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Action Plan to improve Overall Equipment Effectiveness of manufacturing processes of the case company

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I am very excited that I have just completed my final project for the case company. I was offered the position of trainee production engineer in an assembly shop 14 years ago with very less responsibility. During my tenure in the case company I was given some projects such as BOM rectification, cycle time reduction, 5S, etc. I had done all these projects successfully.

I want to express my gratitude to the management of the case company for giving me the chance to continue learning throughout my life while also making a new contribution to the organization's growth. I wish to express my gratitude to all of the company's stakeholders, interviewees, workshop participants, and informants. I would especially like to thank my former colleague Mr. Bhagirath Patel for all the thoughtful and enjoyable discussions that helped to boost my research.

I am grateful to Dr. Thomas Rohweder, my thesis advisor, for his exceptional advice, and to Ms. Sonja Holappa for helping me use appropriate terminology. And the outstanding lecturers from the Industrial Management study program, Dr. Juha Haimala, and Dr. James Collins. In addition, I want to thank all of my classmates for our fruitful group projects and their invaluable peer support.

I would also like to express my gratitude to all of my friends for giving me regular, albeit debatably healthy, breaks from my studies.

And yes, I must say it was a challenging and rewarding project.

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The objective of this thesis is to propose an action plan to improve the overall equipment effectiveness of the plant. The engineering department has expanded its emphasis on internal component manufacture as a result of the substantial shift the case company has undergone. The product manufacturing process controls the current product structure, but because it is a relatively new idea for the case company, nothing is known about it and its key performance indicators have not yet been defined.

The research approach of the study is design research and the study includes four stages. The first stage is a literature review, finding the best knowledge based on the business problem. The second stage is current state analysis gathering the strengths and weaknesses of the process. The third stage is a co-creation effort of the initial recommendations for the process improvement utilizing the outcomes from previous stages. The fourth and last stage is a validation round of the initial recommendations by the senior management providing the feedback to finalize the process improvement recommendations. In addition, a recommendation for an implementation plan was created.

Throughout the study, a number of process strengths and weaknesses were discovered. All findings and recommendations were separated into three categories that made sense. The operation within each category has the potential to be improved, thereby improving the process as a whole.

When put into practice, the study's final suggestions offer a thorough list of steps that will enhance the procedure. The value stream is benefited by improving the process that involves the key engineers and specialists of the product line since this allows them to work more effectively and handle more duties. Every function benefits from process improvement, which eventually helps the customers.

Keywords: Process Improvement, Key performance indicators.

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TPM: Total Productive Maintenance.

ISO: International Standardization for Organization.

OHSMS: Occupational Health & Safety Management System.

RM: Raw Material.

BOM: Bill of Material.

ERP: Enterprise Resource Planning.

OEE: Overall Equipment Effectiveness.

QMS: Quality Management System.

DPR: Daily Production Report.

SMED: Single Minute Exchange Die.

SME: Small and Medium-Sized Enterprises.

CNC: Computer Numerical Control

VMC: Vertical Machining Centers.

1 Introduction

Manufacturing businesses have fought to avoid being driven out of the market during the past few decades, especially following the most recent global economic downturn, by remaining competitive. In order for this to occur, there is a need to increase efforts to reduce manufacturing waste while increasing productivity. Manufacturing firms steer clear of pressuring customers by raising prices and instead concentrate on lowering manufacturing costs by eliminating waste in the production process.

Economically speaking, increasing total profit can be achieved by either lowering the total cost or raising the price of a good. Focusing on cutting costs as a whole makes more sense than raising prices, which can drive away customers.

Organizations and businesses organize and manage their activities through procedures. The right key performance indicators are defined in order to assess the effectiveness and outcome, as well as to facilitate ongoing improvement and modifications to these processes. Businesses, their business units, departments, functions, teams, and individual employees can all work in a controlled, repeatable, and dependable manner thanks to processes. (Hammer 2007)

The strategy, aims, stakeholders, and resources of an organization have an impact on its processes, which represent the state of the company at any given time. Processes must therefore be able to continuously evaluate themselves and make adjustments. Early monitoring and evaluation of a new process is essential to address any potential problems or elements that were not taken into account while the process was being developed.

1.1 Business Context of the case company

The case company is one of the main producers in India of paper stationery equipment, paper conversion equipment, and packaging equipment today. The case company is dedicated to helping its customers produce high-quality goods in a way that is safe, efficient, and environmentally friendly.

Due to the flexibility of the product line, the case company also adapts the entire experience to the specific needs and financial circumstances of each client. Technocrats who support cutting-edge technology through ongoing updates that raise product manufacturing standards make up the case company.

The case company, which serves 90% of the local market and is present in more than 75 countries worldwide, is the industry leader in paper stationery-making machines. Before turning over the operations, the case company offers training, advice, and assistance to each of their clients.

The business is broadening the scope of its competence by now offering post-installation and maintenance, enabling seamless operation. The organization appreciates being the frontrunner in the market because it strikes the proper balance between stability and changes in methods.

The primary idea behind the case company is developing. This research is crucial and significant. The case company devotes time, effort, and financial resources to its research and development because it has a specialty in anticipating probable future market needs.

The world has become a single global market. The case company has expanded its customer base by offering a wide range of products and services. Purchasing spare parts and services is now possible at the touch of a fingertip thanks to e-commerce websites. With more than 3000 installations of products worldwide, the case company keeps raising the bar for itself. It is among the most reputable manufacturers, according to the prestigious "Brand Trust Report."

Figure 1 shows the journey of the development of the products year by year of the case company for the last 50 years.

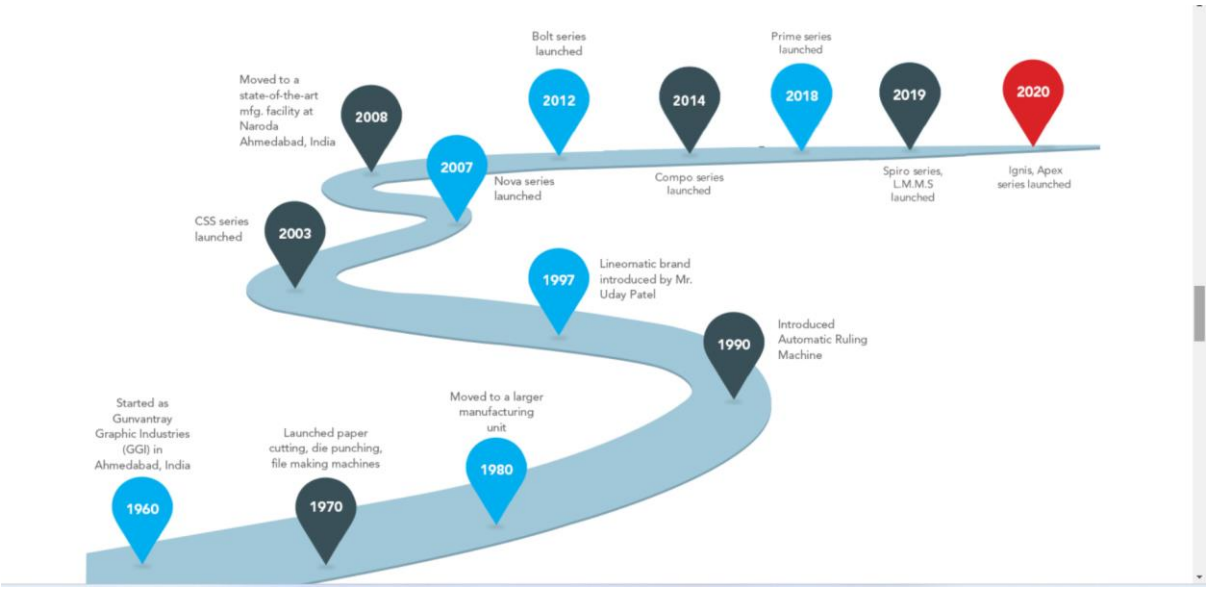

Figure 1: Journey of the case company in the last 50 years

As shown in figure 1 the case company started its journey in 1960 in Ahmedabad, India. They started to manufacture very basic models of paper-converting machinery such as paper-cutting machines, die-punching machines, and file-making machines in 1970. In 1980 they moved to a larger unit to overcome the space constraint to manufacture machines and after that, they launched Automatic reel to sheet machines, Cut size sheeters, and different types of automatic exercise notebook machines respectively in the past few decades.

1.2 Business Challenge, Objective, and Outcome

Over the past several years, the case company has undergone a considerable shift. The case company is managing several functions such as Sales, Marketing, Design, R&D, Production, Purchase, Customer Support Division, Spare Part Division, Quality, and Inventory under one roof. The case company arranged all the components for machine assembly from third-party vendors but the company could not get the components at the required time. To overcome this problem the case company has started its own manufacturing facilities at different places near the corporate office. The case company understands the need to boost overall profit by reducing manufacturing costs by enhancing Overall Equipment Efficiency (OEE). The Plant for which this thesis is carried out consists of one hundred twenty-two members including Manager and General Manager. The team members like Workers, Supervisors & Assistant managers are working in parallel to improve the overall equipment effectiveness of the plant. The team is strong in all aspects of manufacturing processes & works to minimize the

downtime of the machine. The HR team works to minimize downtime related to No-operator. The Purchase team works to minimize downtime related to Raw material availability. The Planning Department works for proper machine loading of each machine with respect to components required for machine assembly and the Production Department works to reduce the cycle time of each component which leads to improved OEE of the plant. The author of this study is a member of this team.

The objective of this thesis is to propose an action plan to improve the overall equipment effectiveness of the case company's manufacturing processes. The outcome of the study is the Action Plan to improve the overall equipment effectiveness of the case company's manufacturing processes. The outcome allows the case company to plan and implement the action plan which is made to improve the manufacturing processes.

1.3 Scope and Outline of the Study

The implementation of further development of the procedure is not covered in this study. Its scope is restricted to evaluating the current situation and proposing improvements to a particular process in the example company.

The study includes 7 sections. Section 1 is an introduction to the study. Section 2 describes the project plan, research approach, research design and collection of data. Section 3 analyses the relevant literature and outlines the conceptual framework of the study. Section 4 captures the current state analysis and summarizes the findings. Section 5 introduces the action plan for the process improvements. Section 6 examines the recommendations in a validation round and utilizes stakeholder and management feedback. Section 7 is for conclusions and discussions.

The following section outlines the project plan, giving specifics on the chosen research methodology, design, and data collection.

2 Project Plan

In the previous section, the business problem, objective, and outcome were described. The chosen research approach and design are initially discussed in this section, after which the techniques for data collection and analyzing data are discussed.

2.1 Research Approach

In everyday speech, the term "research" refers to the pursuit of knowledge. Another definition of research is a methodical and scientific search for relevant data regarding a particular subject. Some individuals view the study as a transition from the known to the unknown. Actually, it is a journey of discovery. (Kothari 2004:1)

The goal of applied research is to identify a speedy resolution for a current issue that a society or commercial/industrial entity is confronting. An example of applied research is a study that aims to reach specific conclusions (such as a solution) in response to a real-world social or professional issue. Examples of applied research include copy research (research to determine whether particular communications would be read and understood), marketing research, evaluation research, and research to detect social, economic, or political trends that may have an impact on a specific institution. Therefore, the primary goal of applied research is to find a solution to an urgent practical issue. (Kothari 2004:3)

Applied research, which combines development and research, generates useful and functional solutions to enhance operations in businesses, claims Kananen (2013: 20-22). Applied research is similar to how firms naturally evolve their operations, according to Kananen (2013: 20-22). Development work can be regarded as science if it is adequately recorded, employs acceptable scientific procedures, and results in new information (Kananen, 2013: 20-22).

Applied research and the use of qualitative & quantitative techniques were chosen as the research approach for this project.

2.2 Research Design

There are four stages in this study. The main focus of this study is the business challenge. To achieve the objective & outcome, the required actions were divided into four separate stages. Table 1 shows the Research Design of this study.

STAGE		DESCRIPTION	DATA	DATA SOURCE	OUTCOME
STAGE -1	LITERATURE STUDY ON O.E.E IMPROVEMENT	FACTORS WHICH AFFECT O.E.E. & PROCESS DEVELOPMENT			THEORITICAL FRAMEWORK
STAGE -2	CURRENT STATE ANALYSIS OF THE CASE COMPANY'S MANUFACTURING PROCESS	CURRENT MANUFACTURING PROCESSES & STRENGTHS & WEAKNESSES	DATA-1	COMPANY DOCUMENTS(DPR) THAT IS DAILY PRODUCTION REPORT & INTERVIEWS	THE FINDINGS OF THE CURRENT STATE OF ANALYSIS
STAGE -3	DEVELOPING THE CASE COMPANY'S O.E.E	STRUCTURING THE PROCESS	DATA-2	MANAGER, SUPERVISORS,PLANNING EXECUTIVE & WORKER'S INTERVIEWS	INITIAL PROPOSAL FOR NEW PROCESS
STAGE -4	VALIDATION OF THE INITIAL PROPOSAL	IMPROVEMENTS TO THE INITIAL PROPOSAL	DATA -3	FEEDBACK FOR THE INITIAL PROPOSAL	FINAL PROPOSAL FOR NEW PROCESS TO IMPROVE O.E.E

Table 1: Research Design of the Study

As shown in Table 1 a literature review is the first stage of the study to understand the current research and discussions on the topic of this thesis. The literature and best practice were researched to find related topics which affect the O.E.E from reliable sources.

The second stage is the current state analysis of the case company's manufacturing processes. Reviewing the current ways of manufacturing, SOPS, and instructions served as the foundation for the current state analysis. In this stage strengths and weaknesses were found and it was summarized.

Stage 3 was completed to jointly develop and record the initial recommendations based on the conceptual framework and address flaws recognized in the current process. By leading and setting up interviews, the main players in the target process were involved in the early recommendations. In addition to the workshops, one-on-one stakeholder interviews were conducted to achieve greater diversity in the cooperation. The outcome of stage 3 was the preliminary suggestions for process enhancement.

The fourth stage was the validation of the initial proposal, as shown in Table 1. Presenting the initial recommendations to the pertinent corporate executives and getting feedback from them. The fourth stage, the final suggestions, was the result of receiving constructive feedback from the management and modifying the proposals accordingly.

2.3 Data Collection

To achieve the objective of the study, data were required which were collected from different sources in each stage. Three rounds of data collection were done on three different categories of data. The next three tables provide summaries of all data-gathering phases. Table 2 shows the Data 1 collection for current state analysis from quality management system documents, Existing documents such as daily production reports, and interviews of the main players in the processes. The observations and the feedback from the interviews were recorded as field notes. From these data, the loop faults or lack of processes were found.

Data 1 : Current State Analysis					
Sr No	**Source**	**Data Type**	**Topic**	**Time**	**Documented**
1	QMS documents	Document	Process information	Accessesd	Quality management system.doc
2	Worker	Interview (Video Call)	Operation Process	13-Jan-23	Field Notes
3	Supervisor	Interview (Video Call)	Process operation & Process Execution	21-Jan-23	Field Notes
4	Planning Executive	Interview (Video Call)	Process operation & Process Execution	28-Jan-23	Field Notes

Table 2: Data 1 Collection

Data 1 was collected with the intention of gathering the data required to conduct a current status analysis, as shown in Table 2. Data 1 was acquired through interviews with process stakeholders, a review of the process documentation that was already in place, and participation in weekly team meetings. The following Table 3 shows the second round of data collection, Data 2 for developing the initial process improvement recommendations.

Data 2 : Developing Initial Proposal					
Sr No	Source	Data Type	Topic	Time	Documented
1	Assistant Manager 1	Interview (Video Call)	Operation Process and all process recommendations	06-Mar-23	Field Notes
2	Deputy Manager	Interview (Video Call)	Process operation inputs, communication and all process recommendations	13-Mar-23	Field Notes
3	Assistant Manager 1 Deputy Manager	Workshop	Discussion on process recommendations	18-Mar-23	Field Notes

Table 3: Data 2 Collection

In this stage, Data 2 was drawn from the interviews of the middle and lower management employees to create the initial proposal or recommendations for the new process. The interviews were conducted by video calling which was allowed to do. Then jointly discussed their views on initial recommendations by facillitating workshop.

In the last stage, Data 3 was collected from the feedback from the validation of the initial recommendations. The following Table 4 shows the last round of data collection.

Data 3 : Validation of Initial Proposal					
Sr No	Source	Data Type	Topic	Time	Documented
1	Manager	Interview (Video Call)	Initial recommendations for process impovement	25-Mar-23	Field Notes
2	Assistant Manager 1	Interview (Video Call)	Initial recommendations for process impovement	18-Mar-23	Field Notes
3	Deputy Manager	Interview (Video Call)	Initial recommendations for process impovement	18-Mar-23	Field Notes

Table 4: Data 3 Collection

This data was collected from the interview with the Manager of the plant and the participants of the Data 2 round. The following section of this study includes a literature study in which different factors were discussed which affect the overall equipment efficiency and process development.

3 Good Overall Equipment Effectiveness Practice in Literature (OEE)

The conceptual framework for the study is developed in Section 3 by compiling the pertinent knowledge already in existence that was discovered from the evaluated literature.

3.1 Introduction of Overall equipment efficiency

Seiichi Nakajima first proposed the OEE when he defined the TPM in the 1980s, and it was seen as the primary measurement within the TPM philosophy. The OEE can be used to assess manufacturing procedures and identify any issues that could impair equipment performance. The equation was developed in accordance with the six major losses that underlie the manufacturing process, and it was linked to three key components: availability, performance, and quality. These three components will be covered in more detail in subsequent subchapters. According to Nakajima (1982), the OEE equation is:

$$OEE = A\ (Availability) * P\ (Performance) * Q(Quality)$$

However, the ratio of Fully Productive Time to Planned Production Time constitutes the heart of OEE calculation. The three components of OEE are depicted in the diagram below, along with the supporting statement.

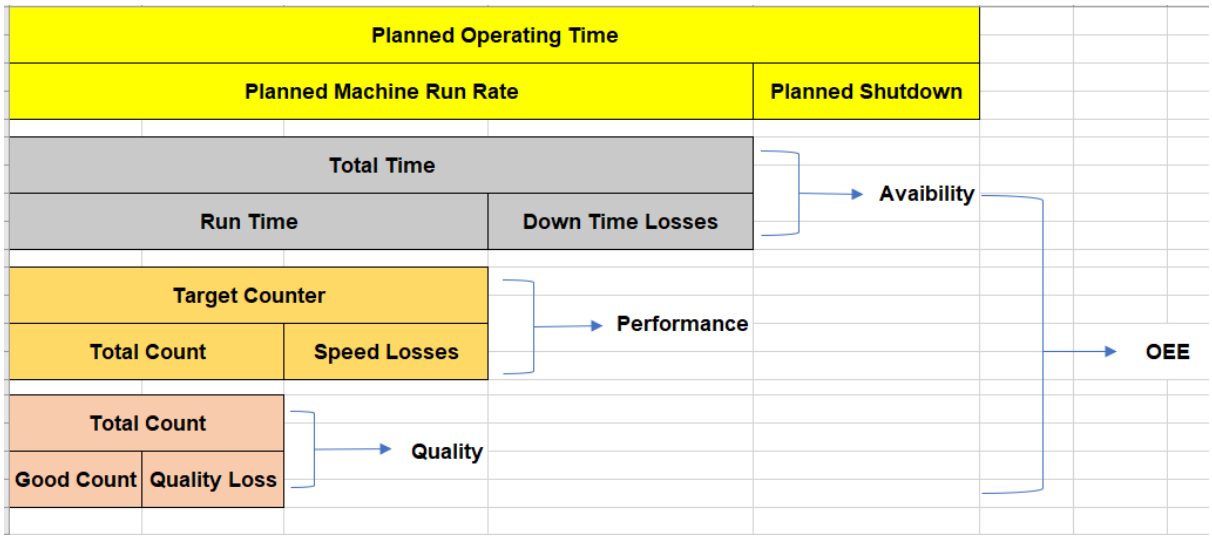

Figure 2: OEE Concept

(Wudhikam 2013; Naidu et al. 2013; Kaing 2015.)

The supporting components for availability, performance, and quality are the primary emphasis of the aforementioned depiction. Due to the OEE, which compares completely productive time to planned production time and analyses equipment effectiveness, the information on planned production time and actual production time is crucial.

The planned operating time is obtained by multiplying the projected machine run rate by the machine's scheduled shutdown time. The Run Time keeps track of the machine's actual running time. When Down Time Losses—which are the actual or unapproved downtime of the facility—are totaled, the result is the Total Time.

Managers must set up the "Target Counter," which is the machine's Ideal Cycle Time, before implementing the OEE process. At the conclusion of the production cycle, frontline employees are required to record the "Total Count" and "Speed Losses," which are related to the calculation of performance. A "Good count" (i.e., immaculate items) and "Quality losses" make up the total count (i.e. damaged products or products that need to be reproduced). These will be used in the quality rate calculation.

The OEE metric's straightforward calculation process and broad impact on production efficiency are two factors that have contributed to its popularity (Almström et al. 2016). However, applying the equation in practice could be challenging when employed in

various industrial situations (Naidu et al. 2013). The essential concept of the OEE is based on the original OEE concept, despite the fact that it is utilized by various manufacturing organizations and frequently adjusted to satisfy specific requirements at factories. This study focuses on developing an action plan to improve the OEE rather than applying the OEE at the factory.

3.2 Factors that affect the OEE

The first picture that frequently comes to mind when considering the production process is the functioning of a machine alongside an employee. Unexpected interruptions are just one of the issues the procedure frequently faces. These issues result in diverse waste products.

The "six big losses," as Nakajima referred to them, can be divided into three basic themes: downtime losses, speed losses, and quality losses (Magnus & Patrik 1999). The production process is less effective as a result of these losses. Table 5 illustrates the six big losses and the categories they belong to:

Sr No	Factors	Losses Category	Six Big Losses
1	Availability Rate	Downtime Losses	Equipment failure
			Set up and Adjustment
2	Performance Efficiency	Speed Losses	Idling and minor stoppages
			Reduced Speed
3	Quality Rate	Quality Losses	Defects and reworks in the process
			Start-up losses/Reduced yield

Table 5: The Six big losses

The detailed explanation of six big losses is described as follows:

Downtime Losses:

1. Equipment Failure:

   The breakdown of the machine is a part of the downtime losses because it will reduce the amount of product produced and negatively impact production.

2. Set up and adjustment:

   The setup and adjustment refer to the losses incurred as a result of equipment failure or defective products that were created when the machine paused an ongoing assembly and set up itself to produce a different good.
   Time losses could happen during this process.

Speed Losses:

3. Idling and minor stoppage:

   An unintentional or momentary stoppage fault or idle equipment could disrupt the production process.

4. Reduced Speed:

   Losses happen when the machine runs slower than expected. In other words, the actual running speed differs from the speed that was planned.

Quality Losses:

5. Defects and rework in the process:

   This is a reference to the goods that should be returned or reworked throughout the production process because they are faulty and imperfect. Machine

adjustments or broken production equipment could be to blame for this. These losses arise in lost time or financial losses due to product degradation and time wasted on rework.

6. Start-up losses/Reduced yield:

Start-up is the process of turning on a machine. The time between a machine starting up and operating steadily is referred to as the start-up and reduced yield periods.
(Wudhikam 2013; Almström et al. 2016.)

The downtime losses serve as the basis for the availability rate. Speed losses are crucial when assessing performance efficiency. The quality losses will influence the quality rate. Due to the fact that different businesses have distinct production procedures, these three loss categories manifest in various ways during the actual manufacturing process.

3.2.1 Reducing Set-up time in CNC/VMC Machine

Downtime, capacity, product quality, and expenses to a certain extent are all influenced by setups. In machining lines, setup losses can reach 60% of the effective capacity. Unwanted actions can be stopped with the use of a SMED, and internal setups can be moved to external setups. The use of additional specialized tools like the Poka-yoke, 5'S, and specially created Quick change fixture and Quick-change jaw mechanisms can further reduce the setup time to an extremely low level. SME manufacturers would have more flexibility due to the short changeover times.

This study aims to determine the importance of quick changeovers in the machining line. The setup operations play a significant role in the production lead-time, which has an impact on the final product's cost. To assess the current setup procedure, techniques like Pareto analysis, root cause analysis, and method study have been employed. Pallet system was suggested for vertical machining centre as quick change fixture foundation on which the current stage fixtures are situated based on the preliminary research. For the turning centre, the fast change jaw system was also suggested. The fastening

mechanisms were made to cut down on undesirable activities by 40% even during the design process.

Through real-time simulation, the Quick-Change Fixtures and Quick-Change Jaws were created and validated. SME's must utilize the most recent technical advancements to increase productivity and profitability in order to attain manufacturing excellence. Any SME can even gain a competitive edge by properly implementing the SMED, which would increase business for the company. The analysis demonstrates that the improbable benefits touted by SMED are indeed possible, but only with the aid of contemporary technology.

Any strategy for satisfying the demands of today's clients must include swiftly mounting and dismounting the workpieces from the machines while maintaining adequate safety, granting a cutting tool access to the areas that need to be machined, and maintaining constant holding pressure on the workpieces. This is especially true for workpieces that are vulnerable to warping due to pressure from mechanical vices and clamps. Productivity. Magnetic work holding is a highly adaptable alternative that users can employ to speed up setup and boost productivity.

Mould manufacturers must continually assess the ideal work holding strategy. They frequently rely on the use of conventional clamping and fixturing techniques, which take a long time to set up before a real machining process can start, as users of CNC machining centers and milling machines. Depending on the quantity, size, and required orientation of the components, machining or milling operations that produce multiple parts or parts with different dimensions require exponentially more setup time, which lowers the overall productivity of the operation. Magnetic work holding is a highly adaptable alternative that users can employ to speed up setup and boost productivity.

3.2.2 Magnetic Alternatives

In comparison to mechanical fastening or clamping, using magnetic chucks to attach workpieces to the machining table or surface saves time.

In order to ensure firm and exact positioning of the workpiece in accordance with the machine's CNC program, workpieces are manually fastened to the bed using holding clamps or vices that must be bolted down or secured as part of the machine setup. If a mould maker wants to machine multiple parts with one setup or multiple parts with different dimensions, magnetic chucks are more adaptable or accommodating. In comparison to using magnetic work holding, each of these scenarios would require a lot more setup time. The holding power of the magnet can outweigh the suction force produced by the vacuum, making them more capable and flexible than vacuum work holding. This is especially advantageous when machining large-size parts.

Vibration caused by machining is decreased by full support, which is the uniformed holding of the entire surface of the workpiece. Due to the fact that they are holding the work over a very large contact area as compared to mechanical vices and clamps, the magnets have a dampening effect on the work. The magnet functions as a buffer between the machine bed and workpiece to dampen or hinder vibration caused by the machine tool, which might alter the outcome of the workpiece, due to its solid-piece design. The end user can operate faster feeds and speeds without chatter by using magnetic chucks.

The machine must be run to meet conditions where a workpiece is held unevenly or is secured to the machining bed by mechanical clamps or vices, usually necessitating several pauses and starts. The surface of the part may become defective due to this stop/start motion, which must be fixed in a post-machining operation like bench cleaning or polishing to remove any flaws. In order to work around mechanical clamps and create the appropriate surface or part arrangement, numerous CNC programs could be required. The ability of the magnet to accurately position and hold the workpiece in place while the grinding wheel, milling cutter, or drill removes material also enables faster feed rates.

Magnetic work holding is becoming more widely used outside of surface grinding activities. In order to enhance the operations of their machines and produce a more effective machine with a higher return on investment, more machine tool manufacturers and end users are looking for ways to increase productivity or decrease setup time. Magnets are now suitable holding devices

for all kinds of ferrous part machining thanks to developments in technology and materials. Magnets can, for instance, produce more aggressive holding forces for the parts while maintaining reasonable size and weight thanks to elements like neodymium magnet (rare earth minerals).

3.3 Basics of creating an action plan in general

As per Arnold Glasow, “An idea not coupled with action will never get any bigger than the brain cell it occupied.”

Everyone wants to have a successful life. Everyone has opinions about how to spend their lives in a way that will bring them the most success and satisfaction, whether in their personal or professional lives. The ideas will only be that if it doesn’t actually carry out that vision.

An action plan is described as a document or checklist that lists the activities or duties that must be carried out in order to accomplish the goals that have been established. An action plan, which is a component of strategic planning, is essential to project management because it enables teams to work together efficiently, communicate clearly, and complete a project from beginning to end.

An action plan can also be used for personal goals outside of the commercial environment. A great action plan explains every step that must be taken to accomplish the goal and assists in doing so quickly and effectively. An action plan can be created for single or multiple goals, depending on the needs.

Project failure can occur for a variety of reasons, but improper planning is one of the most frequent ones. According to Benjamin Franklin “By failing to prepare, you are preparing to fail.” This Mean there will be costly errors if planning and developing an action plan are not given enough time. Preparing in advance gives the necessary clarity on the direction to go in, the technology to use, the roles to assign, and the challenges to overcome.

Some key elements of the action plan include:

1. **Align action with the objective:** Before making an action plan we need to align it with the objective so that the right direction can be fulfilled.

2. **Prioritize the action:** An action plan will provide a comprehensive overview of what has to be done because it requires writing down all relevant tasks. By prioritizing the jobs according to their amount of difficulty or the level of expertise necessary to perform them, will also help to streamline the workflow.

3. **To be Specific:** All the actions should be specific which can solve the problem.

4. **Set a deadline and assign an owner for each task:** Starting new tasks is considerably simpler than finishing one. An established deadline makes sure that team members are constantly making progress and are inspired to complete the task at hand rather than abandon it in the middle. Teams are more likely to follow through when they have a clear endpoint and can picture what success might look like.

5. **Tracking and Monitoring:** Since an action plan enables you to define the actions and procedures you must follow; the project is made simple to monitor. You can simply keep track of your progress, check where you stand in the project development process, and estimate how long it will take to finish.

3.4 Conceptual Framework

Knowledge related to objectives is found in the existing literature which is described in the previous section. In Figure 3 key elements from the literature are captured in a visually compact format.

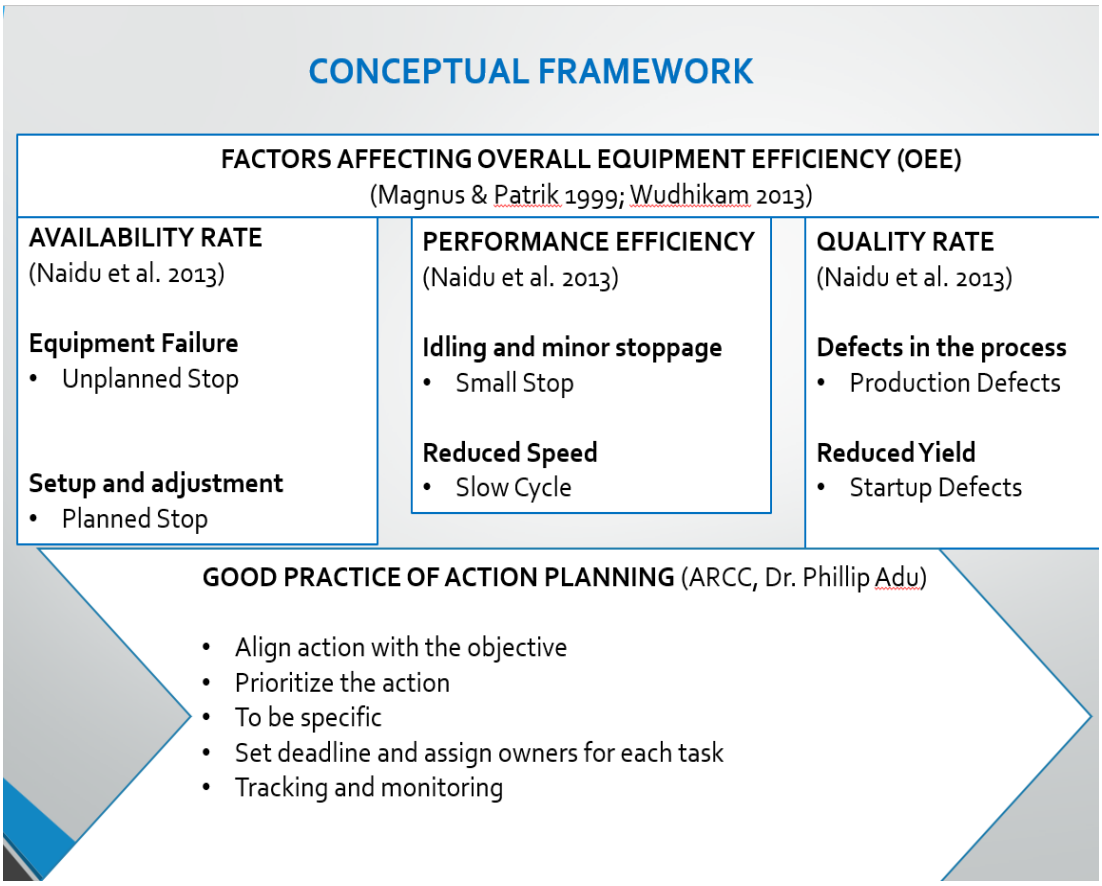

Figure 3: Conceptual Framework

In figure 3 different factors which affect the overall equipment efficiency are described. The factor availability rate combines equipment failure, set up, and adjustment. The factor performance efficiency combines idling, minor stoppage, and reduced speed. The factor quality rate combines defects in the process and reduced yield. The good practices of action planning are also included in the conceptual framework due to their importance, familiarity, and endorsement.

The following section of this study presents the results of Data 1 collection as the findings of the current state and an analysis of the case company's manufacturing process.

4 Analysis of the case company current manufacturing process from the OEE point of view

This section covers the findings of the current state analysis divided into strengths and shortcomings and describes the current state of the manufacturing processes. The previous section introduced the literature review from the existing knowledge from the academic literature. Literature review was performed for seeking applicable improvement ideas for possible weaknesses of the current situation.

This section gives a basic process overview, followed by a more specific procedure, for the current state analysis (CSA). The current procedure is explained, examined, and the conclusions are distilled into positive strengths and detrimental weaknesses.

The Author may give well-supported recommendations about the project scope and workable solutions to address the problems found by having a good understanding of the present situation and recognizing pain spots. As a result, it is possible to outline a route of advancements toward the intended "to-be" state using the obtained knowledge.

4.1 Overview of Current state phase

The company is one of the leading exercise notebooks-making and paper-converting machinery manufacturers in India. Over 3000+ machines are installed and the company has a presence in 75+ countries all over the world. The company has a total of 4 units and over 500+ employees. Over 80% of components are manufactured in-house to cope with customer orders. The case company has ISO and OHSMS certifications which makes the base strong to deal with the customers.

The data was collected for the current state analysis by exploring existing documents from the Quality management system which is a daily production report in which all the idle time and non-productive time are mentioned. For this study, the current practice for manufacturing components, the setup process for manufacturing, the manpower resources, total productive maintenance (TPM), and planning activity was examined.

From the existing process mapping, different process stakeholders were identified, and the subsequent data-collecting stages were targeted at these stakeholders.

The manufacturing process was then observed at the meetings which were held on a weekly basis on a conference call where every stakeholder came up with different ideas or issues faced during the process. At the same time management was involved for a few minutes to give their input with their thoughts.

Weekly meetings were held to process the input that has been received for the manufacturing process and to organize the input into tasks that are realistic and doable. The meetings that last the longest are the ones that discuss the tasks that were completed in the preceding month. In conclusion, activity begins with an input that is processed in a weekly meeting, is followed by execution that is monitored, and finally comes to an end in a monthly meeting.

For a better understanding of the current process and flow, interviews with the workshop participants were carried out. The workshop participants were the main process owners who provide inputs and expect the output from the process. The inputs from the participants were supplemented in field notes after each interview.
Several stakeholders who, according to the documentation in place, were meant to contribute to the manufacturing.

Participants were invited to respond to the questions about the procedure. The goal of this investigation was to learn how effectively participants from different functions are actually involved in the process. The questions are listed in Appendix 1.

Workers, Supervisors & Planning executives were selected as the informants for current state analysis because they were the main drivers of the process from whom necessary information could be gathered.

4.2 Description of the current manufacturing process

The existing process was mapped during the current state analysis and it was drawn into a suitable and explainable format. The main process is mentioned in figure 4 below. The detailed process description is written in the following sub-sections. All the findings in terms of strengths and weaknesses are summarized in Table 6.

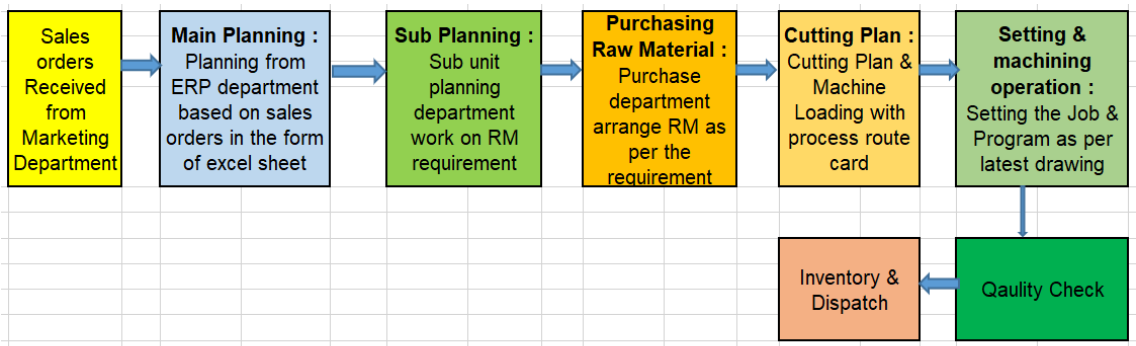

Figure 4 : Current manufacturing Process

As Shown in figure 4, the process is subdivided into 10 sections: Sales Order receiving, Main Planning, Sub Planning, Purchasing, Cutting & Machine Loading Planning, Production, Machining, Quality, Inventory & Dispatch. The following ten sections are describing the current state of the case company.

Sales Order Receiving from Marketing Department

In this case company's Marketing department plays a vital role. It brings a bunch of orders from existing customers and from new customers. The sales order is then generated and all the specific details are mentioned in the order regarding customer requirements. They have a specific format for that so that every department head can easily understand the actual requirement of the customer which is part of the quality management system document. Based on this sales order if there is a specific requirement from the customer then the design department release design for the order and generates the machine BOM (Bill of Material).

Main Planning

Based on the vision of the Marketing department and management ERP department opens forecast orders in the system and updates the Bill of Material for standard models and does the addition-deletion process for the received orders from the Marketing department as per the instruction given by Design Department. After all this basic process is done, the ERP department generates a material shortage report after considering the existing finished goods stock in the form of an excel sheet. This is the core planning of the case company. Based on that all the responsible departments and units get a better idea to move further for procurement and manufacturing of parts.

Sub Planning

After receiving core planning sub unit planning department generates the actual RM (Raw Material) requirement considering the RM stock in the respective unit. This RM requirement is then given to the purchasing department for procurement.

Purchasing Raw Material

After receiving the RM requirement from the planning department, the purchasing department makes a budget category vise by getting quotes from the different suppliers. Management approves the budget and the purchasing department starts to procure raw materials by concerning the priority with the planning department. The purchase department always gets in touch with the quality department to get the standard quality raw material without compromising.

Cutting Plan

After receiving raw materials, the planning executive makes a plan for cutting as per the shortage report. The planning executive makes nesting for each group for cutting to minimize waste. As per the shortage and availability of the raw material, the planning executive decides the process route card quantity for manufacturing after getting confirmation from the manager of the plant. The quantity of the process route card is

selected based on the size of the component and raw material availability. Generally, small components are considered mass production, and bigger size components are considered batch production which is already instructed by management. After completing the cutting process the planning executive handed over the process route card and blanks to the production department as per the machine loading.

Setting the Component & Machining Operation

This is the main process that really affects the Overall equipment efficiency of the plant. This task mainly depends on the skill of the operator and how fast the operator can set the component for manufacturing on the machine bed. For this task operator sets the job as per the layout given by the programmer and makes sure that the tool is not stuck with the mounting clamps. As per the program, an operator sets all the necessary tools in the tool magazine. Also, the operator sets speed and feed as per the condition of the machine. Before operating a machine, the operator checks the program as per the latest drawing which is received from the planning department. After that, all the machining operations are carried out by different machining tools such as drills, milling cutters, boring tools, shell mill cutters, Face mill cutters, and taps.

Quality Check

This stage is very important for the case company since it aids a company in achieving more consistency in the tasks and operations involved in the creation of goods and services. Processes become more effective, waste is decreased, and time and other resources are better used. Customer satisfaction is increased as a result. The case company has its own format for recording the inspection of the bigger components through which the rework and rejection components can be separated. The case company has the best quality inspection tools for doing the same. The best thing about the quality stage is that 100% of inspections are carried out of manufactured bigger components which are less in quantity and sample inspection is carried out for the components which are in mass production.

Inventory & Dispatch

After completing a quality check of the components, the quality department moves forward the components with a process route card to the store department which components are passed in quality check. The components which are marked as a rework or reject, are arranged in separate locations. The inventory department places all the components which are received as finished goods in a fixed location that is predefined. The inventory department preserves all the components in a predefined location by doing a rust prevention activity. As per the defined priority in the shortage report, the inventory department makes a pallet for the components which are going to dispatch by size and type of finished goods component. Then transportation is arranged as per the bulk of the pallets by the admin department so that components can be dispatched timely to the desired location.

4.3 Analysis of OEE strengths and weaknesses of the current manufacturing process

During the current state of analysis for the case company, Data were collected from the interviews in weekly meetings. It was observed that each informant had a clear idea regarding the manufacturing process of the case company. During meetings some good observations were done which can be classified as strengths and some problems were observed which can be classified as weaknesses. The case company has to think about the weaknesses which could be a hurdle in the growth of the organization. There were many findings that are categorized in different ways.

4.3.1 Strengths and Weaknesses of Availability Rate

The availability rate is one of the important factors in the case company's OEE improvement. During the interview stage, some good things were found which are considered strengths. The case company has made a solid reputation in the market by giving customer service as their most priority approach. The company is getting repetitive orders for several years which shows the popularity of the case company. Also, the policy of the company is employee-oriented, and because of that employees are getting job satisfaction. In all the departments the employees are selected through

a panel of highly qualified personnel. So. Skill level of the selected employees in each department is very high in the competition. During the interview stage, one interviewee who is a member of the lower management team threw light on one problem:

There is a sudden failure in the machine while operating a job (CSA interviewee 1)

This has been observed during weekly meetings that while running a machine malfunctioning happened and the machine stopped in between the process which consumes a considerable amount of operation time. The setting of components on the machine is also an important task to save time. One interviewee summed the situation up:

Setup and adjustment methodology is outdated which consumes considerable amount of time (CSA interviewee 3)

This has been observed in weekly meetings that more time is consumed in the setting of the new component. There is a need for a strong technique of setup so that setup time can be minimized at a drastic level.

4.3.2 Strengths and Weaknesses of Performance Efficiency

Performance efficiency is also one of the important factors in the case company's OEE improvement. During the interview stage, some good things were found which are considered strengths. This has been observed in weekly meetings that the support of senior leaders is extremely good which is helpful to motivate the bottom-level team. Also, the core planning of the case company which is done by the ERP department, and the sub-planning which is done by the individual unit are more accurate to fulfill the actual requirement for assembly. The infrastructure of the case company is good enough to accommodate all types of machinery and the storage capacity is very large to store all finished goods. During the interview stage, one stakeholder who is the supervisor of the plant stated the following:

There is a lack of control over non-productive time & undefined roles and responsibilities (CSA interviewee 2)

This has been observed that there is not enough control on non-productive time such as chip cleaning, machine cleaning, tool and insert changing time, rework time, and trial run time. To improve performance efficiency the case company needs to work on non-productive time. Also, this has been observed that everybody is waiting for the action that who will do certain task. This means the roles and responsibilities are not clearly defined.

4.3.3 Strengths and Weaknesses of Quality Rate

Quality rate is the most important factor in the case company's OEE improvement. During the interview stage, some good things were found which are considered strengths. The case company always has quality conscious approach and prepares all the employees to follow the quality norms. There is no space for any compromise with the quality of the component which is going to fit in the machine and hence the quality of the final product can be achieved at the desired level. During the interview stage with the supervisor, he pointed out the following:

So many components fall into rework and rejection (CSA interviewee 2)

This has been observed in the quality report too and because of that significant time is consumed on the machine to rework the components and due to rejection new components need to be manufactured to come up with the requirement.

4.4 Summary of Strengths and Weaknesses

Findings from the current state analysis, which are regarded as either the process's strengths or weaknesses, are displayed in Table 5. Strengths are highlighted in green, while weaknesses are highlighted in red. The sources column lists the places where the results came from.

Sr No	Strength or Weaknesses	Source
1	Solid reputation in the market as Continuously receiving repetitive order	QMS document
2	Staff satisfaction and skill level is high in every department	Weekly meeting
3	Senior leader's support is good enough to motivate the bottom-level team	Weekly meeting
4	The core planning & sub-planning is more accurate	QMS document & Weekly Meeting
5	Sufficient sources & infrastructure is good enough to achieve the defined strategy by Management	Weekly meeting
6	Quality-conscious approach to customer satisfaction	Meeting
7	Large storage capacity to withstand finished goods flow	Weekly meeting
8	Sudden Equipment Failure	Weekly meeting
9	Setup & Adjustment methodology	Weekly meeting
10	Lack of control over non-productive time	Weekly meeting
11	Frequent rework & rejection	Weekly meeting
12	Undefined Roles & Responsibility	Weekly meeting

Table 6: Summary of Strengths & Weaknesses

There was a total of 12 findings, as can be seen in Table 6. There are five weaknesses and seven strengths in the findings. It is apparent that vulnerabilities are dispersed evenly throughout the process when looking at Table 6's weaknesses. No particular step or sector of the process can therefore be regarded as its weakest link.

The conceptual framework is used to develop the initial process improvement recommendations in Section 5. In order to solve the initial business challenge in partnership with the key stakeholders, the conceptual framework is utilized to integrate the recognized process strengths while removing the flaws discovered during the current state analysis.

5 Developing an Action Plan to improve OEE of the Manufacturing Process

The initial recommendations are created in Section 5 using the results of the conceptual framework and the findings from the current state analysis. An overview of the stage, summaries of the recommendations, and a thorough explanation of the creation of plan are all provided in this section.

5.1 Overview of the solution building phase

The initial proposal was created in two interviews and one workshop. All the interviews started by giving general introduction of the current business challenge, the objective and the outcome. Then literature was reviewed based on possible factors which can affect the overall equipment efficiency of the plant. The set of questions was presented after introducing the study.

The conversation was then directed toward how to streamline that particular process. Co-creation involved idea generation, debates, discussions, and evaluations of the suggestions. In general, the participants were engaged and eager to share their thoughts and assess those of others. Since it was anticipated that the first recommendations across the categories would overlap, the participants had the chance to address all the topics and the entire process during the final portions of all the events.

All the interviews were organized one to one by video call. Data 2 was soon after the events and was transcribed from the field notes, which included co-creation commentary, discussions, and disputes. The participants also entered their feedback into the notes and at the time of the video call, it was gathered and added to the field notes.

The major participants in delivering Data 2 were chosen from the middle management team. The main decision makers were mainly belonging to this group. So, one small workshop was arranged to get the data and interviews were taken.

Lastly, the field notes of every event were combined to create the initial recommendations. The original recommendations were once more grouped using the same reasoning. Although there was some overlap between the recommendations and the categories, each item was only recommended once and put into the category that was the most appropriate for it. The following five summaries contain all of the first recommendations that were jointly prepared.

5.2 **Proposal for Availability Rate**

During the co-creation workshops and interviews it was recognised that the availability rate needs some plan for preventive maintenance so that problem of sudden equipment failure can be minimized. It was observed during the manufacturing process machine suddenly stopped. When it was investigated, minor problems were found such as low hydraulic oil, a drop-in air pressure, table movement problems, malfunctioning, etc. One of the interviewees made the suggestion:

A preventive maintenance plan must introduce month wise which covers all the machines in the plant

Some times only preventive maintenance plan would not work. It was suggested by one of the interviewees:

Daily/Weakly/Monthly checkpoints must create for each machine

Having the maintenance-related knowledge, the proposal was given to hand over this task to the maintenance engineer with high priority.

It was also observed that the time taken to set-up the new component was very high which directly affect the plant overall efficiency. So, there was need for proper and universal fixture to set-up the majority of the components. After long discussion and debates one of the interviewees made the suggestion:

Introduce new fixture (Magnetic Chuck) for setting new components

As it was a big and costly project, this task was hand over to Manager because it required quite long discussion with Managing director to pass the budget for new fixture with medium priority.

5.3 Proposal for Performance Efficiency

All the stakeholders agreed to improve performance efficiency by controlling the non-productive times and by defining the roles and responsibilities. It was recognized during the interviews and weakly meetings that non-productive times needs to be control to improve the performance efficiency. One of the interviewees made suggestion:

List out the non-productive times

It was strongly believed that whatever we want to improve, first it needs to be list out. There are numbers of types of non-productive times such as chip cleaning, rework job, setting, tool/insert/fixture change and loading-unloading time. Once it is listed out, it needs to be measure. So that target area can be decided. It was suggested by one of the interviewees:

Measure and record non-productive times

Measure and record non-productive times help in which area needs to be focused. This task hand over to supervisor as he manages all shop floor related work. This task was given on high priority.

All duties and responsibilities must be clearly defined and documented in order for the case firm to enable transparency. This will boost overall clarity for the particular function by providing a clear picture of the unique roles and responsibilities that it has. The homogeneity of the acquired data is ensured by conducting documentation and definition in a similarly structured manner. This makes sure that the import duties and tasks carried out in routine operations are recorded and can serve as a foundation for ongoing improvement. By segregating important duties and responsibilities carried out daily, weekly, and monthly, the base may be built.

The assistant manager is managing all shop floor-related activities and because of that, he knows all loop faults in the process. So, the task of gathering data of target areas was hand over to Assistant manager and accordingly to define the KRA (Key responsible area) for each employee and assign them for respective target area with the help of HR was handed over to Deputy Manager on high priority as he has this authority to define.

5.4 **Proposal for Quality Rate**

During the co-creation workshops and interviews it was recognised that the quality rate needs some format for inspection report. Frequent rework and rejection in the process affect the overall equipment efficiency of the plant. It was suggested by one of the interviewees:

Record the First Piece of inspection

It is always necessary to check the first piece for the small batch production after manufacturing and before starting the rest of production. It gives more clarity and confidence to start the production to the operator. A considerable amount of time can be saved if it is measured at the right time. It was suggested to hand over this task to the worker followed by the QC engineer because these two persons are the process owner. The same way it was also suggested:

Record the batch production inspection

If the item has number of quantities in production then it is necessary to record inspection of the components frequently. The same thing was suggested to hand over this task to the worker followed by the QC engineer because these two persons are the process owner.

5.5 Summary of Initial Proposal

The conceptual framework was used to produce the initial proposal, and as a result, the summaries of the early recommendations are organized into the same categories. Table 7 displays the co-developed early recommendations for all categories, the initial findings from the current state study, and the conceptual framework's relevant topics.

OBJECTIVE		To propose an action plan to imporve OEE of Plant				
		SUMMARY OF INITIAL PROPOSAL				
Categary	Objective (Improvement Areas	ACTION	PRIOIRTY	KPI	DEADLINE	RESPONSIBLE PERSON
Avaubility Rate	Sudden Equipment Failure	Make Preventive Maintenance plan	High	Maintenance Plan	June	Maintenance Engineer
		Create Daily/Weakly/Monthly check points for each machine	High		ASAP	Maintenance Engineer
	Setup & Adjustment Methodology	Introduce new fixture (Magnetic chuck) for setting of component	Medium	Magnetic chuck	June	Manager
Performance Efficiency	Lack of control over non-productive time	List out the non-productive times	High	NA	ASAP	Supervisor
		Measure and record non-productive time	High		ASAP	Supervisor
	Undefined Roles & Responsibility	List out the target areas	High	KRA	July	Assistant Manager 1
		Assign owner for each target area	High		July	Deputy Manager
Quality Rate	Frequent Rework & Rejection	Record First piece inspection (Report)	High	Inspection Report	May	Worker/QC Engineer
		Record Batch production inspection (Report)	High		May	Worker/QC Engineer

Table 7: Summary of Initial Proposal

The first category is defined by Availability Rate. In this category the main focus is kept on total machine running hours. The first two proposals are maintenance related in which preventive maintenance plan and creation of daily, weakly and monthly check points for each machine are suggested.

The second category is defined by performance efficiency in which focus is kept on non-productive times and roles and responsibility of each employee. The third proposal is to list out the non-productive times and forth proposal is to measure and record non-productive times. It is necessary to capture all type of non-productive times and try to minimize those times to improve the overall equipment efficiency. To tackle undefined roles and responsibility two proposal are given. The fifth proposal is to list out the target areas which affect the overall equipment efficiency of the plant. After listing all target areas, it should be important to assign the owner of all targeted areas which is the sixth proposal.

The third category is defined as a quality rate in which the focus is kept on frequent rework and rejection which is happening during the manufacturing process. Rework

and rejection are the most important topic which drastically affect the overall equipment efficiency of the plant. To rework the components machine and man-power is engaged which leads to the fall of efficiency of the plant. So, that seventh and eighth proposal is made to record first piece inspection report before small quantity of production and to record batch production inspection report for large quantity of production respectively. The format for the first inspection report and batch production inspection report are mentioned in Appendix 2 and 3 respectively.

The co-creation of the initial recommendations was accomplished successfully with the active participation of the main stakeholders. All the conclusions of the current status analysis were covered in a set of 9 initial recommendations. In Section 6, it is explained how the co-developed initial recommendations were validated.

6 Validation of Proposal

The validation of the jointly developed initial recommendations is discussed in Section 6. The validation stage is firstly covered in general detail in this section. The final recommendations and the study's findings are then presented. It gives an explanation of the validation feedback after the final suggestions. This section concludes by describing the modifications made to the original suggestions.

6.1 Overview of the validation phase

By presenting the initial recommendations to the case company's senior management of choice and soliciting their input and criticism, the initial ideas were validated. The feedback was necessary to determine whether the recommendations had any chance of being implemented from a business standpoint. The senior management team was evaluating the feasibility, cost-effectiveness, and effectiveness of the suggested process enhancements.

Due to the location and time zone variations, the validation was completed in three meetings on video call. The Manager represented senior management at the meeting, and the Assistant Manager and Deputy Manager represented middle management. The conference followed the same format, with an introduction of the study's premise, a synopsis of the results of the current-state analysis, and an overview of the themes of the conceptual framework. The first suggestions were then divided into three groups. The senior manager reviewed, evaluated, and commented on the recommendations following each category, creating Data 3 for this study. Immediately following the sessions, the input was transcribed from the field notes that had been taken during the discussions. Based on Data-3, the initial recommendations were adjusted and formed into the final recommendations.

6.2 Summary of the Final Proposal

Table 7 lists the final proposal for the overall equipment efficiency improvement. The suggestions are arranged according to the same categories that were used for the study.

OBJECTIVE		To propose an action plan to imporve OEE of Plant					
	SUMMARY OF FINAL PROPOSAL						
Categary	Objective (Improvement Areas from CSA)	Initial Proposal	Final Proposal	PRIOIRTY	KPI	DEADLINE	RESPONSIBLE PERSON
Avaubility Rate	Sudden Equipment Failure	Make Preventive Maintenance plan	Unchanged	High	Maintenance Plan	June	Maintenance Engineer
		Create Daily/Weakly/Monthly check points for each machine	Unchanged	High		ASAP	Maintenance Engineer
	Setup & Adjustment Methodology	Introduce new fixture (Magnetic chuck) for setting of component	Keep it on hold. Need to check the budget. It might be applicable if M.D will agree	Medium	Magnetic chuck	June	Manager
Performance Efficiency	Lack of control over non-productive time	List out the non-productive times	Unchanged	High	NA	ASAP	Supervisor
		Measure and record non-productive time	Unchanged	High		ASAP	Supervisor
	Undefined Roles & Responsibility	List out the target areas	Unchanged	High	KRA	July	Assistant Manager 1
		Assign owner for each target area	Unchanged	High		July	Deputy Manager
Quality Rate	Frequent Rework & Rejection	Record First piece inspection (Report)	Unchanged	High	Inspection Report	May	Worker/QC Engineer
		Record Batch production inspection (Report)	Unchanged	High		May	Worker/QC Engineer

Table 8: Summary of Final Proposal

When comparing the final and initial proposal, as indicated in Table 8, just one item was changed. Section 5.5 contains the initial proposal, and Section 6.4 describes the revisions that were made to create the final recommendations.

6.3 Developments to Proposal

Overall, the top managements' feedback from the initial recommendations received very excellent reaction. The study's introduction and the preliminary work both got praise. Also, the advantage of the recommendation across the entire process and the significance of the study were acknowledged:

The list prepared as recommendations is quite good and this work is very important to improve the overall equipment efficiency of the plant (Manager)

The recommendations given to create a preventive maintenance plan and prepare check points is really good. The maintenance engineer is doing the preventive maintenance activity but it is off the record. It needs to be plan on paper.

The idea given to prepare the preventive maintenance plan is excellent (Assistant Manager 1)

The recommendation given to create a check points is accepted very quickly because it is a very important task to prevent the machine from sudden break down.

The recommendation for introducing a new fixture was discussed in more detail during the final meeting. The time taken by the operator to set any new component on machine was very high in general. So, it is very important proposal to solve this problem.

The Magnetic Chuck is a good choice to replace the existing style for clamping the component (Manager)

The only concern with this recommendation is the budget. The manager of the plant needs to discuss with Managing director and explain the importance.

The recommendations for performance efficiency were very basic things which must need special attentions from the shop floor team who are the process owners and decided in validation meeting that Assistant Manager will take due care and list out the target areas.

The key responsible area for each employee must define (Manager)

The case company needs acceleration to enhance the speed of the production and for that the key responsible area must define for each employee and must allocate the ownership of the task. Deputy manager will define the KRA for each employee with the help of HR team which is decided in final validation meeting.

The recommendations for quality rate was discussed in validation meeting very effectively and Managing director of the case company showed their interest to discuss about this topic. The quality of the components manufactured for machine assembly is the first concern for the case company. Also, frequent rework and rejection of the components increase the process cost and raw material cost respectively. So, recommendations for quality rate were very well examined and accepted by the manager.

The deadline and responsible person defined for each proposal were accepted by the validation team in general.

6.4 Changes made to Initial Proposal

Only one change is adjusted on the basis of Data-3, the feedback from the validation. The change is presented in Table-8.

Changes made to the Initial Proposal		
Categary	**Initial Proposal**	**Final proposal**
Avaibility Rate	Introduce new fixture (Magnetic chuck) for setting of component	Keep it on hold. Need to check the budget. It might be applicable if M.D will agree

Table 9: Changes made to the initial proposal

As shown in Table 9, the change is related to the clamping method of the component. The proposal given to introduce a new fixture for that. The proposal changed to verify the actual cost of the fixture and will be accepted after M. D’s approval because the cost of such fixtures is very high.

The initial proposals' validation was carried out according to plan. Due to the extensive engagement of the major stakeholders during the earlier stages, the initial proposals provided in the validation sessions were already improved and practicable. The study's seventh and last section offers a summary of the projects, managerial implications, and offers a self-evaluation of the study.

7 Discussion and Conclusion

This final section of the study contains an executive summary, recommendations for the practical next steps in a form of an implementation plan, a self-evaluation of the study and its results, and finally the closing words. This section is all about discussion and conclusion regarding this study.

7.1 Executive Summary

In order to increase the case company's overall equipment efficacy, the study's objective was to provide an action plan. The recommendations that emerge from the study help the case company plan and put process improvements into place. The engineering department has expanded its emphasis on internal component manufacture as a result of the substantial shift the case company has undergone. The product manufacturing process controls the current product structure, but because it is a relatively new idea for the case company, nothing is known about it and its key performance indicators have not yet been defined.

The study's research methodology was design research with qualitative data collection techniques. There were four phases of the investigation. A conceptual framework was developed based on the results of the first stage, which involved a literature review with the goal of identifying potential elements that might affect the example company's overall equipment effectiveness. A current state analysis that outlined the process's strengths and weaknesses was the second stage. The third stage involved a co-creation process in which the important stakeholders came up with the initial recommendations for process improvement. The study's final recommendations for process improvement were produced during the fourth and final stage's validation round of the initial recommendations, which involved soliciting input from top management.

The Literature review was carried out first to find out which kind of factors can affect the overall equipment effectiveness. The conceptual framework includes the existing knowledge and best practices targeting the possible weaknesses and good practices for making effective action plan. The current state analysis was performed by stakeholder interviews. The findings were divided into three categories for the

weaknesses to focus more on improvement ideas. The availability rate category included weaknesses related to machine availability for production. The performance efficiency category focused on the non-productive time and roles and responsibilities of each employee. The quality rate category addressed the frequent rework and rejection of the components during manufacturing.

The initial recommendations were developed in collaboration with the major process stakeholders over the course of one workshop and two interviews. The study's general introduction, the results of the current state analysis, and the pertinent body of prior knowledge assembled to the conceptual framework served as the starting point for all events. Every event featured a particular subject based on one of the categories of weaknesses as well as a general component of addressing every category. Following the same rationale used to classify the flaws, recommendations were gathered from all of the co-creation events and classified into three groups.

A total of three initial recommendations were placed into the availability rate category. The recommendations relate to machine availability for manufacturing of components. In other words, how many hours effectively machine is available for manufacturing.

Four initial recommendations were placed into the performance efficiency category. Recommendations include identification of non-productive time such as chip cleaning, machine cleaning, Loading-unloading, changing of tools and fixtures and reworking the component. It also includes the roles and responsibility of each employee which was undefined.

The last category, quality rate included two initial recommendations such as recording first piece inspection and batch production inspection in the form of a report.

The initial recommendations were validated by the case company senior managers related to the manufacturing department. The validation was performed in three meetings, first with the Assistant Manager 1, second with the deputy manager, and then with the Manager of the plant. All three meetings started with an introduction of the study in general, the findings of the current state analysis, and the relevant existing knowledge compiled into the conceptual framework. After the introduction, all the co-created initial recommendations were presented. The recommendations were

evaluated and commented by the management. In general, the response was positive and the range of the initial recommendations covering the whole process was seen as a benefit.

When put into practice, the final recommendations offer a complete set of steps to raise the case company's overall equipment effectiveness. The value stream is benefited by improving the process that involves the key engineers and specialists of the product line since this allows them to work more effectively and handle more duties. Through speedier manufacturing, process improvement benefits all functions, business units, and ultimately the customers associated with the product line.

7.2 Recommendations for an implementation plan

When putting the findings of this study into practice, the recommendations to increase the case company's overall equipment effectiveness can be carried out in any order since they are not all interconnected and the designated responsible persons come from various departments. Priority will be given to the recommendations with As Soon As Possible closing dates, though. Based on the results of the current state analysis, three categories of final recommendations are offered in Section 6.

The implementation is to be started with maintenance related activity such as making the routine check points of each and every machine and with list out the non-productive times and measuring the same. This activity needs only consistent focus of the process owner and because of that priority was given to those recommendations. The next step for the implementation plan is suggested for quality rate category which is record the first piece and batch production inspection in the form of report which are presented in Appendix 3.

The next step is to make a preventive maintenance plan which is required to prevent the machines from sudden stop. The format for the preventive maintenance plan is presented in Appendix 4. The last step to implementing the final recommendation is to list out the targeted area on which manual focus is required and assign the process owner for each task. For more detail it is suggested to develop the KRA (Key responsible area) with help of HR team.

7.3 Self-evaluation of the study

The initial business problem was the case company not achieving overall equipment effectiveness. Based on the business problem, the objective was to propose an action plan for the process. The study's findings are presented in Section 6 along with a thorough list of suggestions for streamlining the procedure that have been approved by the senior management of the case company. As a result, the study's findings totally meet its objective.

The results of this study are specifically targeted toward the identified process weaknesses. One can wonder if all the weaknesses were found or if the conclusions chosen to move on were accurate. There is no guarantee that all potential strengths and weaknesses will be found, even though the current state analysis of the study allowed a wide range of stakeholders to contribute by leveraging all the different departments. It's possible that not even all of the process's stakeholders were able to accurately identify or explain every finding. Nevertheless, the study's objective was achieved because a significant number of strengths and weaknesses from a broad and diverse set of informants were documented. The study's objective is met through specific and verified improvement suggestions for weaknesses.

Involving the important stakeholders was required, but it finally turned into a problem as the team began to alter the procedure in the middle of it. Having the participants first consider the process's strengths and weaknesses during the current state analysis stage, followed by jointly developing improvement suggestions during the initial recommendations' formulation stage, they then began to put the method into practice and fix it as they went. However, the results are pertinent since the final recommendations take into consideration the evolving process. Some of the hastily changed processes would have been avoided with a quicker implementation of the research design.

The validity (creditability and transferability), reliability, logic, and relevance of the study are assessed in the following sub-sections by first explaining how these criteria have been defined in the research literature.

7.3.1 Validity

Taylor (2003) asserts that the adjective "validity" is always connected to statements like "the validity of conclusions drawn from the research results." It is easier to judge the truthfulness of an assertion when it is sound, justified, logical, and backed by evidence (Taylor, 2013: 2). Internal validation in research concerns the issue of whether the outcomes were made possible by the reported research design and its execution. Internal validity is at risk, but the key is to determine whether the findings are authentic despite the researcher's and the research method's biases. The assertions of internal validity are supported by data and logical justifications. External validity is the assertion that the findings are generalizable beyond the particular circumstance and setting of the study (Taylor 2013: 10–14).

In an essay for qualitative research evaluation, Andrew K. Shenton (2004) collected factors of credibility and connected creditability to internal validity and transferability to external validity. Shenton (2004) advocates triangulation as a strategy for enhancing the credibility and trustworthiness of research. Triangulation is the process of acquiring data utilizing a variety of techniques, a large number of informants, and a variety of sources (Shenton 2004: 63–66).

According to Saldana et al. (2011), credibility is correlated with the veracity of the author's study. Projects involving qualitative research require the presentation of strong evidence. Even so, we can never demonstrate the veracity incontrovertibly. Triangulation is another method recommended for generating confidence (Saldana et al., 2011: 135).

Triangulation was used in this study to ensure internal validity and creditability. In the current state analysis, Data 1 was acquired using a variety of techniques and resources. Data 1 was gathered through phone interviews and a study of the QMS documentation already in place. Data 2 was compiled through two theme interviews and one workshop during the stage of co-creating the initial recommendations. The Data 2 gathering was split up into numerous events to accommodate a broader audience. By incorporating the results of prior interviews into the next workshop, triangulation was also used.

The informants for Data 1 and Data 2 were chosen to represent all the case-related departments and functions. The informants were also selected at various stages of their professional careers, at various stages of their employment with the case company, and at various organizational levels. Participants included managers, technicians, and engineers from the relevant departments, with backgrounds spanning from a few months to several decades. The unit's senior management members who were chosen to participate in Data 3 each represented a different sector of the company.

7.3.2 **Reliability**

According to Shenton (2004), reliability addresses the issue of how similar results would be obtained if the study were repeated in the same setting using the same procedures and participants. The process used in the research should be described in full so that it can be replicated by other researchers in the future. As a result, a study report ought to contain information about the research design and how it was carried out, as well as a thorough evaluation of the project (Shenton 2004: 71–72).

The research design for this study is stated in Section 2.2, and the details of how it was carried out are given in each section of the report, including the literature review in Section 3, the analysis of the current state of the field in Section 4, and the formulation and validation of the recommendations in Sections 5 and 6. The data collection process is documented in detail, including all event dates, and themes. Additionally, section 7 of the study contains a thorough self-evaluation.

According to Creswell and Miller (2000), an audit trail can be used to improve the validity and transparency of research. An audit trail is created by accurately and chronologically documenting all data-gathering activities in a research log. If necessary, a thorough record enables the research's data to be audited by an outside party (Creswell and Miller, 2000: 128).

The author's field notes acted as an audit trail for all the data he observed, heard from sources, or read from already-existing records. All of the information in the field notes has a source, a context, and a location associated with it.

7.3.3 **Logic**

For this study, logic is assessed first for the chosen research strategy, then for the original project plan, and finally for the project plan's execution. Section 2 presents the research strategy and the project plan.

Because design research has traits that suit the objective of the study, it was chosen as the research methodology. The study's conclusion was supposed to be useful, functional, targeted at a particular business issue, and particularly applicable to the case company. It made sense to choose between applied research and design research. The four steps of the research design were assembled. Since the business issue related to the plant's overall equipment effectiveness, the pertinent literature from the best practices was initially evaluated. After process mapping, the current state analysis was carried out. The results of the literature were then used to jointly develop a list of case company-specific improvement ideas. The senior management then reviewed the recommendations to determine their viability, potential, and applicability.

In a nutshell, the logic is to identify the issue, determine the appropriate treatments, develop a precise solution, and validate it. And the study was carried out exactly according to the project plan's rationale.

7.3.4 **Relevance**

Stefano Mizzaro (1997) asserts that there are numerous varieties of relevance, not simply one. Relevance can be defined as the relationship between two items, such as an issue that has to be solved and a paper containing information. The information in the document and the problem's solution are now relevant to one another (Mizzaro, 1997: 811). The degree of the study's outcome's relevance to the case company is used to gauge its relevance.

Since the case company chose and established the initial business problem, relevance is evident in this study from the outset. The study is grounded in the need to address a real and recognised issue, not in some external concept or purported innovation. Consequently, the study's promise is relevant.

By including the major case company stakeholders in the data collection and outcome generation processes, the study's relevance is ensured throughout. Since every participant, respondent, and co-creator is involved in the process at hand, every stakeholder is relevant to it. By looking for information pertaining to the weaknesses of the current state analysis, relevance was found in the conceptual framework stage. Only literature that offered solutions for the issues that had been discovered were brought.

The senior management of the case company endorsed the initial proposals. The significance of the recommendations was taken into account during validation. Only one of a thorough set of nine initial suggestions was changed. The majority of the original suggestions were thought to be relevant to this study's objective. The recommendations are also much more relevant following the modifications made in response to senior management's validation comments.

Despite the fact that the objective of this study was to suggest an action plan for the process, Section 7.2 includes a suggestion for an implementation strategy. By taking into account the recommendations' relationships and order, the recommended implementation plan makes the study more relevant to the case company.

7.4 Closing words

As the organizations and the contexts evolve, processes also need to adjust. Even if an improvement may sometimes be delayed, it is still preferable than never. The improvement is frequently preferred as constant tiny moves forward with enough time to plan and check in between of doing and acting. An overall equipment effectiveness of the plant is an essential and crucial part for the business. It deserves routine care, maintenance, and attention. Now the first steps are taken with this study, leading to the next steps by adopting the recommendations.

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Appendix 1

Interview questions during current state analysis

1. Is there a process description of the company?

2. What is company strategy?

3. How do you get the input for your task?

4. What are your roles & responsibility?

5. How is company strategy alignment shown in the process?

6. How are the priorities defined to manage the tasks?

7. What are the loop faults in the process of your department?

8. What are the strengths of the process in your perception?

9. What are the weaknesses of the process in your perception?

First Piece Inspection Report Format

The Case Company					
First Inspection Report					
Raw Material	Part no	Process Sheet No		Batch Qty	Date
Shift	Operator Name	Machine Name	Set up No	Set up Time	
Sr No	Drawing Dimension	Observed Dimension			
		Operator	Supervisor	QC Inspector	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
	Sign				
	Approved By				
Remark If any					

Batch Production Inspection Report Format

The Case Company					
In Process Inspection Report					
Raw Material	Part no	Process Sheet No		Batch Qty	Date
Shift	Operator Name	Machine Name	Set up No	Set up Time	
Sr No of component	Drawing Dimension	Observed Dimension			
		Operator	Supervisor	QC Inspector	
1					
2					
3					
4					
5					
10					
15					
20					
25					
30					
	Sign				
	Approved By				
Remark If any					

Appendix 4

Preventive Maintenance Plan Format

PREVENTIVE MAINTENANCE PLAN																											
Sr No	Machine Name	Zone	Month	JAN				FEB				MARCH				APRIL				MAY				JUNE			
			Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	RADIAL DRILL	ASSEMBLY																									
2	HF-1	VMC																									
3	VF-7/1																										
4	VF-7/2																										
5	BFW TURNING	ROLL & SHAFT																									
6	CNC PINACHO																										
7	ATUL LATHE																										
8	COMPRESSOR	UTILITY																									
9	GENERATOR																										