E_{\text{total}} = \frac{37.60\% + 39.73\% + 26.04\% + 28.87\% + 38.60\% + 37.65\%}{6}
\]

\[
O.E.E_{\text{total}} = 34.75\%
\]
A Pareto chart displays data in a hierarchical order identifying where any given problem occurs most frequently. The next Pareto charts are drawn depending on the previous down time calculation:

FIGURE 3-3

FIGURE 3-4
FIGURE 3-5

FIGURE 3-6
FIGURE 3-8

BM BIRAGHI 720 NEW Down Time

FIGURE 3-9

GIESS 1 & 2 Down Time
BM BIRAGHI 100 & 125 & 720 new & 720 old
Down Time

![BM BIRAGHI 100 & 125 & 720 new & 720 old Down Time Graph]

FIGURE 3-10

All section’s machines Down Time

![All section’s machines Down Time Graph]

FIGURE 3-11

40
In this phase we also define: the project team, the problem and goal statements, the project scope, the project plan and projected benefits.

The project team is the plastic engineer Mr. Yusri Makki as “Black Belt”, Mr. Ali Mahmoud as “supervisor” and the students Mustafa Salah and Mohamed Abd Elmunim as “team members”.

Problem statement: There was some problems in the quality and productivity of the “plastic” section in COLDAIR Factory, these problems were appeared when the O.E.E. (Overall equipment effectiveness) which is an indicator to the success of a manufacturing process was calculated, and based on data from Jul-2014 to Dec-2014 the O.E.E. was 34.75% when the international standard value is “85%”.

Goal Statement: The objective of this project is to improve the quality by increasing the O.E.E. from 34.75% to be double “69.5%” at the end of June-2015.

The scope of the project is the “plastic” section of COLDAIR Factory, and the longitudinal scope starts at main store material supply and ends at assembling line.

We put a specific plan for this project, this plan shows the high level time lines for each Phase in next table:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Starting</th>
<th>Ending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define</td>
<td>3 week in Jan.</td>
<td>2 week in Feb.</td>
</tr>
<tr>
<td>Measure</td>
<td>3 week in March.</td>
<td>1 week in April.</td>
</tr>
<tr>
<td>Analyze</td>
<td>2 week in April.</td>
<td>3 week in April.</td>
</tr>
<tr>
<td>Improve</td>
<td>4 week in April.</td>
<td>1 week in May.</td>
</tr>
<tr>
<td>Control</td>
<td>2 week in May.</td>
<td>2 week in June.</td>
</tr>
</tbody>
</table>

The Projected financial benefits estimated saving about 13.35 k SDG average every month. Other benefits is the improvement of process control.
Depending on the Pareto charts we define the CTQs (Critical To Quality) characteristics:

- Prioritized CTQs:
  1. Reduce Tool Change Down Time.
  2. Reduce heating up Down Time.
  3. Reduce air drop Down Time.

- List of Stakeholders:
  1. Yusri Makki.
  3. Mustafa Salah Mohammed.

- Identify Business Strategies and Goals:
  1. Improve customer satisfaction.
  2. Improve process control.
  3. Improve profitability.

- Prioritize CTQs Based on Customer and Business Requirements is to improve plastic section’s machines.

The next table shows the Stakeholder Analysis:

<table>
<thead>
<tr>
<th>Name / Position</th>
<th>Function</th>
<th>Level of participation</th>
<th>% of Time</th>
<th>Type / Level / Frequency of communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yusri Makki</td>
<td>BB</td>
<td>consult</td>
<td>50%</td>
<td>weekly</td>
</tr>
<tr>
<td>Ali Mahmoud</td>
<td>Plastic Supervisor</td>
<td>include</td>
<td>50%</td>
<td>weekly</td>
</tr>
<tr>
<td>Mustafa salah</td>
<td>Student</td>
<td>include</td>
<td>100%</td>
<td>full time</td>
</tr>
<tr>
<td>Mohamed Abd Elmunim</td>
<td>Student</td>
<td>include</td>
<td>100%</td>
<td>full time</td>
</tr>
</tbody>
</table>

3.3.2 Measure:

In this phase we focus on measuring the key aspects of the current process and collect relevant data. Also we use measures or metrics to understand performance and the improvement opportunity.

The Process Map depicts a simple Process diagram to identify the Input X’s (influences) and Output Y’s (Process Y’s, result variables). The process diagram serves as the “direction guide line”.

42
The units of measurement $Y(s)$ is time in hours. The target and specifications or defect definition is to reduce tool change over down Time in “GIESS 2” machine from average 1.6 hour to 0.8 hour. We focus on this machine because it is important machine in the section, which has a long cycle time and needs finishing processes also it produces the basic parts of the refrigerators.

The Down Time breakdown for each type machine shows the most problems of machines, and focus on the most problem which is the tool change Down Time defined from the previous Pareto charts, this is shown in the next figure:

FIGURE 3-12

Operational definition of $Y(s)$ is shown by the next table:
Tool change Down Time in “GIESS 2” machine is specifically studied, and the details shown by the next table:

<table>
<thead>
<tr>
<th>Project Y(s)</th>
<th>What is the Unit</th>
<th>What is the Opportunities</th>
<th>What constitutes a defect</th>
<th>Current</th>
<th>Target</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Tool Change</td>
<td>Time in (Hours)</td>
<td>Down time</td>
<td>Down Time</td>
<td>1.6 hr</td>
<td>0.8 hr</td>
<td>Using Lean six sigma</td>
</tr>
</tbody>
</table>

The next step is to measure what is measurable, so we define “As Is” process which is a value stream map and process flow diagram.
Thermoforming machine tools change is shown by “As-is” detail process map:

FIGURE 3-13

“As-is” Micro-Level process map is shown by details next:

FIGURE 3-14
Data Collection Plan is shown by the next diagram:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Type Measure Project: &quot;Y&quot;</th>
<th>Type Data</th>
<th>Operational Definitions</th>
<th>Other Conditions to Record</th>
<th>Collecting/Recording</th>
<th>Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool change Down time</td>
<td>Output/ input</td>
<td>continuous</td>
<td>Time</td>
<td>Record all breaks of Tool change Down time</td>
<td>Machine cooling</td>
<td>Mould assembling and Disassambling</td>
</tr>
<tr>
<td>MGs efficiency</td>
<td>Output/ input</td>
<td>percentage</td>
<td>Record daily production and scrap</td>
<td>Working time per second</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ar-keep DT</td>
<td></td>
<td>time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating up DT</td>
<td></td>
<td>time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrap per</td>
<td></td>
<td>unit</td>
<td>Daily scrap</td>
<td>Total products</td>
<td></td>
<td>Daily Operation form</td>
</tr>
</tbody>
</table>

TABLE 3-13

Defective units for Jan-2015 and Feb-2015 are shown by the next diagrams:
FIGURE 3-16

Down Time for thermoforming machines in Feb-2015 is shown by the next diagram:

FIGURE 3-17
Process Improvement Target is given by next figure:

![Bar chart showing OEE improvement]

**FIGURE 3-18**

### 3.3.3 Analyze:

In this phase was focused on analyzing problems, and specified causes and effects that must be considered. So potential causes X(s) were identified and significance of X’s was investigated by collecting data using graphical or quantitative analysis.

Significant Causes were identified to focus on \( Y=f(X) \) to evaluate the impact of X’s on Y(s). Here the critical factors of a “good” output and the root causes of defects or “bad” output were identified.

Prioritization of Potential Vital X’s shows tools change Down Time and identifies variation sources by the next diagram, figure and table:
<table>
<thead>
<tr>
<th>cause</th>
<th>effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>lack of production assistance tools</td>
<td>increase down time</td>
</tr>
<tr>
<td>no routine maintenance plan for MCs</td>
<td>increase the probability of machines break down</td>
</tr>
<tr>
<td>no prevention maintenance plan for moulds</td>
<td>increase the probability of moulds break down</td>
</tr>
<tr>
<td>no follow-up for machines prevention maintenance</td>
<td>increase the probability of machines break down</td>
</tr>
<tr>
<td>no production plan</td>
<td>low MCs efficiency</td>
</tr>
<tr>
<td>down time not recorded at the same time</td>
<td>unreliable data</td>
</tr>
<tr>
<td>daily report designed by English language</td>
<td>increase the probability of incorrect data</td>
</tr>
<tr>
<td>poor of tools change plan</td>
<td>increase down time</td>
</tr>
<tr>
<td>mis-communication with other sections</td>
<td>increase down time</td>
</tr>
<tr>
<td>poor method for delivery formed parts to the production line</td>
<td>increase scrap percentage / lost</td>
</tr>
<tr>
<td>Ops have poor knowledge about production measurements</td>
<td>low productivity</td>
</tr>
<tr>
<td>lack of Ops awareness about MCs troubleshooting</td>
<td>increase scrap percentage / lost</td>
</tr>
<tr>
<td>the trace of defective parts are out of control</td>
<td>increase scrap percentage / lost</td>
</tr>
</tbody>
</table>

**TABLE 3-14**
Tools change Down Time causes are determined using next Fishbone diagram and figure:

![Fishbone Diagram](image)

**FIGURE 3-21**

**Giess Machine Change Over Improvement**

<table>
<thead>
<tr>
<th>Step</th>
<th>Before (Minutes)</th>
<th>After (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Cooling Down</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Previous mould Disassembling</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Remove Previous mould from machine</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Disassemble the equipments from previous mould</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Assemble equipment on Current mould</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Put the current mould on machine</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Adjust the current mould on machine</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Machine Window plate Adjustm ent</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Machine Frame Adjustm ent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td>76</td>
</tr>
</tbody>
</table>

**FIGURE 3-22**
Thermoforming scrap causes are determined using next Fishbone diagram:

We use the procedure of (Whys) to determine to causes of problems.

- Why Air Drops?
  Compressed air not enough for GIESS machines.

- Why?
  Compressed air less than 6 bar.

- Why?
  The main compressed capacity less than factory capacity.

- Why?
  Implement new projects at factory (increase of pneumatic machines) without increase the number of compressors.
Why Heating up Down time for thermoforming machines (GIESS 1, GIESS 2) take long time?
Heat transfer from plasti-therm to the mold need long time.

Why?
Plasti-therm switch on offer shift starting.

Why?
Plasti-therm switch connected with machine elect cycle.

Why?
Machine design.

Thermoforming scrap causes are scrap due to mold defect, and Items defected during transportation to the production line, also scrap of items can increase due to lack of operators’ skills.

- Why scrap?
  - Mold defect.
- Why?
  - Air hose and ejector failure.
- Why?
  - Mold hoses and ejector were not checked before Tools change.
- Why?
  - No prevention maintenance, no SOP “Standard Operating Procedure” for tools change.

Why Items defected during transportation to the production line?
Bad method to handling and transportation.

Why?
No SOP, no tracking.

Why defect units?
Due to lack of operators’ skills.

Why?
Lack of troubleshooting awareness.

Why?
No troubleshooting sheets are available in machines.

Why?
No training plan.
Causes of items defected during finishing process are shown by next figure:

![Diagram showing causes of items defected during finishing process]

**FIGURE 3-24**
Causes of raw materials defect are shown by next figure:
3.3.4 Improve:

In this phase we focus on identifying and testing the best improvements that address the root causes. So we generate potential solutions, select and test solution, then develop implementation plan.

We pick out fifteen problems from last steps, and we take action to improve them, then we show the result in many figure before and after the implementation of the improvement.

Problem 1:
Assemble hot water hoses, fixation clamps and air equipment online.

![Before](image)

Action taken:
Assemble hot water hoses, fixation clamps and air equipment off line
Results:
Reduce Tool change down time 10 minutes

Problem 2:
Increase air drop Down Time and reduce efficiency.
Increase number of defective units.
**Action taken:**
To reduce air drop Down Time, connect 7.5 bar compressor to the line of air supply.

![Diagram showing the connection of the compressor](image)

**Results:**
Reduce Air drop down time 10 minutes.

**Problem 3:**
Waiting forklift from other section “Waste time”.

![Image of forklift](image)
**Action taken:**
Use electrical forklift special for tools change.

**Results:**
Reduce Down Time 20 minutes.

**Problem 4:**
Mold heating up take long time.
Action taken:
The plasti-therm electrical cycle redesign to switch on by security gourd.

Results:
Reduce Heating up down time 90 minutes.

Problem 5:
Mold heating up after tools change take long time.

Action taken:
Pre-heat the mold before fixit on machine table.

Results:
Reduce Heating up Down Time 40 minutes.
Problem 6:

Operator receive carder orally.
Operator told supervisor about Down Time orally.

Action taken:
Establish weekly plan for every machine.
Train the operators to fill daily report by self.

Results:
Increase data reliability.
Problem 7:

Waiting for machine cooling down.

Action taken:
Use Thermal Gloves for disassemble the previous mold.

Results:
Reduce Tool change Down Time 25 minutes.
Problem 8:

Oil leaking and dusty.

Action taken:
Clean and shine and painted.
Fix leaking problem.

Results:
Improve work area environment.
Reduce maintenance time.
Problem 9:
Oily and dirty puncher.
Work in Process expose to the damage.

Action taken:
Clean and shine and painted puncher.
Work in Process covered with plastic film.

Results:
Improve work place environment.
Protect Work in Process “WIP” from damage.
Problem 10:
Oil leaking and dusty.

Action taken:
Clean, shine and paint.

Results:
Improve work area environment.
Reduce maintenance time.
Problem 11:
Bad work environment.

Action taken:
Clean, shine and paint.

Results:
Improve work area environment.
Reduce maintenance time.
Problem 12:

Bad work environment.

Action taken:

Clean and shine and painted.

Results:

Improve work area environment.
Problem 13:
Oily and dirty vacuum pump of thermoforming machines.

Action taken:
Clean and paint.

Results:
Improve work area and increase the ability of problem detecting.
Problem 14:

Loss of water connection of injection molds.
Looking for water connection.

Action taken:
Made hose connection stand and put it near injection machines.

Results:
Reduce tool change Down Time of injection molds by reducing the looking for water hose time about 10 minutes.
Problem 15:

Lack of assistance tools.
Losing of tools.

Action taken:
Bought new assistance tools.
Keep in tool box.

Results:
Reduce looking for tools time about 10-to-20 min.
The next figure shows the improvement of the work environment using 5s:

**FIGURE 3-26**

- Tarig Basheer
- Waleed Ibrahim
- Adam Elsideeg
- Jad Alah Hammad
- Amir Idrees
- Khalid Taj Elsir
- Mohammed Hamid
- Idrees Ismael
The next table explains the optimal settings of Causal X’s “Project action”:

<table>
<thead>
<tr>
<th>cause</th>
<th>effect</th>
<th>action</th>
<th>responsible</th>
<th>date</th>
</tr>
</thead>
<tbody>
<tr>
<td>lack of production assistance tools</td>
<td>increase down time</td>
<td>buy set of tools for every MC</td>
<td>Mechanic Eng</td>
<td>Jan-15</td>
</tr>
<tr>
<td>no routine maintenance plan for MCs</td>
<td>increase the probability of machines break down</td>
<td>schedule MC routine maintenance</td>
<td>Plastic Admin</td>
<td>March</td>
</tr>
<tr>
<td>no prevention maintenance plan for moulds</td>
<td>increase the probability of moulds break down</td>
<td>schedule mould prevention maintenance</td>
<td>Plastic Admin/Mechanic Eng</td>
<td>15-Jan</td>
</tr>
<tr>
<td>no follow-up for machines prevention maintenance</td>
<td>increase the probability of machines break down</td>
<td>schedule MC prevention maintenance</td>
<td>Mechanic Eng</td>
<td>15-Jan</td>
</tr>
<tr>
<td>no production plan</td>
<td>low MCs efficiency</td>
<td>schedule production plan</td>
<td>Plastic Admin</td>
<td>15-Jan</td>
</tr>
<tr>
<td>down time not recorded at the same time</td>
<td>unreliable data</td>
<td>training</td>
<td>Plastic Admin</td>
<td>Jan</td>
</tr>
<tr>
<td>daily report designed by English language</td>
<td>increase the probability of incorrect data</td>
<td>use the report designed by Arabic language</td>
<td>Plastic Admin</td>
<td>15-Jan</td>
</tr>
<tr>
<td>poor of tools change plan</td>
<td>increase down time</td>
<td>design SOP for tools change</td>
<td>Plastic Admin</td>
<td>15-Jan</td>
</tr>
<tr>
<td>mis-communication with other sections</td>
<td>increase down time</td>
<td>use the appropriate form</td>
<td>All plastic amps</td>
<td>15-Jan</td>
</tr>
<tr>
<td>poor method for delivery formed parts to the production line</td>
<td>increase scrap percentage lost</td>
<td>quick order to take the right method</td>
<td>Plastic admin/production superintendent</td>
<td>Feb</td>
</tr>
<tr>
<td>Ops have poor knowledge about production measurements</td>
<td>low productivity</td>
<td>training</td>
<td>Plastic Admin</td>
<td>Jan</td>
</tr>
<tr>
<td>lack of Ops awareness about MCs troubleshooting</td>
<td>increase scrap percentage lost</td>
<td>training troubleshooting paper for every MC</td>
<td>Plastic admin</td>
<td>March</td>
</tr>
<tr>
<td>the trace of defective parts are out of control</td>
<td>increase scrap percentage lost</td>
<td>design raw material follow-up card</td>
<td>Plastic Admin</td>
<td>Jan</td>
</tr>
</tbody>
</table>

**TABLE 3-15**

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3.3.5 Control:-

In this phase we focus on identifying sustainment strategies that ensure process performance maintains the improved state. So we create control and monitoring plan, implement full scale solution, and then finalize transition.

The components data of the Down Time and there percentage for the plastic section of the factory, for months from “January” to “May” are shown in the next chart:
The scrap percentage for the plastic section of the factory, for months from “January” to “May” is shown in the next chart:

We found that the projected financial benefits saving about 10 k SDG as average. Other benefits is the improvement of process control.

The results of O.E.E. calculation for “April” and “May” compared with the Base-line are shown by the next chart:
From last table it’s clearly shown that an O.E.E. has been increased and an improvement has been made. Also with monitoring and supervision during June, that result could be maintained and this improvement would be sustained.
CHAPTER 4
4.1 Conclusion:-
As a result of this project, Heating up and Tools change Down time was reduced, Air drop Down Time was reduced by connecting “7.5 bar” compressor to the line of air supply, also the working environment has been improved. It’s clearly shown that our improvement make the Overall Equipment Effectiveness to reach “54.8%” from “34.75%” and that means the quality of the plastic section of COLDAIR Factory have been improved. This is an indicator to the success of the project. That is not enough but with continuous improvement, the Overall Equipment Effectiveness would be close to the world class value which is “85%”.

4.2 Recommendation:-
Based on the previous conclusion we recommend the COLDAIR Company, and specifically the Plastic Section Management to do the following:

1- Make continuous improvement using Lean Six Sigma to develop the quality at the Plastic Section and try to reach 85% O.E.E.
2- Install an enough capacity generator which supply all section with electricity during cut-off periods.
3- Develop an automatic system to start heating up machines four hours before beginning of shift time to be ready for operation.
4- Improving inventory system to store the final products instead of putting them in large quantities near machines.
5- Introduce continuous training program for the operators to make them more effective in doing their jobs.
4.3 References:-

6. www.peoplecert.org/en/Test...Six_Sigma/...six_sigma.../Generic_FAQ.pdf
7. http://www.worldlibrary.org/articles/six_sigma
15. Prof. S. K. Patil, Application of Six Sigma Concept in University Libraries, a Key to Success: A case study of Jayakar Library, University of Pune (India).