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Thesis Report

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Production Development and Management

Developing a standard pre-setup procedure for machines

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Abstract

To succeed in the global market manufacturing companies, need to meet and satisfy customer demands rapidly and productively. Therefore, many manufacturing companies are implementing lean techniques and tools to reduce waste and achieve their production targets. The decrease in setup time process using pre-setup configuration helps in increase production rate and machine availability. The key rules of the pre-setup concept are to reduce time in the setup of the machine, decrease unnecessary transportation of setup tools and clear instruction for the machine setup operator. The pre-setup concept can be easily and quickly adopted into current setup process. The improvements from the pre-setup process can be noticed in machine availability and reduce in setup time process in a short period of time to achieve the targeted production rate. This research presents a methodology to assess the pre-setup process in a manufacturing system. This research is divided into two parts, wherein the first part the problems and area in which setup can be improved are identified and in the second solution for the identified problem is presented. The study is carried out using two research methods they are a literature review and case study. The literature review assessment criteria for each characteristic of pre-setup is noted down and solution for the identified problems are developed.

Keywords: Standard pre-setup, Pre-setup, SMED, Lean production

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1 Introduction

1.1 Background

"Manufacturing excellence" has become a vital part in attaining economic growth and for lasting in the globalized century (Jit Singh & Khanduja, 2009). The last century has transformed "industrial age" to "information age" which in industrial terms increases capability (Banerjee, 2000) and reduces product cycle times (Perry & Sohal, 2001). Eventually in the past two decades industries are witnessing technological innovations and doctoral of new managerial proposals (António & Gil , 2011). The technological innovations like automation, robotics, machines and Information technology has increased productivity by providing greater control and planning of operations. (António & Gil , 2011). After the world war II Toyota Motor Company developed a lean manufacturing model as an effort to reduce the manufacturing cost (Wahab, et al., 2013). This methodology is called lean production or lean manufacturing which uses less input and maximises the output of any manufacturing industry by decreasing lead times, increasing profit, reducing cost and improving quality (Karlsson & Åhlström, 1996). Further, (Jiunn & Taho, 2015) (Dusan, et al., 2017) (Mohammad, et al., 2015) (Ruiz-Benitez, et al., 2017) has shown lean manufacturing as a successful waste reduction technique (Kannan, 2017) (Kerga, et al., 2017) (Netland, 2016) (Allahverdi & Soroush, 2008) in increasing the productivity (Dusan, et al., 2017). The success of lean production techniques and plethora of tools available for waste reduction forced manufacturing industries to adopt lean production (António & Gil , 2011).

To reduce the set-up time (Shingo, 1985) has developed a Single Minute Exchange of Die (SMED) methodology, which is a process based innovation (Filip & Marascu-Klein, 2015). In this case study a standard pre-setup procedure is developed for quick changeover process by having SMED lean tool as a basis to improve productivity, availability of machines and to reduce lead time.

1.2 Problem description

The rapidly changing market, customer demands, and the need of customised products has added fuel to the buzz word shorter set-up time which is considered to be a vital part of any manufacturing industry's production process (Jit Singh & Khanduja, 2009). Therefore to meet customer and market demands manufacturing industries are trying to produce smaller lot size in an economical way with reduced set-up (Cakmakci, 2009) and lead-time (Spann, et al., 1999). This could be made possible if the set-up process is quick and efficient.

Despite many attempts in reduction of setup time, some companies fail to adopt lean techniques, where in fact, two out of three companies fail in implementing lean project (Netland, 2016). In a survey, where 70% of American manufacturing companies adopted lean projects, only one in four was satisfied with the results (Pay, 2008). Author (Pavnaskar, et al., 2003) suggests three types of misapplications in adopting lean culture,

- Wrong tool selection
- Multiple application of tools to a single problem
- Usage of same tools to all problems

(Cakmakci, 2009) has classified lean tools according to its applications as in Fig 1.

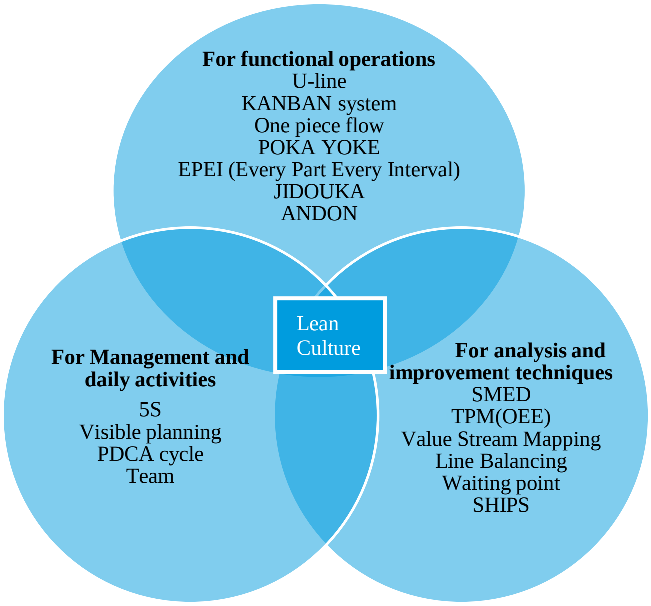


Figure 1 Classification of lean tools (Cakmakci, 2009)

Studies have suggested many ideas to overcome this failure, one of them is standardisation of pre-setup process to eliminate or reduce non-value-added activities during the setup process (Arai & Kenichi, 1998).

1.3 Purpose and research questions

Aim: The purpose of this thesis is to explore the pre-setup process to improve productivity and efficiency.

Research questions:

Research question 1 is formulated to study and understand the pre-setup and setup activities that directly affects setup time.

1. What are the non-value-added activities involved in the pre-setup and setup processes?

Research question 2 is framed to explore and identify the possibility to reduce the overall setup time.

2. How can the pre-setup and setup processes be more efficient?

1.4 Delimitations

This is a single case study carried by considering the following limitations. Firstly, machining and set-up tools for the machines are adequate. Secondly, sharing of machine tools is avoided. In addition to this, frequent set-up changes in short intervals, oversized set-up tools and tool life are not assessed in this case study. This study is also limited to manufacturing industries using CNC machines and the results will vary in the similar firms due to the different production processes.

2 Theoretical background

2.1 Lean Production

Lean production is a successful Japanese model originated from the Toyota production system which predominantly reduces the wastes in the production processes by identifying and eliminating the non-value added activities (Rahman & Karim, 2013) (wahab, et al., 2013). The non-value-added activities are the time spent in the production process that does not add any value to the finished product for which the customer is willing to pay (Tyagi, et al., 2015). Lean production strives in achieving zero wastage of time, funds and resources to maximise productivity and profitability in any business (Hill, 2018). According to (Hill, 2018) the seven different wastes are prevailing in production process and are described below.

a. **Transport**- Unnecessary transportation of raw materials, finished products and work-in-process which does not add any value to the product.
b. **Inventory**- Excessive storage of raw materials, work-in-progress and finished products than the immediate needs which does not add any value to the end-product.
c. **Motion**- Unwanted movement around the workplace that contributes in yielding non-value added time.
d. **Waiting**- Work-in-progress waiting for next production process leading to non-value added time.
e. **Overproduction**- This refers to the production of goods prior to the required period and it considered to be a serious waste as it disguises other inefficiencies in the system.
f. **Over processing**- This waste involves more processes than the actual requirements to meet the customer demand. Oftentimes, identifying and eliminating this waste is tedious.
g. **Defects**- Producing defective parts yields high rework cost or scrap rate.

Despite these wastes **8th waste** is newly identified as **poorly used talents** and the costs associated with it. (Dileep, 2014) frames the principles of lean as,

a. Elimination of waste by identifying non-value added activities and removing them to maximise the use of available resources (space, human, money), Just-in-time inventory and wiping off safety nets.
b. Achieving flexible production systems for producing mixed products with greater efficiency even at low product volumes with quick set-up process and production of small unit sizes.
c. Carrying continuous improvement activities for cost reduction, improving productivity and quality by stimulating dynamic change process , concurrently managing product/process development.

2.2 Single Minute Exchange of Die (SMED)

The single minute exchange of die came into existence to reduce the complexity and time involved in the setup process which was developed by Toyota Production System (Shingo, 1985). This is also coined as quick changeover of tools and it follows a scientific approach compatible to any industrial machines to cut down the setup-time (Moreira & Silva Pais, 2011)The goal of practicing SMED is to maintain setup-time below ten minutes. Practically, achieving this goal has become highly tedious due to the time constraints and unavailability of the resources (Moreira & Silva Pais, 2011).

The implementation stages considered in SMED are: (Moreira & Silva Pais, 2011)

- Analysing operations involved in setup process
- Differentiating internal & external operations

    1. Internal operations: The setup activities which can be carried while the machine is stopped.
    2. External operations: The setup activities can be carried simultaneously while the machine is running (Bin, et al., 2014).

- Transforming internal to external operations
- Optimizing the setup operations in a such way that can be done safely and rapidly
- Evaluating the methodology impact

The implementation model of SMED before and after improvement is shown in table 1 and table 2.

Table 1: Example of Internal & External Setup Activities Chart (Before Improvement)

S.no	Activities	Average time (in mins)	Preparation	Replacement	Adjustment	Internal	External
1	Stop machine	6		☑		6	0
2	Loading program	26		☑		26	0
3	Removing pins	35		☑		35	0
4	Thickness measurement	16	☑			0	16

The improvement activities are developed having the ECRS as a basis which is an inherent part of the SMED (Adanna & Shantharam, 2013). According to (Adanna & Shantharam, 2013) the definition for ECRS is as follows.

Eliminate – This term suggests in eliminating all unwanted movements and activities. For instance, waiting for raw material, machine setup and programming the machine.

Combine- The term combine suggests performing activities parallelly to save time. For example, loading the program and picking the tools can be done together.

Rearrange/**R**educe – This results in reduction of activities. For example, reducing the number turns in bolts.

Simplify – Simplification suggests breaking down complex activities and simplifying them by combining and rearranging to save time.

Table 2: Example of Internal & External Setup Activities Chart (After Improvement)

S.no	Activities	Improvement terms				After improvement			
		Eliminate activity	Organize externally	Reduce setup	Reduce/eliminate	Change in activities	Time	Internal	External
1	Stop machine					No change	6	6	
2	Loading program				☑	Modify program	12	12	
3	Removing pins		☑			Performed externally			
4	Thickness measurement	☑				Eliminated	0		0

SMED's are widely used in industries because they aim in achieving increased productivity by reducing setup time (José, et al., 2016).

2.3 Spaghetti Diagram

Spaghetti diagram is a simple tool to visualize the movement of men and material (Tanco, et al., 2013). The objective of spaghetti diagram is to reduce transportation waste and to increase the floor space (Wilson, 2010). These diagrams are drawn using a simple floor layout to indicate the movement of both men and material by taking notes or by filming the motion (Wilson, 2010).

2.4 5S

One of the important lean tool practiced in the industry is 5S, which involves the continuous improvement process for sustaining the changes they attain to strive for excelling in overall organizational performance (Omogbai & Salonitis, 2017) The 5S follows a sequence of activities to make a safe work place with reduced failures and break losses like machine breakdown, thereby improving the quality of the work environment.
5S stands for five steps or activities for a safe and efficient work place, such as: (Filip & Marascu-Klein,, 2015) & (Gomes, et al., 2013)

SORT: Set the required tools in-order for providing easy access by identifying the necessary and unnecessary tool and preserving the important documents that are associated with the ongoing tasks.
SET: Labelling the storage area for tools which avoids misplacement of tools and looking for right tools. This act minimises the operator's motion as the tools are placed in an area where they are efficiently used.
SHINE: The workstation and tools used should be kept clean. Cleaning schedule should be developed by answering the questions what, when and how the tools and equipment's should be cleaned it should be cleaned.
STANDARDIZE: Documenting the work and integrating 5S as a culture within the organization.
SUSTAIN: Cultivating the habit of continuous improvement.

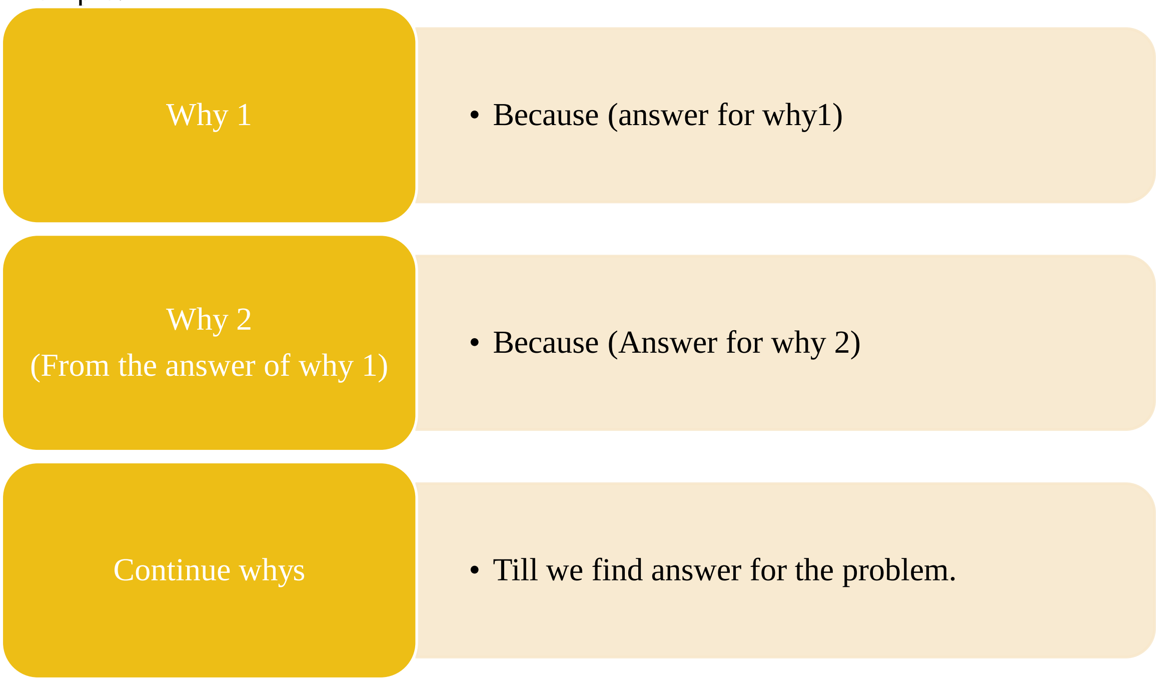
2.5 5 Why Analysis

The 5-whys is a method used in root cause analysis in which they ask repeatedly "Why?", from which problem is broke down from higher level symptoms to identify root causes (Card, 2016). 5-whys is one of the techniques used in the analysis phase of Six Sigma (Gangidi, 2018). 5-whys is most useful when problem have involved human interaction in it (Perry & Mehitretter, 2018).

Method to carry out 5-why analysis (Gangidi, 2018) (Perry & Mehitretter, 2018):

- Note down the complete problem happened to keep the analysis on track and help to analysis the root cause even more effectively.
- Note down why that problem happened and write the answer besides.
- If the provided answer from the why doesn't provide the actual root cause then ask again why for the given answer.
- Continue the process until you find the actual root cause for the problem formulated. This may take fewer or more than 5 steps to identify the root cause.

Example:



2.6 U-line

According to (Arai & Kenichi, 1998) a standard pre-setup table is designed as follows.

The necessary tools and materials required for the machine set-up is gathered by following an operator performing the machine set-up. In this case, this is done during the SMED analysis of the current situation. Then from the SMED analysis of the current situation, activities which can be done before the set-up process are listed and a layout is designed for the pre-setup process and an experienced person is trained to collect all the tools and equipment's required for performing the setup process. Generally u-shaped pre-setup layout is preferred for better visualisation, but it can be designed according to the plant layout. The pre-setup process should be done a day before the set-up process.

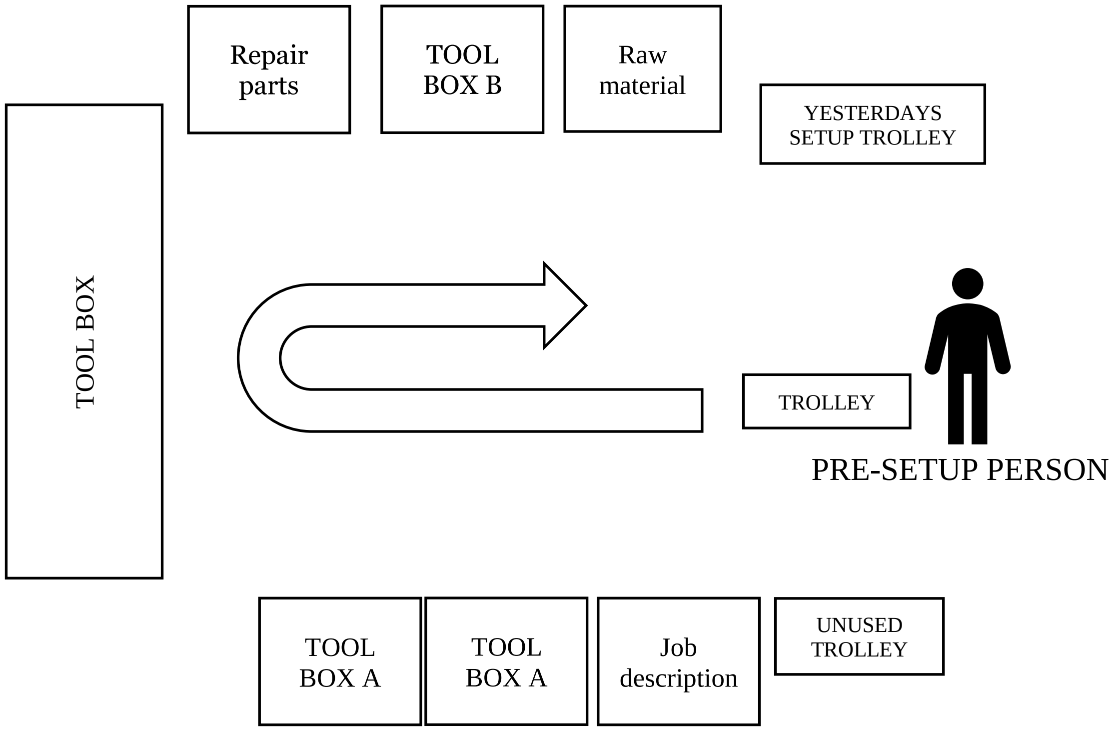


Figure 2 U-shaped layout of the pre-setup process (Arai & Kenichi, 1998)

3 Method and implementation

3.1 Research process

The research process initially started with a discussion with the production manager presenting the ideas of the case study, with the further interest on the topic a proposal was developed and sent to the case company to be approved by the production manager. The proposal consists a detailed plan of the case study describing the data collection from the shop floor and analysis of data along with the time plan. Agreeing the proposal mutually the designed case study is conducted.

3.2 Literature Study

Literature study is carried into two phases, in the first phase textbooks and encyclopaedias on relevant fields were studied to understand the broader aspect of the project area. In the next phase, peer-reviewed journals form the library database (primo), google scholar, Scopus and science direct were studied to get the insights of the project area.

3.3 Relation between research questions and method

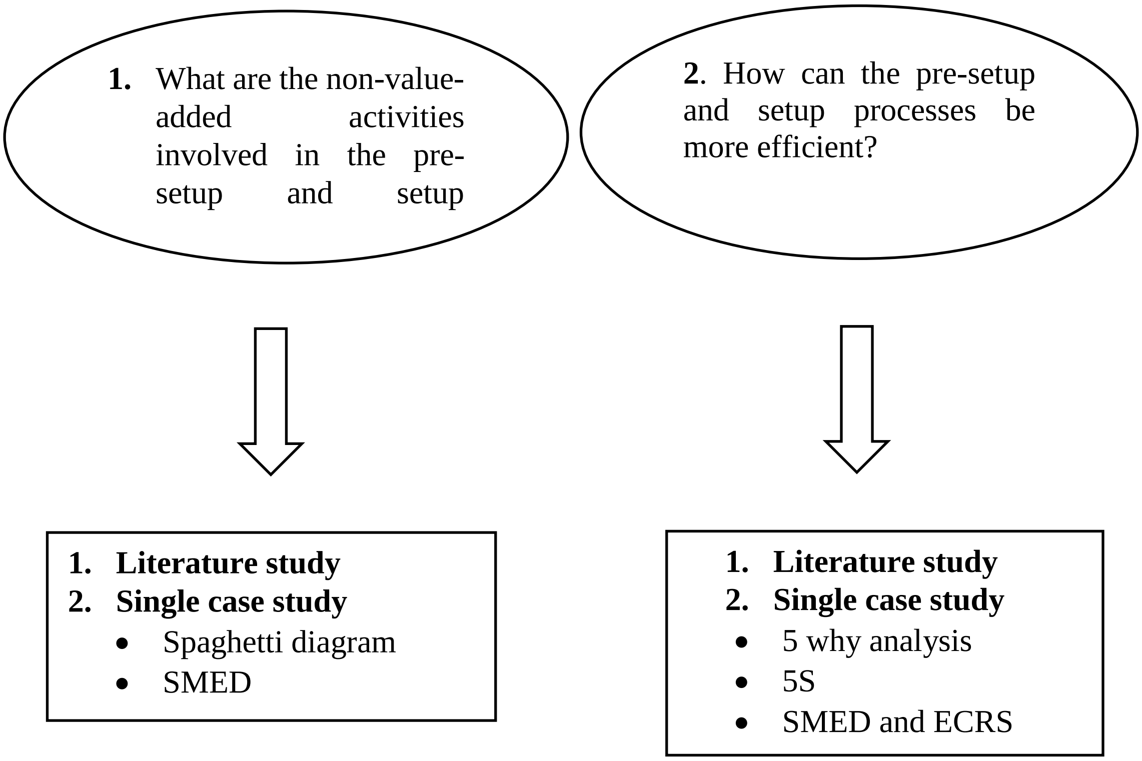


Figure 3 Relation diagram between research questions and method

The research questions are answered by conducting a literature study as mentioned in the section 3.1. Further, the literature study has gained the required theoretical background for this research topic. Empirical data is collected by conducting a case study using the SMED and spaghetti diagram lean tools for answering the first research question. For the second research question, 5 why analysis is used for finding the root cause and SMED is used along with ECRS. Finally, 5S is used in parallel as a standardisation tool.

3.4 Research approach

This research approach is framed to deductive as the theories studied are compared to the real-life context to draw conclusions about a phenomenon (Williamson, 2002).
Since the aim of thesis is to explore the pre-setup process to improve productivity and efficiency, the data’s collected are both qualitative and quantitative. The research is predominantly quantitative but qualitative approach is also applied to elucidate the numerical data. Thus, the study will be a combination of both quantitative and qualitative data.

3.5 Case study

Case study is a method that helps the researcher to study the phenomenon under investigation in its real-life context (Yin, 2003). A case study allows to use myriad methods for collecting the evidences in approaching the research question, which typically depends on the researcher’s view towards the problem. This strategy is appropriate when an in-depth understanding of the studying phenomenon is required whilst, retaining the holistic characteristics of real-life-events (Philan, 2011).

The substantial problem faced by the case company processing products from metal pipes is the increased setup time in their highly mixed production lines. The production manager of the case company has identified two main causes for the problem. Firstly, lack of knowledge prevailing among the operators and production leaders in understanding the difference between setup and pre-setup process. Therefore, the work performed by them is done from their experience and not by understanding the setup and pre-setup activities scientifically. Secondly, the absence of standard procedure in performing setup and pre-setup activities.

After analysing the case description and formulated research questions, the knowledge about the case is found to be inadequate. Thereby, also considering the complexity indulged in the problem a single case study methodology is selected to be appropriate for answering the research questions in the limited span of time. Hence, a Swedish medium scale company experiencing the setup related problems is chosen as the case company for carrying this project in its natural setting.

3.6 Data collection

The data collected for the research is classified into primary and secondary data. Primary data´s are the foundation of the research and secondary data´s are useful for our own work. Primary data´s are collected through interviews, questionnaire, measurement and observations. Secondary data are collected from the company reports, documents which are publicly available.

3.6.1 Observation

Observation is preliminarily carried in the natural setting of the phenomenon of study to gather enough background information before the start of data collection (Williamson, 2002). During the observation activity, a pen and note is used for taking down notes regarding the shop floor activities for later adding them in the interview questions.
Observing shop floor activities: While visiting the shop floor basic understanding about different departments and the process associated with them were gained. The machines in the shop floor were visited while functioning and the machine operators

were using a computer synced with the Computer numerical control machines (CNC) were noticed. While further enquiring about the activity, operator informed that it's a software used for measuring Overall equipment effectiveness (OEE) of machines. Data´s are feeded by the operator whenever the machines are stopped with the reason for stopping. Then, the software processes the data given and generates a machine availability report for a day, week, month or for a year as shown in **Figure 4**.

Observation of S01 set-up process: After the completion of interviews, the set-up process of S01 is entirely video filmed from start till the end. A video camera was used by one author to film the set-up process and other author was drawing the spaghetti diagram to capture set-up person movements to different stations.

3.6.2 Interview

Interviews are frequently used techniques for collecting qualitative data in case studies (Williamson, 2002). The understanding of people's point of view is easy through interviews in a naturalistic approach.

3.6.2.1 Semi structured interview

Semi structured interviews were conducted with production manager, production leader and Set-up person prepared with a standard list of questions which also included questions a raised after the observation of shop floor activities. By conducting semi-structured interview, interviewee has the freedom to express their views on the questions in expansive manner and raise further topics relating to it (Williamson, 2002). The answers from the interviewee are taken down in the notes and later transcribed into the single word document created. **Table 3** contains the interview details used in this research.

Table 3 Interview table

Interviewer	Interviewee	Place	Type of Interview	Duration of Interview (in minutes)
Author 1&2	Production Manager	Cabin	Semi-structured	45
Author 1&2	Production Leader	Cabin	Semi-structured	35
Author 1&2	Set-up person	Shop floor	Semi-structured	20

3.6.3 Secondary data

Secondary data´s are the foundation for our own work. Collecting secondary data is the collection of facts from the previously available company data for decision making.

Production software data: The machine reports are generated from the production software after the completion of interview and observation session. The inputs to the production software are constantly feeded with the reasons for starting and stopping the machines. Therefore, machine reports are automatically generated for a day, month, week or year. For this research, a monthly report of the machine S01 was generated with the help of production manager to visualise the monthly machine performance statistics.

3.6.4 Data analysis

The notes taken from the interview results are transcribed into a single word document. The authors find the relation between different respondents' answers and establish conclusions with their interpretations.

The data obtained from the observation video of the set-up process is the most critical data analysis in this entire research as it has both qualitative and quantitative data. For transcribing these data an excel sheet is created as shown in **Table 1**. The video-film of the set-up process is viewed by both authors and the set-up process is critically examined with the relevant theories to fill the excel sheet (Moreira & Silva Pais, 2011). After this, duration time of the set-up video and total time entered in **Table 4** are verified to be the same. This check ensures that all the captured set-up activities are transcribed properly into individual activities. Then the listed activities in **Table 4** are grouped under pre-setup, set-up & quality which breakdowns the entire set-up activities into easily interpretable manner with the time and their corresponding percentages (Adanna & Shantharam, 2013). To understand the demographics and performance parameters of production, several semi-structured questions were asked via interviews. All the interview questions are listed under appendix 1. Further analysis of the collected data is carried out using certain standards and tabulating the results. The improvements of the current set-up process are created using the standards which we obtained out of extensive theoretical background (refer **Table 5).** Thereafter, **Figure 6** showing the SMED analysis results of S01 before and after improvements are like **Table 4 & Table 5** including the percentage and time of eliminated activities. This shows that the identified non-value added activities which are either eliminated or preponed to the pre-setup process is all accounted to achieve the same total set-up time of the current set-up process.

3.6.5 Validity and reliability

According to (Williamson, 2002) these terms considered to be complicated in nature when put under explanation or investigation. Despite this (Williamson, 2002)**,** has given two simple definitions for the term's validity and reliability. **Validity** in measurement means, whether the conducted research measures the intended thing according to its design (Williamson, 2002). **Reliability** is defined as the consistency in results when the research is repeated (Williamson, 2002).

In this research data collection is gained through all the primary and few secondary data collection techniques which makes the collected data to be validated and cross checked for the authenticity. During the primary data collection phase interviews, and observation are used to gather the required data. Then, secondary data is collected from company sources in the form machine reports. Finally, the primary and secondary data are systematically analysed in relation to the literature study outcomes as a way of scientific approach.

The research we carried out results in higher internal validity since the major data collection technique used is observation through Video recording. If the suggested improvements are incorporated the firm will successfully optimize the set-up process, having said that the results cannot be generalized since the resulted data corresponds to the selected case. Achieving the results repeatedly with the similar technique give rise to higher reliability, in our case of research the set-up time would remain more or less the same if no improvement strategies are considered. Therefore, we can conclude that the results are reliable in nature and can be replicated in an isolated condition which is specified with boundary parameters. The same technique can be incorporated to check if the firm has optimized its setup process once the company introduces changes in the approach of set up process.

4 Findings & analysis

4.1 Case description

To justify the problem stated by the case company, preliminary research & analysis carried in the OEE measuring software (AXXOS) used by the case company which revealed pie charts containing machine availability reports with the reasons for machine's downtime. Our objective is to consider a machine named SO1 and validate the results to the machine alone.

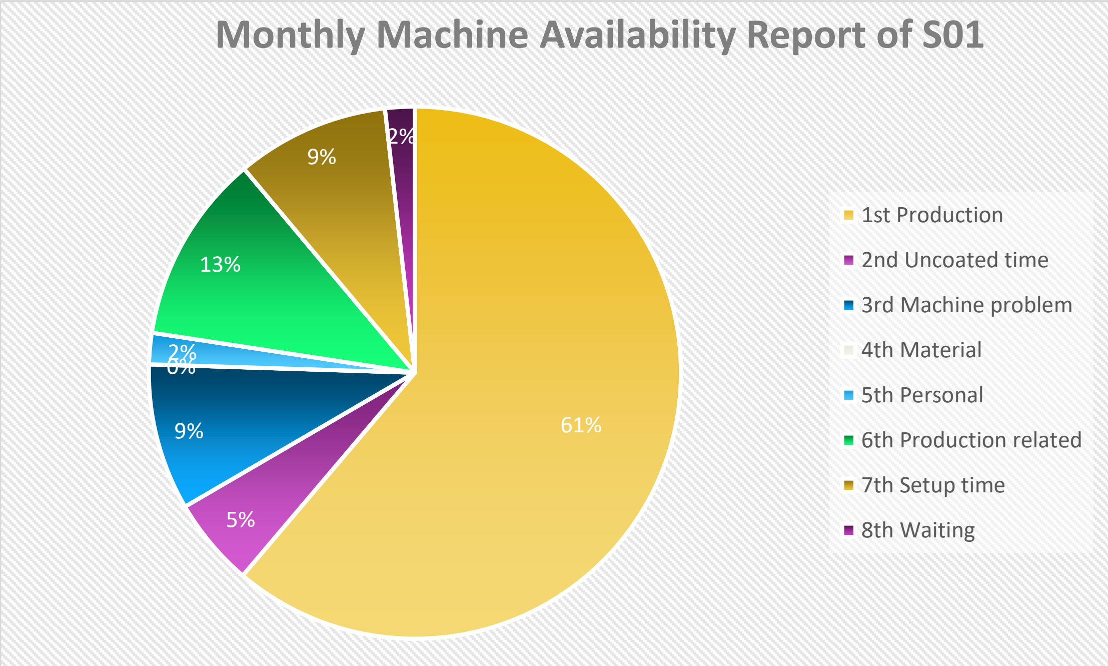


Figure 4 Monthly machine availability report of S01

The **Figure 4** represents monthly machine availability report of S01 and the machine availability is found to be 61% from the generated company report. The reasons for decrease in machine availability is majorly due to production related problems and maintenance of machine which owes to 13% and 9% in affecting the availability of machines. The least factors responsible for the machine unavailability are unquoted time (feed data input to the computer synced to the machines), shortage of personals and unnecessary waiting related problems which are 5%, 2% & 2% respectively. As the aim of thesis is to create a standard pre-setup procedure, set-up problem contributing 9% of machine unavailability knit together with the machines is studied by conducting SMED analysis of the set-up process.

4.2 Analysis of S01 set-up process

The current set-up process of the S01 is analyzed using the SMED and spaghetti lean tools. The spaghetti diagram as shown in **Figure 5** envisions the set-up person and material movement from start till end of the set-up process in S01.

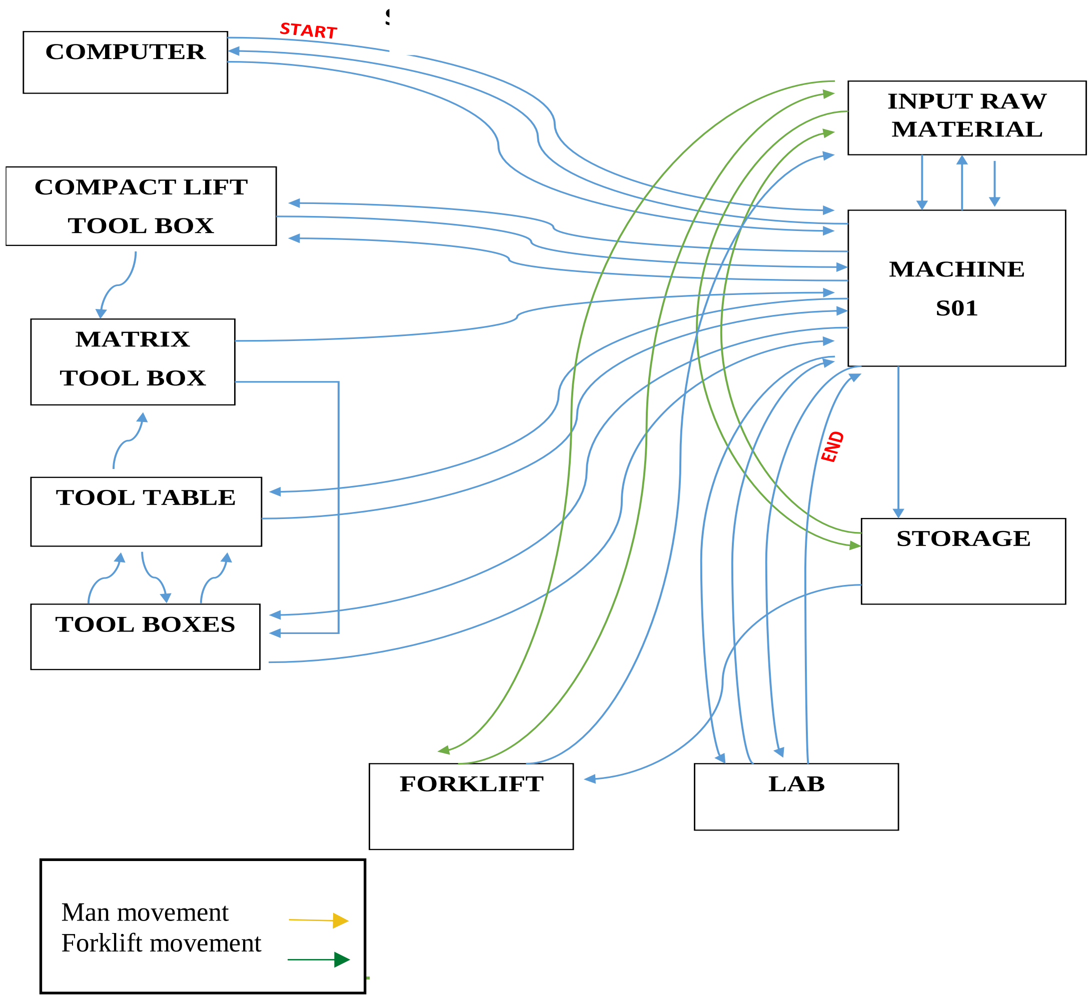


Figure 5 Spaghetti diagram of the current set-up process (operator and transportation movement)

Then, **Table 4** depicts the sequential activities happening at each station as shown in **Figure 5** of the S01 set-up process, with the time consumed for each activity. Following this, the set-up activities of S01 are classified into five different categories preparation, replacement, adjustment, internal and external activities respectively.

As a first in the setup process, the set-up person of S01 accesses MONITOR ERP planning software and prints the following sheets entering the job order number,

- CAD drawing
- Tool mounting procedure sheet
- Raw material calling sheet.

CAD drawing: The CAD drawing contains specifications of the job as per customer requirements and places for two approval signatures for the production ramp up. After producing a part, the set-up person and another operator will measure one by one to see, whether the produced part meets the specifications in accordance with the provided CAD drawing.
Tool mounting procedure sheet: This sheet contains the list of tools required for producing the job, their positions on the turret, shafts, storage location and quantity required.

Raw material calling sheet: The information's about the raw material needed for the job and location in the storage area is available in this sheet.

The set-up person carries these sheets to S01 and sticks the CAD drawing sheet to the work table wall and the tool mounting procedure sheet on the CNC protection cover. Then the set-up person checks whether the space is free for storing the new job's raw material and in this scenario, the space is occupied by an empty pallet used for the previous job. At last, set-up person codes the reason for stopping S01 in the AXXOS monitor system before starting the next set-up activities.

Unmounting and mounting of tools, shafts and chuck collets: Before proceeding with the unmounting activities, set-up person ensures that there is no previous job's raw material left in the S01's chuck. Following this, set-up person detaches the feeder unit from S01 to unmount the shaft coupled with the chuck and walks to the Compact lift tool box with the old shaft. He then enters the job order number in a monitor synced with the compact lift tool box and picks the new shaft by measuring its diameter as mentioned in the tool mounting procedure sheet. Again, the set-up person walks back to S01 and starts mounting the new shaft to the chuck, finally attaches feeder unit to S01 after mounting. In the next step, chuck collets in the head stock and tail stock is demounted. The set-up person repeats the same activity as he did for replacing the shaft and additionally walks to the matrix tool box for collecting turret tools. Here, the set-up person enters the tool calling details in the system one-by-one by seeing the tool mounting procedure list. Further, set-up person returns to S01 for mounting chuck collets and turret tools according to the tools mounting procedure sheet. While mounting the tools, fixing a new drill bit the set-up person walks to the workstation near the matrix tool box for using tool fixtures and then continues to mount the drill bit in the turret. In need of a hammer tool required in the mounting process, set-up person walks again to the workstation and backs to S01 for continuing to mount tools.

Referencing the turret tools: After mounting all the turret tools, reference point for each turret tool is set in alignment to the head stock and tail stock. For doing this, set-up person moves turret tools to the head stock and tail stock until it touches the piece of paper held there. Once the motion of paper is hindered by the turret tools, set-up person feeds the reference point in the CNC program. Now, set-up person sends the CNC program to S01 and checks the functioning of the program to ensure feed rate, flow of coolant and the sequence of operation.

Raw material: To feed the raw material, set-up person identifies the location of raw material from the raw material calling sheet. For transporting raw material pallet, fork lift is accessed and is placed in the marked place near the feeding unit of S01.

Producing components: The set-up person loads the raw material and feeds them to the CNC. Whereas, input feed of raw material is calculated manually, and the first component is produced. A standard quality procedure is followed producing a new component and its repeated until it meets the specifications as in the CAD drawing sheet. Firstly, the set-up person measures the first produced component with Vernier and then goes to lab for measuring the angle. In this process, the specifications were different, and the set-up person adjusts the program accordingly. This is done twice since the second produced component did not match the specifications. At last, third good component met the requirements and it's verified by another operator by repeating the same procedure. Finally, the operator approves to start the production by signing the job sheet.

The need of 5S is clearly indicated by the activities 4,7,10, 11 & 13. During these activities set-up person doesn’t have a place for storing the removed tools, especially in the activities 11 & 13 fixtures and a hammer tool is not readily available near S01. In the other activities 4,7 & 10, set-up person replaces the removed shaft and chuck collets with new ones. Additionally, set-up person also brings the turret tools required for the current job from the matrix tool box, while returning chuck collets in the compact tool lift. These are carried in hand and shredded in the table close to S01. The quantity of tools picked depends on how much a set-up person can carry in his hand which clearly depicts the need of 5S.

Table 4 SMED analysis of current setup process

Sr No		**Time Taken**		**Classification of activities**				
	Activities	Start	End	Preparation	Replacement	Adjustment	Internal	External
1	Printout of product details from computer	00:00:00	00:01:06	•			00:01:06	
2	Adjusting tool turret to home position	00:01:06	00:01:34			•	00:00:28	
3	Checking space for raw material	00:01:34	00:02:30	•			00:00:56	
4	Unmounting shaft from the chuck	00:02:30	00:06:19		•		00:03:49	
5	Replacing the old shaft with the new one	00:06:19	00:08:16	•			00:01:57	
6	Mounting new shaft to the chuck	00:08:16	00:11:46		•		00:03:30	
7	Removing chuck collets	00:11:46	00:15:50		•		00:04:04	
8	Replacing old chuck collets with new ones and collecting required turret tools	00:15:50	00:19:55	•			00:04:05	
9	Mounting new chuck collets	00:19:55	00:22:42		•		00:02:47	
10	Unmounting & mounting new turret tools	00:22:42	00:31:10		•		00:08:28	
11	Inter changing drill bit	00:31:10	00:38:32	•			00:07:22	
12	Mounting new drill bit	00:38:32	00:46:23		•		00:07:51	
13	Getting hammer (Adjustment tool)	00:46:23	00:46:48	•			00:00:25	
14	Continue in fixing new turret tools	00:46:48	00:49:47		•		00:02:59	
15	Adjusting tool reference points	00:49:47	00:58:10			•	00:08:23	
16	Sending programme to machine from computer	00:58:10	01:00:21	•			00:02:11	

17	Checking the program and adjusting	01:00:21	01:09:47			•	00:09:26	
18	Removing previous raw material pallet and getting new raw material	01:09:47	01:16:27	•			00:06:40	
19	Feeding raw material	01:16:27	01:16:44		•		00:00:17	
20	Machining & Checking 1st piece	01:16:44	01:22:22	•			00:05:38	
21	Adjusting programme	01:22:22	01:29:20			•	00:06:58	
22	Checking 2nd piece in lab (Angle & Radius)	01:29:20	01:35:53	•			00:06:33	
23	Adjusting program	01:35:53	01:37:31			•	00:01:38	
24	Checking 3rd piece and approved 'ok' by setup person	01:37:31	01:40:12	•			00:02:41	
25	2nd setup man checks 4th piece	01:40:12	01:41:58	•			00:01:46	
26	2nd setup man checks in lab (Angel & Radius)	01:41:58	01:45:50			•	00:03:52	
27	Approval to start production	01:45:50	01:46:16	•			00:00:26	
	Total Time		**01:46:16**				**01:46:16**	**00:00:00**
Note - Cells highlighted in yellow represents external activities								

4.3 Improvements in the current setup-process of S01

In the set-up process of S01 improvements are carried as shown in **Table 5.** The identified set-up activities are analysed with improvement terms eliminate activity, organize externally, reduce set-up and reduce/eliminate which is combinedly called as ECRS technique. By doing these eight external activities (1,3,5,8,11,13,16 & 18) are organized externally in the pre-setup process.

Since, eight activities are identified to be organized externally a pre-setup procedure is needed to be developed to standardise the set-up and pre-setup process. The development process of standard pre-setup procedure is explained in the following sections in detail.

Table 5 Improvements of current setup-process

S.no	**Activities**	**Improvement terms**				**After improvement**			
		Eliminate activity	**Organize externally**	**Reduce set-up**	**Reduce/Eliminate**	**Change in activities**	**Time**	**Internal**	**External**
1	Printout of product details from computer		✓			Performed Externally	00:01:06		00:01:06

2	Adjusting tool turret to home position					No-change	00:00:28	00:00:28	
3	Checking space for raw material		✓			Performed Externally	00:00:56		00:00:56
4	Unmounting shaft from the chuck					No change	00:03:49	00:03:49	
5	Replacing the old shaft with the new one		✓			Performed Externally	00:01:57		00:01:57
6	Mounting new shaft to the chuck					No change	00:03:30	00:03:30	
7	Removing chuck collets					No change	00:04:04	00:04:04	
8	Replacing old chuck collets with new ones and collecting required turret tools		✓			Performed Externally	00:04:05		00:04:05
9	Mounting new chuck collets					No-change	00:02:47	00:02:47	
10	Unmounting & mounting new turret tools					No-change	00:08:28	00:08:28	
11	Inter changing drill bit		✓			Performed Externally	00:07:22		00:07:22
12	Mounting new drill bit					No change	00:07:51	00:07:51	
13	Getting hammer (Adjustment tool)		✓			Performed Externally	00:00:25		00:00:25
14	Continue in fixing new turret tools					No change	00:02:59	00:02:59	
15	Adjusting tool reference points					No-change	00:08:23	00:08:23	
16	Sending program to machine from computer		✓			Performed Externally	00:02:11		00:02:11
17	Checking the program and adjusting					No-change	00:09:26	00:09:26	
18	Removing previous raw material pallet and getting new raw material		✓			Performed Externally	00:06:40		00:06:40
19	Feeding raw material					No-change	00:00:17	00:00:17	
20	Machining & Checking 1st piece					No-change	00:05:38	00:05:38	
21	Adjusting program	✓				Eliminated	00:00:00	00:00:00	
22	Checking 2nd piece in lab (Angle & Radius)					No-change	00:06:33	00:06:33	
23	Adjusting program	✓				Eliminated	00:00:00	00:00:00	
24	Checking 3rd piece and approved 'ok' by setup person					No-change	00:02:41	00:02:41	
25	2nd setup man checks 4th piece	✓				Eliminated	00:00:00	00:00:00	

26	2nd setup man checks in lab (Angel & Radius)	✓				Eliminated	00:00:00	00:00:00	
27	Approval to start production					No change	00:00:26	00:00:26	

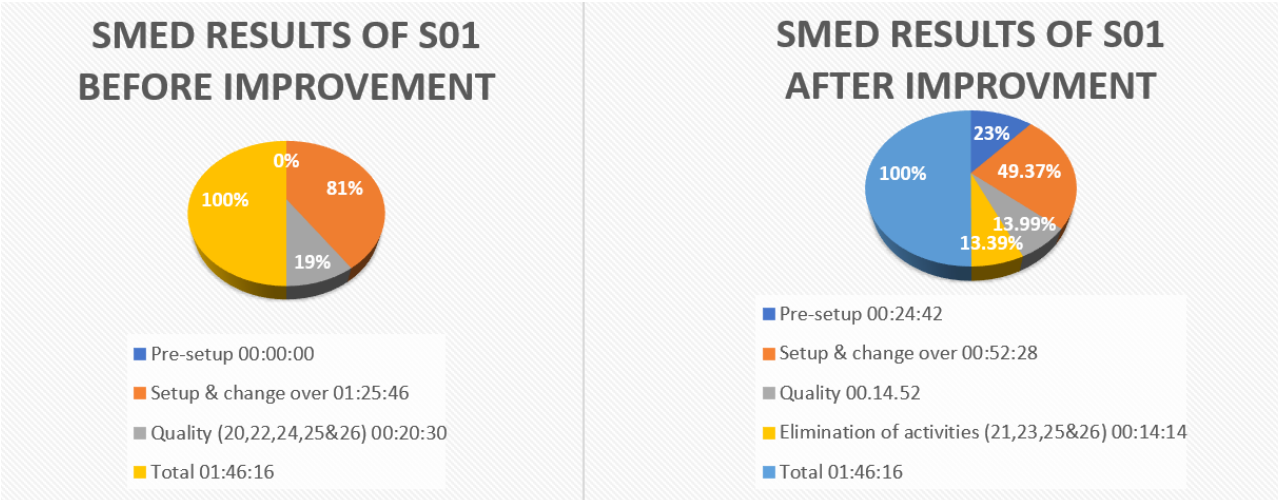


Figure 6 SMED results of S01 before and after improvement

Figure 6 depicts the difference between before and after improvements state of S01. From **Figure 6** the absence of pre-setup process in the current set-up process can be concluded and **Table 4** findings has also highlighted external activities present in the S01's current set-up process**.** These two factors act as important catalysts to develop a standard pre-setup process. Following this improvement techniques are applied to the current set-up process and expected improvement results are calculated as shown in **Figure 6.** As a result, 23% of set-up process activities which is the resultant of identified external activities are planned to be performed in the pre-setup process. During this improvement process, activities 21,23,25&26 are eliminated as these are repetitive and quality related issues contributing non-value added activities. This elimination of activities drops the set-up & changeover to 49.37% and quality related activities to 13.99% from 81% & 19%.

4.4 5-Why analysis on the Pre-setup problem

Problem statement

Operators can't find or search for tools required for machine set-up, which leads to decrease in machine availability.

Why	Answer
Why 1 Why operators waste time for searching tools.	• Because they don't keep tools back where they belong.
Why 2 Why operators don't keep tools back where they belong.	• Because they think its required later or as a waste of time in collecting tools for next job.
Why 3 Why operators don't keep tools back even if they don't know whether they will use it or not in future.	• Because they think pre-setup is a part of setup process, so no idea what pre-setup requires.
Why 4 Why operators don't know what pre-setup requires.	• Because they can't recognize or see the essiential of it in their eyes.
Why 5 Why operatot can't see in their eyes.	• Because no pre-setup or standard procedure for pre-setup is practiced.

Conclusion
Pre-setup should be organised in a standard layout depending on the company's production and raw materials used, in such a way that any one can understand the instructions easily. Therefore, one designated operator for pre-setup must be asigned.

5- why analysis method is used on problems identified from the SMED process. The problem identified was “why the operators can’t find or search for the tools required for setup of the machine, which leads to a decrease in a machine availability.” The continues 5-Whys was asked about the identified problem to find the root cause of the problem. The conclusion obtained by 5-Whys analysis was “Pre-setup should be organized in standard layout depending on the company’s production and raw material used, in such a way that anyone can understand the instructions easily. One designed operator for pre-setup must be allocated”. There are three major outcomes from this conclusion.

4.4.1 Pre-setup must be organised in a standard layout depending on the company
This solves the problem of searching for the tools in different places in the company, which leads to a decrease in searching time and unnecessary transportation within the company. Standard layout helps the operator to collect the required tools for setup at once or twice depending on the type of setup and tools used for setup. Standard layout helps the operators to identify or collect the information of missing tools or damage tools and easy to place an order for new tools required in future. This even helps to arrange or place the new arrival tools arriving in the tool storage. This standard layout

must be designed depending on the type of manufacturing and tools used. Example: frequent setup process or heavyweight tools used for the setup process.

4.4.2 Standard layout in such a way that anyone can understand the instruction easily

This is one of the important parts while designing the standard layout in the company because it's important that the operator understands the layout easily and quickly. It may be a new operator or operator from another department can come to collect the tools required for setup process, if he or she can understand the storage area easily then waste of time in searching and dislocation of tools will be avoided. A chart or information board must be placed before the storage area so that the operator will understand where to collect the tools and return it back after the usage. Standardized layout even helps the team leader or production developer to identify any problems in a storage area or comparison with another department during continues improvement process.

4.4.3 One set-up person for pre-setup

One set-up person is allotted for carrying the pre-setup to avoid the following,

1. Reduced time for collecting tools from storage.
2. Eliminate the misplacement of tools.
3. Proper follow up for the new tools required and damaged tools.
4. Decreases or eliminates buffering of return tools.

4.4.3.1 Reduced time for collecting tool from storage

If a set-up person is trained for doing pre-setup process, then he or she can plan for the upcoming setups and tools required for the setup process are arranged. This reduces the time in searching for the tools because the set-up person monitors the tool inventory.

4.4.3.2 Eliminate the misplacement of the tool

When set-up person knows exactly the location and quantity of tool present in the storage, the chances of misplacement will be reduced or eliminated. When the displacement of the tool is eliminated then searching for similar kind of tools to perform the task by adjustment will be reduced. This will increase the confidence and responsibility of setup operators to finish the setup process on time.

4.4.3.3 Proper follow-up on new tools requirement and damaged tools

When the setup-person plans to collect or check for the tools, they can place an order for a new tool if the tools are found to be inadequate or damaged and follow-up on the order is done to ensure that the tools are available before the start of machine setup. This will decrease the sudden stop of setup or sudden change in setup due to missing of tool required for the setup process. Even when setup-person receive the tools back from after setup, they can check for wear and tear of the tools, so that they can decide to order for new tools or not. Even they can record the data of tool life cycle and wrong handling of tools by the machine operators. This will reduce the damage and wastage of tools due to wrong handling.

4.4.3.4 Decrease or eliminate buffering of wrong tools

When a set-up person is trained for the pre-setup process, then they will collect back the tools used for the previous process from the machine operator when the current setup process is finished. Later set-up person must place the tools back to their allocated location. By having this standard procedure machine operators get time to concentrate on their production and decrease the time wasted in placing back the tool after the setup. This process also helps in providing the tools to another operator who needs the same tools for different setup process in another machine in a short time.

In conclusion of the 5-way analysis, a standard layout should be created containing all the tool inventory and it should be in an easy way so that anyone in the company can understand storage layout. The trained set-up person will be following the developed standard pre-setup process. This solution tackles the problem of searching for the tools and reduce the time wasted by the machine operator, which directly increases the machine availability.

As a solution to this problem, a standardised pre-setup process is developed by using the U-layout as shown in **Figure 7.** For executing this procedure, an experienced operator/worker who’s is well versed in understanding job drawings, familiar in handling tools and raw materials is chosen as the set-up person. This set-up person will be performing the eight external preparational activities identified and shown in **Table 4** in a standard sequential manner and is explained in detail in the following section.

4.5 Standard pre-setup procedure

The standard pre-setup procedure is done in the U-layout with the help of following three items,

- Trolley
- Tool box rack
- Tool table

The set-up person firstly collects the job drawing, tool specification and raw material calling sheet. After reading these sheets, tool boxes of required shapes is picked from the tool box rack as shown in placed on trolley and the required tools are collected by moving around the U-layout. The boxes containing tools are named with the machine numbers for identification and the set-up trolley is left at the other end of U-layout ready for the next day’s set-up. The required raw material is collected and placed near the machine when the set-up process is started.

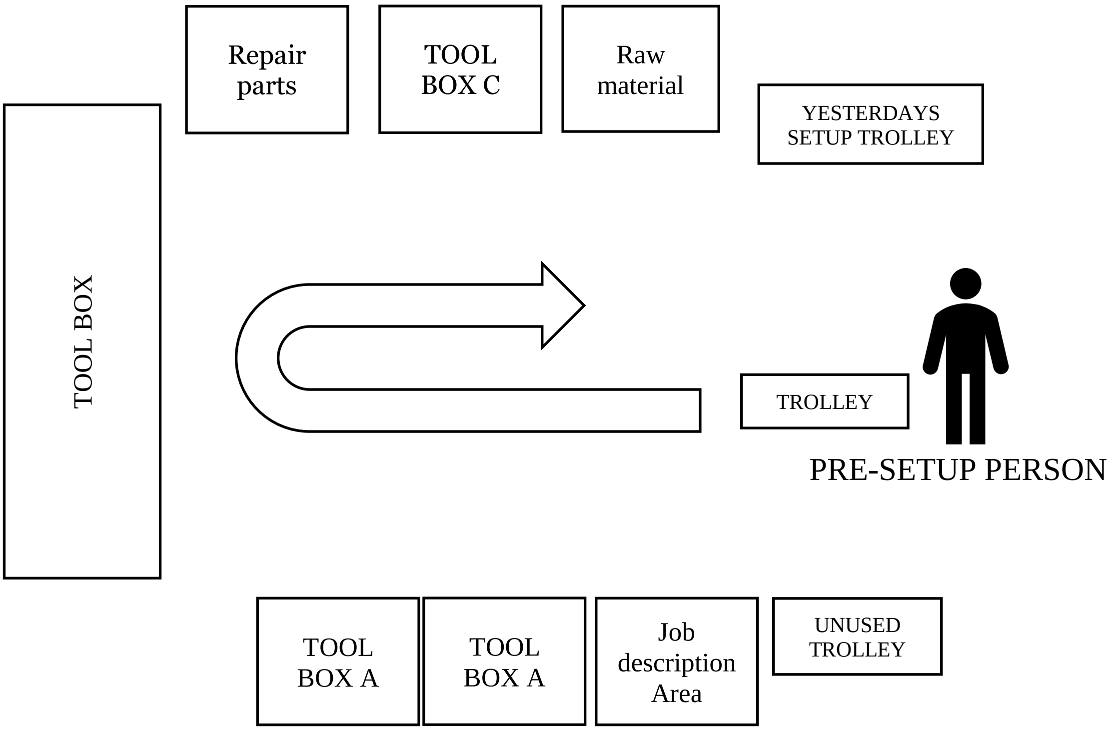


Figure 7 U-layout for pre-setup process (Arai & Kenichi, 1998)

Figure 8 Tools box rack (Anon., 2016)

Figure 9 Tool table(Anon., 2018)

U – line shape arrangement of tools in storage area helps in reduction of setup time, explained in the following points

1. Standardised layout
2. Decreases of Unwanted Movements
3. Good Visualization

4. Require less Space

4.5.1 Standardised layout

As discussed in the 5-way analysis a standard layout must be practised throughout the company. This helps the operator to understand and identify the tools easily, even when they visit or go to another department for collecting tools.

4.5.2 Decreases of Unwanted Movements

U-line arrangement decreases the unwanted movements of the set-up person collecting the required tools. Because of the "U" design, toolboxes are present opposite to each other, while in straight-line arrangement first and the last box will be in the same line away from each other. Therefore, the set-up person needs to collect tool from the first and last box which ends up in more transportation corresponding to wastage of time.

4.5.3 Good Visualization

Even when a new machine operator comes to collect tools, he or she will get a good visualization of tool storage area and they can easily identify the desired toolbox for accessing tools by standing anywhere inside the tool storage area. Even the maintenance and cleaning the storage area before finishing the day can be identified easily if any toolbox door is open or improper placements of tools inside the toolbox.

4.5.4 Require less space

Moving space must be provided in front of the toolboxes as the operator needs space to access the toolbox and, in some cases, trolley will be taken along with them to collect tools. U-shaped toolbox storage area shares the common space in between the parallelly placed tool boxes, which eventually decreases the space consumed by the toolbox storage area providing adequate space for set-up person movements.

5 Discussion

5.1 Discussion of methods

To answer the research questions to fulfil the aim of the research, structuring of the methodology was very important. The chosen research method was literature review and a single case study. The existing literature study on pre-setup provided basic ideas about pre-setup but lacks in providing insights on how to implement it to a manufacturing system. For this, interpretivist approach and single case study was chosen to acquire deeper understanding about the chosen phenomenon. With different data collection techniques different data from different source were collected and analysed. This provided good strength for the research and for comparing the results. The required data was provided by the company as it manages their data very well in multiple software's and supportive stuff. The RQ1 and RQ2 were answered using literature review and analysis of the data. RQ2 could have been explained more in detail by conducting multiple case study and studying the results after implementing the suggested changes, which was not feasible due to strict time constraints.

5.2 Research question1. What are the non-value-added activities involved in the pre-setup and setup processes?

The findings for the research question 1 can be differentiated in two phases. In the first phase, SMED and spaghetti diagram lean tools is applied to the set-up process of S01 as suggested by the authors (Shingo, 1985), (Tanco, et al., 2013) & (Wilson, 2010). The outcomes from these methods are shown in **Table 4 and Figure 5.** Then in the phase two, all the activities as listed in **Table 4** are critically examined by combining SMED & ECRS techniques and **Table 5** with the required improvements is formed. During this activities examination process, Elimination of activities(E) and organizing activities externally are considered as evaluation criteria's as they are in high alignment with the aim of this case study. Finally, **Table 6** is the outcome of non-value added activities in the S01 set-up process directly answering research question 1.

Table 6 Non-Value added activities in the S01 set-up process

Activity number	Activities	Improvement terms				After improvement			
		Eliminate activity	Organize externally	Reduce set-up	Reduce/Eliminate	Change in activities	Time	Internal	External
1	Printout of product details from computer		✓			Performed Externally	00:01:06		00:01:06
3	Checking space for raw material		✓			Performed Externally	00:00:56		00:00:56
5	Replacing the old shaft with the new one		✓			Performed Externally	00:01:57		00:01:57
8	Replacing old chuck collets with new ones and		✓			Performed Externally	00:04:05		00:04:05

	collecting required turret tools								
11	Inter changing drill bit		✓			Performed Externally	00:07:22		00:07:22
13	Getting hammer (Adjustment tool)		✓			Performed Externally	00:00:25		00:00:25
16	Sending program to machine from computer		✓			Performed Externally	00:02:11		00:02:11
18	Removing previous raw material pallet and getting new raw material		✓			Performed Externally	00:06:40		00:06:40
21	Adjusting program	✓				Eliminated	00:00:00	00:00:00	
23	Adjusting program	✓				Eliminated	00:00:00	00:00:00	
25	2nd setup man checks 4th piece	✓				Eliminated	00:00:00	00:00:00	
26	2nd setup man checks in lab (Angel & Radius)	✓				Eliminated	00:00:00	00:00:00	

The outcomes from the first stage clearly highlights the absence of pre-setup process as all the set-up activities are carried after turning off S01 meaning the need of standardised set-up process.

Considering lean approach to the problem faced by the case company, SMED and spaghetti lean tool was chosen to analyse the setup-up process as the literature study provided proven results in reducing set-up process. Operator movements being predominantly occurring in the set-up process spaghetti was combined with SMED as it's a good visualisation tool for monitoring transportation. The data required for these lean tools were gathered from the same video recording planned for the pre-setup and set-up process, which is a greatest advantage in combining these tools. Next, the set-up person needs to be educated with the importance of changes or process improvements taking place in the shop floor needs as they are the focal point in implementing and practicing the changes. For this, we strongly believed that the analysis outputs of SMED and spaghetti diagram **Table 4 and Figure 5** would be a good visualisation tool for educating the set-up person how their current doings are generating more non-value added activities and the need for process improvements.

During the findings & analysis phase, the important parameters we were looking in the case company were, identifying a set-up person and a department ready for accepting challenges and changes. This selection process was done with the production manager and team leader. After this S01 and a set-up person was selected for analysing the current set-up and pre-setup process as they were constantly involved in continuous improvements. The main tool for conducting this study was a video camera, recording the entire activities occurring during the set-up and pre-setup process. A suggestion would be to use video cameras of high battery life as the set-up and pre-setup process are often longer. While analysing the set-up person's activities we came to know that they aren't doing any pre-setup activities as all the activities started after stooping S01. This was the first juncture urged us to develop an entirely new pre-setup procedure. Though we had planned date and time for analysing the set-up process, unexpectedly machine breakdown happened which was a small set-back in our case study as we were unprepared to handle. Luckily, another time and date were scheduled the next day for carrying the analysis of current set-up process to avoid delays. During the analysis of the set-up process the set-up person was left undisturbed while working and the questions regarding the activities performed were taken later with the help set-up video. This helped in collecting the exact set-up time taken.

The advantages with the lean tools used in this case study is good visualisation which gave a holistic view of the set-up process. Likewise, spaghetti diagram visualized the operator's movement and places visited during the set-up process indicating the transportation waste as in **Figure 5.** Considering the confidentialities and privacy of the interviewees in the case company set-up video of the current set-up process and interview responses is not disclosed.

5.3 Research question 2: How can setup and pre-setup process be more efficient?

Improvement in setup and the pre-setup process is determined in this thesis using three lean methods, they are 5-whys analysis, U-line arrangement and 5S. In which, 5-Whys analysis identifies the solution to the problem found in SMED **Table 4** and the result found from the 5-Whys analysis is implemented using U-line arrangement and 5S as shown in **Figure 7,8 &9**. The reason behind the implementation of 5-Whys analysis because 5-Whys analysis is one of the techniques of finding root cause analysis (Card, 2016). Finding the root cause of the setup and the pre-setup problem was necessary because if any implementation of temporary will cause some more problem in the future. This would result in the failure of the research and development on the pre-setup and setup process. The repeated continues question were asked on the problem found from the SMED analysis, finds the root cause of the problem found. The answers found from the 5-Whys analysis guided the way to make pre-setup and setup process more efficient.

In the 5-Whys analysis, the question was asked about the SMED result and the next question was formed by the previous question answer which made sure that the discussion was kept inside the area of the topic. The main problem found from SMED and Spaghetti diagram analysis was that "the operators can't find or search for tools during setup process". After completing 5-Whys analysis on the problem found, the conclusion obtained was that "Pre-setup should be organized in a standard layout depending on the company production and the raw materials used but in such a way that anyone can understand easily the instruction, one dedicated operator for pre-setup must be allocated". The result came from this analysis gave three areas in which improvements must be done. The first area is to implement a standard layout in the company which eliminates unwanted transportations found in the spaghetti diagram Figure 5 and helps the operator to identify to collect desired tools fast and easily. One of the major key point while designing the standard layout is to design according to the type of production of the company. The second area found in the 5-Whys analysis conclusion was that anyone can understand the layout easily. Preparing a standard layout which any operator in the company can understand easily is important because if a new operator or operator from another department comes to collect the tools, then they must find it easily which leads to improvement in two ways. One is that it reduces the time for searching tools and other is dislocation of tools in the storage area will be reduced. An information chart of the layout must be present at the beginning of the storage area. The third most important result from the 5-Whys analysis is that a designated operator must be appointed in the storage area. The pre-setup operator improves the process of setup and pre-setup in many ways. They are reducing the time for collecting tools from the storage area by planning for the upcoming setup. Eliminates the misplacement of tools in the storage area as the pre-setup person will be the more experienced person in the tool's storage area. Even the pre-setup person can manage to share the common tools between two different setup process taking place at the same time if necessary, in pick season of production. Proper follow up for the new tools required for future setup and checking for any damage in the tools when the operator returns the tools from the setup process. This helps in maintenance of data about tool life cycle and the way operator handles the tools while setup process. Decrease or eliminates the buffering of tools in the storage area when the setup operator returns the tools after completion of setup of the machine.

From the conclusion of the 5-Whys analysis, a standard layout must be designed for storage area. One of the most efficient and effective layouts found was the U-line arrangement for medium and small-scale industries to (Arai & Kenichi, 1998). The advantage of the U-line arrangement is to decrease unwanted movements in the storage area as all the toolboxes will be arranged in one standardized layout. It provides good visualization of the whole layout by standing in the centre of the layout to identify any toolbox number or to check for the maintenance of the tool storage layout. Even it requires less space compared to a straight line or parallel arrangement of the tool storage area.

6 Conclusion

The goal of this thesis was to develop and improve the pre-setup concept in the setup process. This provides understanding and knowledge about the importance of the pre-setup process during the increase of machine availability. The two-research question is formulated to achieve the intended goals. The first research question explains the non-value-added activities involved in the pre-setup and setup process. To answer this question a literature study on present pre-setup concepts and lean techniques in setup process improvements such as SMED (single minute exchange die) and spaghetti diagram was used. This identifies delay in collecting the required tools and unnecessary movements of the setup operator during setup of the machine. The second research question mainly focused on how pre-setup and setup process can be more efficient. To answer this question the root cause analysis tool 5-Whys analysis along with U-shape arrangement and 5S was used to demonstrate how the pre-setup process can be more efficient. Finally, a standard pre-setup procedure is developed which consequently improves the productivity and machine availability.

6.1 Future research

In future, the concept of standard pre-setup procedure can be developed for large setup process and more frequently occurring machine setups. Further considering the tool life, machine stop time for replacing the worn out tools can also be further decreased which also reduce the machine down time. Having automated tool storage systems like elevator tool storage or matrix toolbox reduces the time and complexity in picking the tools as they are called with their unique bar code names. More importantly to increase the reliability and validity of the report the concept of triangulation should be deployed by using other techniques for studying the current set-up process to validate the results.

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8 Appendix

1. How is the shop floor divided?
2. What are the departments in the shop floor?
3. Who is responsible for the departments?
4. How do you measure the production performances in the shop floor?
5. How should we access the software?
6. What are all the machines available?
7. Who is responsible for set-up & pre-setup?
8. Who is more experienced person in the shop floor?
9. What are all the places you normally visit during the set-up process?
10. Why are for searching tools?
11. Why are you not returning the tools back?
12. Why are you not returning the tools if they are not used?
13. Do you know what pre-setup requires?
14. Why don’t you know about pre-setup?