ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

IMPROVEMENT OF OPERATIONAL QUALITY OF A LABELING AND PACKAGING INDUSTRY BY IMPLEMENTING LEAN MANUFACTURING PROCESS

M.Sc. Engineering (Mechanical) THESIS

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OCTOBER 2018

Improvement of Operational Quality of a Labeling and Packaging Industry by Implementing Lean Manufacturing Process

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A THESIS PRESENTED TO THE DEPARTMENT OF MECHANICAL AND CHEMICAL ENGINEERING, ISLAMIC UNIVERSITY OF TECHNOLOGY DHAKA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE FOR

MASTER OF SCIENCE (M. Sc.) IN MECHANICAL ENGINEERING

OCTOBER 2018

Candidate's Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Acknowledgements

I would like to begin by saying Alhamdulillah and grateful to Almighty Allah who made it possible for me to finish this project successfully on time. Equally say a big thank to my supervisor Dr. Mohammad Ahsan Habib, Associate Professor, Department of Mechanical and Chemical Engineering, IUT for all his support, ideas about experiments, discussions, time and for explaining so patiently the hard topics and checking this thesis and papers above all his care and concern. These will ever remain in my memory. Thanks to my examiners for their constructive ideas, suggestions and double-checking my work.

Special thanks to all faculties for their support and encouragement throughout the period of my studies.

I will like to say a big thank you to the Head of Department Professor Dr. Md Zahid Hossain, for his continues encouragement and support during the period of my studies.

I would like to express my gratitude to the management of Avery Dennison Bangladesh. Their unparallel support & commitment to the betterment of the Bangladesh accessories industries continuously motivated me to continue & shape my work.

Finally, I will like to express my lasting gratitude to my family members for their patience, support, encouragement, enthusiasm and prayers.

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Nomenclature

VSM = Value Stream Mapping

JIT = Just-in-time

CCR = Customer Complain Rate

UEE = Utilized Equipment Efficiency

UPLH = Unit Produced per Labor Hour

KPI = Key Performance Indicator

ICR = Internal Complain Rate

WIP = Work in Progress

LT = Lead Time

DOI = Drop Off Interval

Abstract

A research has been carried out to check if lean manufacturing is applicable for label & packaging industry. Lead manufacturing or lean production means faster production & best quality that is achievable with minimum waste generation. In the field of industrial production, lean manufacturing is a common phenomenon. Now-a-days, every company wants to adhere to the principles of lean manufacturing. Every industry is trying to offer shorter lead time with highest productivity which is the only way to sustain in this competitive market. According to the researches that have been carried out in different industries, lean manufacturing can arrest seven wastes of production floor which can result in better profitability. This study has been performed to analyze application of lean tools to minimize several waste types such as waiting, defects & motion. Here are some key performances indicators (KPI) like Customer Complain Rate (CCR), unit produced per labor hour (UPLH), utilized equipment effectiveness (UEE) are selected to analyze productivity at different processes. Value stream mapping (VSM) has been carried out to identify scope of process bottlenecks & current lead-time. It has been observed that if all selected lean tools such as VSM, Kanban, Set up time reduction & Why- Why analysis are properly applied & sustained in each individual processes then departmental KPIs are improved. Therefore, it can be said that production process assisted by lean manufacturing gives shorter lead-time and better production with optimum quality & lesser wastes.

Chapter 1 Introduction

Lean manufacturing is the summation of commitment & continuous improvement. Today every organization is cutting off their production cost without sacrificing quality & they want to achieve that within shortest lead-time. Now for achieving these goals lean manufacturing offers different approaches to eliminate different types of waste, which are normally found in any type of production floor. Lean manufacturing helps us to identity & understand value from customer's perspective. It involves checking and analyzing the flow of information or materials, which are required to produce a specific product with the intention of identifying waste and methods of improvement. Lean manufacturing can be applied in any type of production floor.

1.1 Principles of Lean Manufacturing

Now a day's many companies are adopting lean manufacturing as it gives a chance to achieve competitive edge. It is an incorporated system where all energy and creativity within an organization are gathered towards optimizing the aspects that are valuable for the customer. There are several key lean manufacturing principles that plays vital role in implementing lean. One has to be directly involved in the production floor to understand the depth of lean manufacturing. If we apply these principles without proper understanding then most likely it will result in failure & lack of commitment from people in any industry, which ultimately make the process unproductive. There are many established methodology in lean manufacturing, used in different industries. But all these have common goals like identifying problems & reducing wastes as much as possible.

1.1.1 Identify Value

Identifying value is often considered the first step in the journey of becoming lean. It requires businesses to define what customer's value and how their products or services meet those values. Though products are made by the manufacturer, but its value is defined by the customer. Industries need to understand the value a customer expects on their products and services, which can help them identifying how much money the customer is willing to pay for a particular product.

Each production method is made of various types of processes & all of them are divided into two categories- Value added process & non-value added process. Value added process means customer wants to pay for the outcome of a process. Similarly, non-value added process means processes for which customer will not pay any money. But most of the time it can be seen that to get a desired customer output, manufacturer has to engage in many non value adding processes. But as these stages doesn't hold any value to customers so it is very important to producers that it processes remain as little as it can be.

1.1.2 Map the value stream

After defining the value for customer, the next goal is to map the value stream. It is the combination of various stages that makes up the value stream. Stages includes from sourcing of raw materials to delivery of finished goods to the customer door. Value stream also comprises of networking of information flow. All of these are done to identify easily all the value adding & non-value adding processes. So that manufacturer can limit all non-value adding processes as some of the steps are not avoidable to get the desired output. Lean tools like value stream mapping (VSM) can be used to visualize the entire production flow. After doing so, it will be easier to find & minimize the gaps. Figure 1.1 shows a drawing -like a "map" of the flow of material or information through the process.

The main goal is to clearly understand every step that does not create value and then find ways to eliminate or improve those steps.

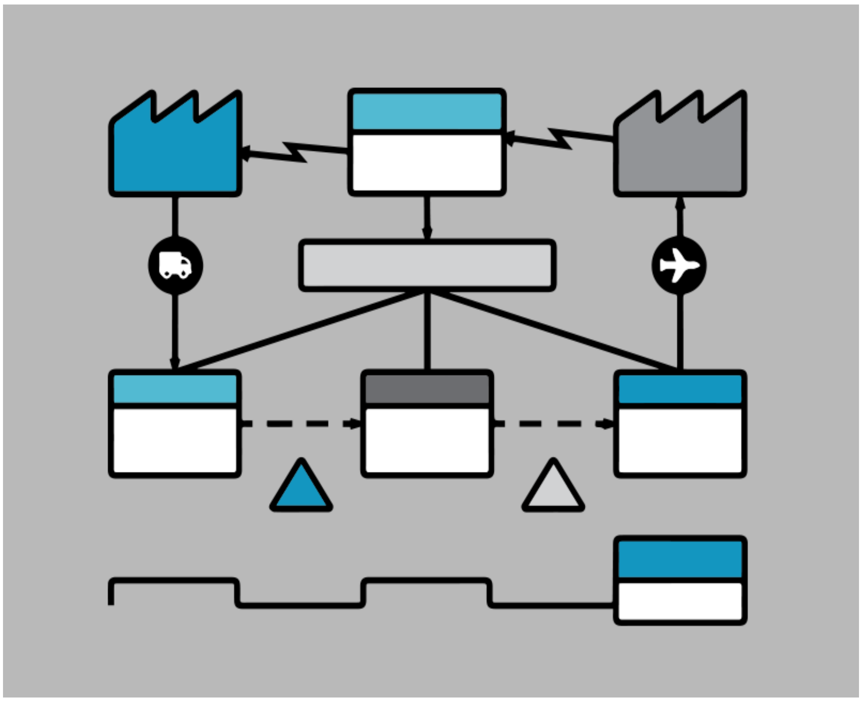

Figure 1.1: Value Stream Mapping

1.1.3 Creation of flow

The next goal is to ensure flow without any kind of interruption. After eliminating or limiting the wastages, we have to ensure that all the value creating stages are designed in a way that no additional time or movement is needed to produce the customer desired output. It has to be a tight sequence without any bottleneck to manage smooth delivery to customer. As per researches in many industries over the year, this is one of the challenging area in manufacturing unit as it requires cross functional activity across the departments to finally achieve an optimum output.

This step of lean manufacturing is largely depended on the previous step of mapping the value stream, as disruption less flow is only achievable if every waste is eliminated. There can be seven types of probable flow- raw material flow, work in process flow, finished goods flow, flow of operators, flow of machines, flow of information & engineering flow.

1.1.4 Establish a pull system

A manufacturer in an effective value stream system will only produce products only when customer demands for it. It has been specifically represented in Figure 1.2 that one will only start new work if the customer demands it. This is an important tool to manage inventory as products don't need to be built in advance. Lean manufacturing does not support push system as it is entirely depended on forecasting which is in most cases not accurate.

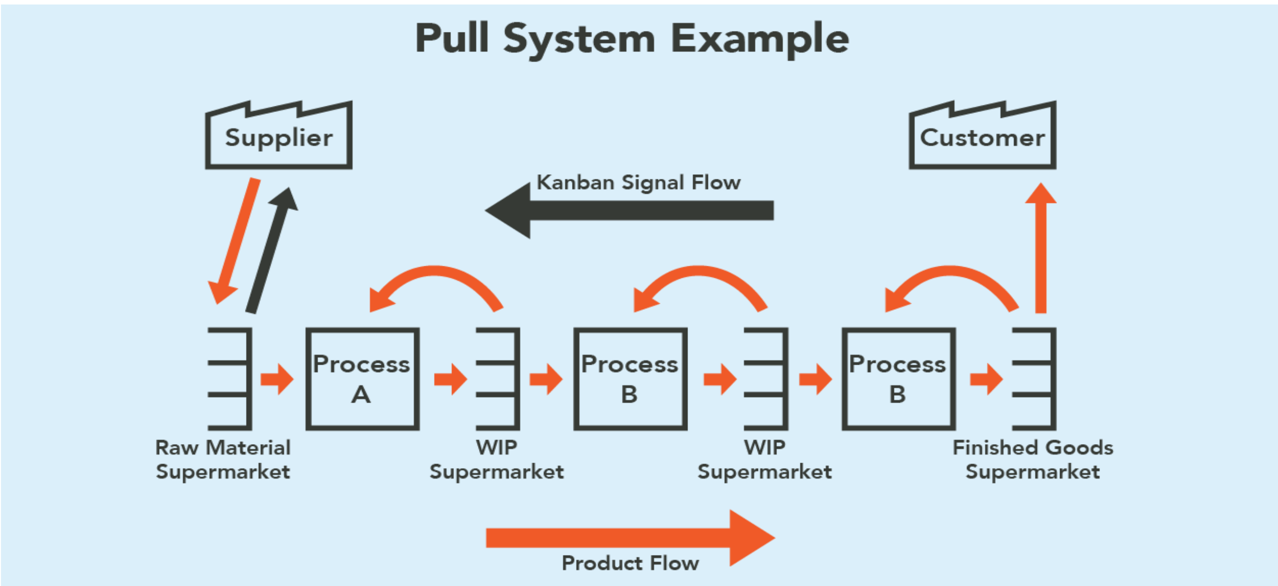

Figure 1.2: Lean manufacturing pull system

1.1.5 Pursue Perfection

After accomplishing all previous four principles, the last stage is to make it the corporate culture and practice it continuously. It is our commitment to thinking lean, which will help any organization to become more competitive in the market. As the processes continuous to grow, it is our duty to look for continuous improvement, which will bring sustainability & perfection to the manufacturing unit.

1.2 Seven wastes of lean manufacturing:

If any process or step, material or information does not have any value in the eyes of customer or if there is any such product for which customer is not willing to pay the manufacturer, can be considered as waste. In any type of business, the greatest obstruction to achieve profitability is waste. There are seven type of wastes in a production floor which is showed in Figure 1.3-

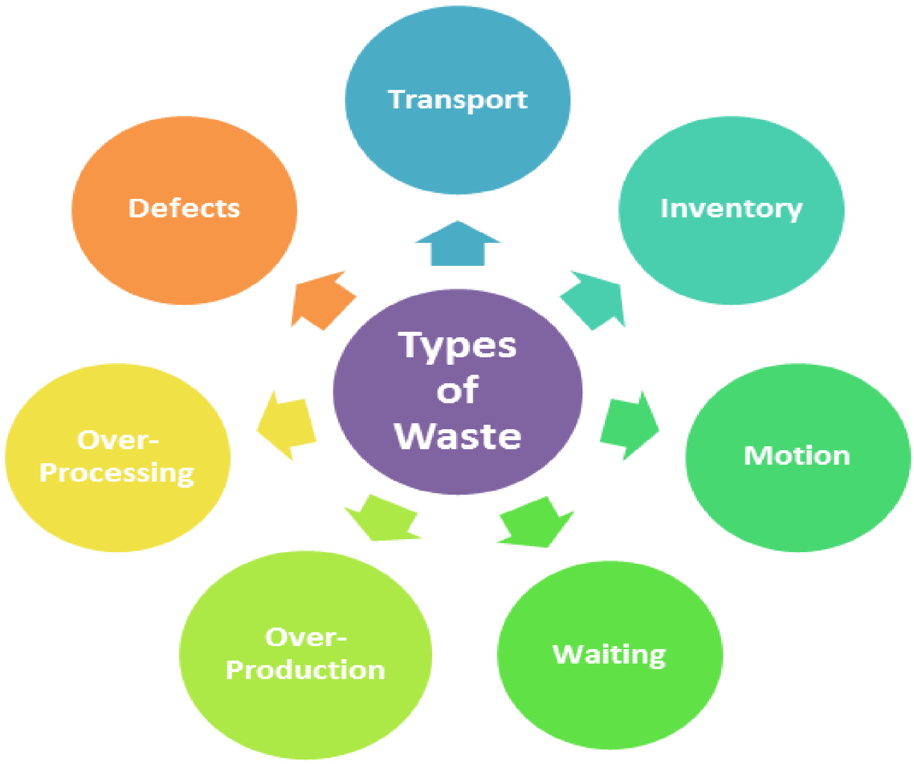

Figure 1.3: Seven waste of lean manufacturing

1.2.1 Transport

Any movement of WIP or raw material, which is not necessary, is a waste. Figure 1.4 shows red lines as all the movement that the person requires to do as a part of conventional work which can be easily reduced by stream lining his workstation with the sources. It can increase the lead-time significantly & increase the risk of causing damage to the material, making the product much more expensive. Any type of transportation, small or large , can be considered as waste if it does not add any value to the product for which customer is willing to pay.

Figure 1.4: Transportation waste

1.2.2 Inventory

It is another major waste that can be seen in the production floor. Raw material, WIP or any kind of finished goods if it doesn't have any immediate usage or waiting to be sold to customers, can be considered as waste. Maintaining all these things often requires money. So the more inventory rises, the maintaining cost will go high also. As the inventory is unavoidable, so it is vital to stock only things which have immediate usage. Besides that inventory comes with space allocation & packaging of finished goods, that's why there will be always a risk of getting damaged goods for which customer will not pay anything & the whole operation will be complete loss.

There are some steps that can be taken to avoid excess inventory such as keeping raw material & finished goods inventory as small as possible, establishment of Just in time (JIT) process.

1.2.3 Motion

If there is any kind of unnecessary motion by human beings or by any machinery, it is considered as waste. It is a very common scenario in our manufacturing unit that, very often the time & effort of our operators are being wasted due to lack of efficient floor layout or inefficient machine. No customer will pay extra if extra motions are required to shape the final product as it doesn't have any value in their eye. Lack of standard procedures or even lack of trainings can generate waste of motion. Figure 1.5 shows a perfect example of motion related waste where a person needs to go to different position to transfer goods.

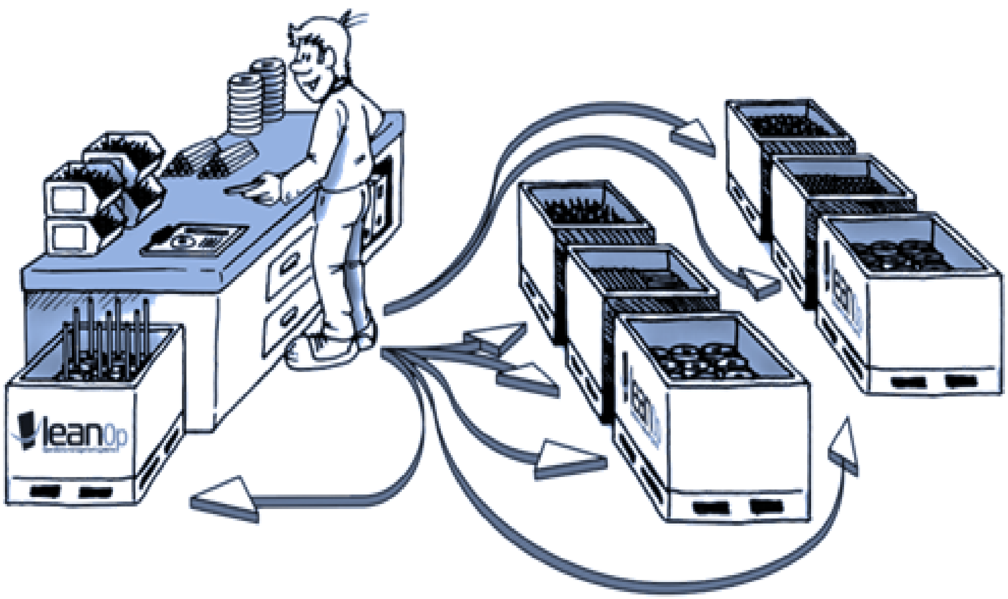

Figure 1.5: waste of motion

Excessive travel among many work station is categorized under waste of motion. Six sigma 5S methodology can be applied in the production floor to limit or entirely eliminate wastes which were generated by motion. Proper training on standardized process can also be arranged to raise awareness among shop floor employees to identify & at the same time rectify motion waste.

1.2.4 Waiting

One of the lean principles is creation of flow & waiting time is considered to be the biggest barrier in its way to implementation. It can happen due to unplanned machine downtime, insufficient planning, unskilled operators & also because of shortage of raw material supplies. Besides that, if two interdependent processes are not properly synchronized it will generate waiting time. Basically it is the time for which company is paying to the operators or even paying for the machineries but the output is not as per standard capacity or expected. So ultimately waiting in any of the processes will make the entire process slow, which can result in higher lead-time, late shipment or missed deadlines for customers. It strips huge amount of profit from the sale, making a huge impact on the business.
Standardized work instruction with minimal buffers between process can reduce waste due to waiting significantly.

1.2.5 Over Production

Of all the wastes in the field of lean manufacturing, over production is by far the most important as it creates the most negative impact on business profitability. Over production occurs when products are being produced more in quantity than the customer is willing to pay at that particular time. That is why it is considered as waste. Over production can introduce waiting, inventory & motion waste into the system by itself if not careful. If over production exists in a system then challenges or problem will never come to surface, rather it masks real inefficiencies. Establishing a pull system & balancing between supply and demand of customer, over production waste can be minimized.

1.2.6 Over Processing

Many companies expend extra labor or energy consists of many extra processes for which customer will not pay, is called over processing waste. Because at that moment customer has no demand for those extra features, which manufacturer is providing with the product. Again, failure to provide products as per customer specification will require reproducing or repairing goods, which is also a form of over processing. This type of waste is very difficult to identify. Over processing, has direct relation with the pricing as extra steps will incur undesirable value, which will go unpaid. Only performing manufacturing processes that meets customer requirements, waste of over processing can be eliminated.

1.2.7 Defects

Defects are another waste, which has direct impact on sales as customer will be dissatisfied upon receiving it. It is our common practice, not taking any action pro actively to arrest it. Sometimes it may become the reason of claim from the customer end. Besides that, reimbursing defective items will take time, material, effort & money from the producer. Even in serious cases it can result in loosing customer also.

Developing a standard quality assurance program to detect abnormalities to solve immediately & creating an environment to solving issues pro actively rather than doing it in postproduction can reduce the entire defects amount noticeably. Besides that operators of each process needs to be trained on specific quality requirement so that they stop all defective goods in the generation stage.

1.3 Background & present state of the problem:

There are many kind of lean tools. But not all of them are suitable to be implemented in every case scenario. Incorrect application of lean tools may result in inefficiencies of an industry, which can end up in reducing confidence level of employee (Karim and Arif-Uz-Zaman 2013). Some of them are universally applicable such as VSM, 5S, visual system etc and some of them are partially applicable based on the current situation such as –Set up reduction, JIT, production leveling, TPM etc. Many lean tools would be even inapplicable to some manufacturing units such as cellular manufacturing (Abdulmalek and Rajgopal 2007).

One of the main lean manufacturing tools is VSM. It is widely used to figure out bottlenecks in the entire process from raw material sourcing to delivery to the customer's door. Sometimes it can be applied on a single production line to check the flow of information, WIP or raw materials. Multiple VSM with the calculated production lead-time and total cycle time can show real differences that give a chance to re-model the area to get the best possible output (Adepu, et al. 2015).

In this competitive market, customers are now more dynamic than ever. They want better lead time with good quality & also cheaper price. In this type of challenging situation, now a day's every companies are trying to establish the culture of lean. Without lean, there is always a chance of over production & under production. Lean's systematic approach of elimination of waste & developing PDCA practice can help the producer to achieve its goal (Miller, Pawloski and Standridge, A case study of lean, sustainable manufacturing 2010).

There are many lean tools such as –kaizen, one piece flow, scrap reduction,5S, work place organization & mane others. This is a common problem occurring in almost every manufacturing business & it is huge wastage of time in almost every process associated within a production process. There is always a wait for the right tool, which is needed to loading or unloading the WIP for the next step within the job. Load leveling & visual controlled can be used successfully to arrest this problem. But applied lean tools has to be properly understood before implementing, otherwise it can end up producing more wastes than before (Pavnaskar, Gershenson and Jambekar 2003).

Avery Dennison is one of the fortune 500 companies in Bangladesh which supplies different types of garment accessories. It has several products lines. The study was done in Digital department. Digital department produces graphics tags & many paper-packaging items. The department comprises of three major segments- printing (This is the part where goods are being printed via machines on the a paper sheet), die cutting (printed paper sheets are cut in different shapes as per customer requirements) & finishing (Here goods are being inspected & given final form to deliver to customer door). It has been observed that the internal speed of these processes do not match with each other, which results in unnecessary inventory in the production floor. Besides that, it has come to attention that a huge amount of time is being wasted due to waiting for goods or even waiting for proper tools, which is needed to approach processing. This total time considered as idle waiting time or time, which is not generating any value for the customer.

Finishing is a segment where all types of human motion can be seen. Even then, there will be some motion, which is in particular, will not add value to the finished goods from customer's perception. Those steps are non-value adding process & those motions are unnecessary. However, some of those non value adding process has significant impact on the finished goods & to some extent unavoidable. These have to be sorted out to eliminate non-value adding motion from the finishing stage.

1.4 Objective with specific aims:

The research work has following objectives:

a) To study & prepare VSM of digital production floor for determining bottle areas.

b) To achieve faster finishing process by developing new quality visualization process.

c) To achieve shorter set up time by reducing waiting through kanban die rack in cutting section.

d) To reduce motion in finishing zone by implementing new layout.

e) To achieve a shorter lead-time for Digital department orders.

1.5 Organization of this thesis

This thesis comprises of five chapters. Chapter 1 gives a brief overview of the background and concept of this study. Finally, significance of the research and the objectives of this study are summarized. This chapter also outlines the organization of this dissertation.

A comprehensive literature review is given in the Chapter 2, which categorized into five sections. First section describes different lean principles of lean manufacturing, which are mandatory for any organizations to start practicing lean. In the second section, different types of wastes, which are identified in the process industry. The third part comprises of different lean tools, which have already been utilized in industries to cover wastes. The forth section will give us the idea of performance evaluation factors for lean implementation will be discussed.. Finally, extensive literature review on future directions will be discussed.

Chapter 3 describes the methodology and development of new processes to minimize waste

Chapter 4 describes the details of after effects of lean tools implementation & sustainability in die cutting stage & finishing. Finally it shows the impact on lead time lean manufacturing provides by eliminating some of the wastes

The conclusions and summary of the contributions are presented in chapter 5. In addition, some directions for future work related to this study are also presented.

Chapter 2 Literature Review

2.1 Introduction

Lean approach was actually developed in Toyota. But the idea was first represented in a book named "The Machine That Changed The World" (P.Womack, T.Jones and Roos 1990). It is called lean manufacturing as it requires less of everything compared to the conventional system to produce the same quality goods or service (Wolf 1991). Lean manufacturing is the most talkative topic in the current days (Rahmana, Sharif and Esa 2013).. Lean thinking can be described as the tool of the value finder for customers. It can be implemented in a wide variety of area- manufacturing to service, mass production to small volume generation, labor based industry to tech giant industries (Bhamu and Sangwan 2014) (Lewis 2000). There has been a positive approach in the process industries in the last decade for implementing lean principles in the whole supply chain system to be more competitive in the present market (MELTON 2005). Lean focuses on productivity, which is as fast as possible with cheaper cost by improving efficiency of the process (Antony 2011). The basic principle of lean is openness to change of any driving factor & also adeptness of waste minimization without scarifying product or service quality (Motwani 2003). The decision to implement lean manufacturing can be tricky as there will be always a substantial difference between employee management, floor layout, machine types, process information flow. So it can be taken by analyzing the historical analysis of previous organizations who have gone through similar types of changes & their outcomes (Richard B 2000).

In a simulation basis case study, the lean principles of lean manufacturing has been represented in terms of inventory reduction, manpower utilization, reduction of internal transportation, order lead time improvement with better system flow time (DETTY and YINGLING 2000). Others have added faster introduction of new products, customer satisfaction, and statistical process control with it (Upadhye, Deshmukh and Garg 2010). Lean implementation is comparatively easy when all the people are driven to achieve organizational goals, which are committed by lean processes. Policy deployment can be a method to communicate quality & productivity goals (Bhasin 2008).

It has been found in many search study that lean model varies one discrete manufacturing to another based on it's environment. Such as a research on food company shows that the lean model of automotive industry is not properly applicable on the UK based food and drink industry (Jain and Lyons 2009)

There are basic five lean principles based on which lean thinking is established (LIAN and LANDEGHEM 2007). Value stream is one of them. It can be considered as a representation of series of information flow to the information consumer. It ensures the chain of steps that maintain information management is properly integrated with each other (Hicks 2007).

Other important factor is value. Identifying value requires detailed audit reports, information assessments, in-depth discussions because the concept of value is more biased (Hicks 2007).

Flow is another key lean principle. Passing information through shortest possible time & removal of any duplication process is one its focus point. One of priorities of information flow is it should flow as soon as it generates in the process. Also material or information flow must follow simplest way rather than a complex route (Hicks 2007)

Another important lean principle is pull system. It encourages the manufacturer to produce only the part, which is required by the customer, & it should be delivered only when customer desires for it. It also ensures that an additional information or material flow should only be created if there is a demand for it from customer's end (Hicks 2007).

The last but not the least lean principles is continuous improvement. It signifies that regular reviews of current process flow are always a necessity. It is very important to support any improvement opportunities as well as any process change. If there is any level of waste change then it also can be captured via continuous reviewing of the process. Training for any new process or updated processes has to be ensured. Lean process is only fruitful if it keeps on track & continuous improvement through continuous checking is only way to ensure it (Hicks 2007).

2.2 Waste of lean manufacturing

When something has no value to its owner or end user, it can be considered as waste. As waste is always defined in terms of value, so to announce something as waste, we have to know about it's value first (Mossman 2009). It is very critical that lean thinking is established as working environment in the industry & always look for eliminating waste by exploring new ideas & better ways of doing work and Without creativity it will all go in vain (Motwani 2003). Though main objective is to reduce variability to cater waste minimization but eliminating one source will help to eliminate only some of the waste, not all waste can be reduced unless the manufacturer can attend each type of variability concomitantly (Shah and Ward 2007).In a book named "Lean Construction", it has been mentioned in chapter "Tool for identification and reduction of waste" that usually 3% to 20% of the steps add value to the customers & their portion in the total cycle time is only 0.5% to 5% (F.Alarcon 1997)

One of the wastes is waiting. According to Silva who conducted a study of applicability of VSM in the apparel of Sri lanka, 99% of a product's cycle time in conventional manufacturing process is spent in idle mood (Silva S K P N 2012).An excellent way to utilize idle time is to engage in training or maintenance related works (Hines and Rich, The seven value stream mapping tools 1997)

Another hidden waste is motion. All kind of movement that does not add value to the product can be considered as motion generated waste. There are many reasons behind this waste but reprocessing, inefficient layout & defects are mainly to be blamed. It consumes both work force & time (Hicks 2007).

Anything that doesn't conform with the customer's expectation & may end up by taking claims can be considered as defects. Another kind of waste is over production. Normally absence of pull system can generate this waste as it ensures ceasing of production on time. Unnecessary movement of wip from one place to another generates transport related waste. Speed mismatch, improper planning & lack of visual signs generates high inventory. It is categorized as a waste as it takes lot of space & also human handling which doesn't have any value. Defects, over production often requires further improvement of products which gives birth to extra processing as customer wouldn't pay for this additional steps (Hicks 2007)

2.3 Lean tools

For any change management, it is very important that employees are involved in the root level to nurture creativity & contribute, as a changing agent. For lean implementation, same thing needs to be the first step (Panwar, et al. 2015).There are some basic crucial steps which creates the basic structure of lean transformation.

Table 2.1: Lean Transformation Principles (Reagan 2004)

Steps	**Details**
1	Searching for a change agent, someone who can watch & understand the whole business process
2	Find a sensei & borrow a learning curve
3	Seizing a crisis moment to motivate actions across the industry
4	Value stream mapping of entire production families
5	Identify & pick something important & start removing waste as soon as possible

A study on electronics manufacturing company revealed that management support plays a vital role in lean deployment. It contains both negative & positive impact. Negative impact can be reduced by personally participating in lean manufacturing initiatives, which will eventually avoid rift between manager & operator relations. Many positive impact was also recorded like- leading kanban & Five S program by executive committee which boosted the motivation of shop floor people (Worley and Doolen 2006).

It has been described that lean tools or methodologies are the ways of work within an industry to reach a value for satisfying customers (Anvari, Ismail and Hojjati 2011). A study on textile industry suggested a lean implementation model in which value stream mapping is shown outside of the pyramid as it can be used in any stage of lean implementation scenario (George L. Hodge 2011)

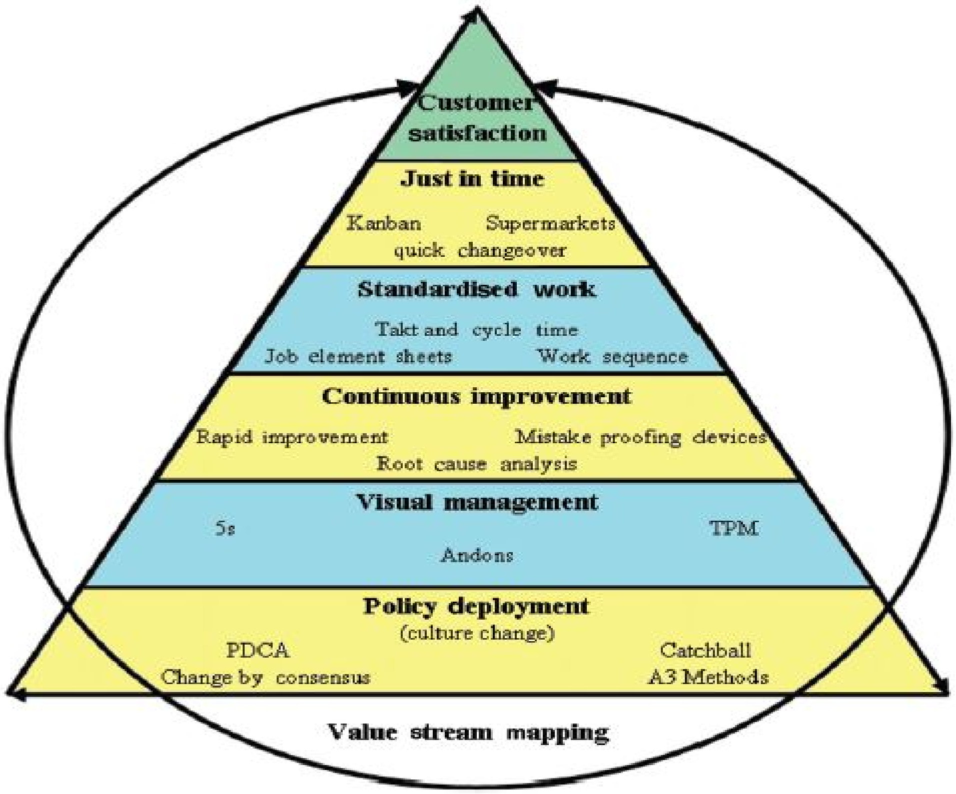

Figure 2.1:Lean implementation model (George L. Hodge 2011)

It refers to the entire mapping of an organization from product design to product inspection & all the way to the delivery to customer door. With the perception from customers end, the map shows the process into two segment- value adding & non value adding process (Engelund, Breum and Friis 2008) (Jimmerson, Weber and Sobek 2005) (AR and Al-Ashraf 2012) (Panwar, et al. 2015). In a research, it has been shown that to establish VSM- changeover time, transportation time, queuing, handling and machine time data is needed to map it. Line observations were done to gather knowledge of current processes as well as identifying types of wastes in the system (AR and Al-Ashraf 2012). It actually helps managers to under their current flow & their bottlenecks & helps them to innovate better deign in future (Chowdary and George 2011) (Singh, et al. 2010). VSM can be done in almost any business unit. It can be logically argued that if any product is developed for selling to customer, there is a value stream for it. The only challenge is seeing & working on it (Seth and Gupta 2005). An important remarks was done on VSM is that there needs to be a management presence in VSM so that people must interact with each other & also with the process, otherwise the actual benefits will not be seen (Sultana and Islam 2013). A study in a bicycle industry has showed that VSM helped them to reduce their waste generation through making continuous flow whenever possible, deployment of super market & establishment of pull system to create every part every day (Grewal 2008).

In a research paper, first step was to identify specific value that needs to be reviewed & secondly a series of preliminary interviews with engineering managers as it is imperative what managers think & should be removed from the process. Besides that, it is vital to gather manager's view on the importance of understanding the overall industrial structure, irrespective of any waste removal (Hines and Rich, The seven value stream mapping tools 1997)

To cater defects problem research work has been carried out in an apparel industry by doing basic cause effect diagram with the man, machine, method & material segments, which represents major dilemma of each types & gave an area to improve (Islam, Khan and Khan 2013).

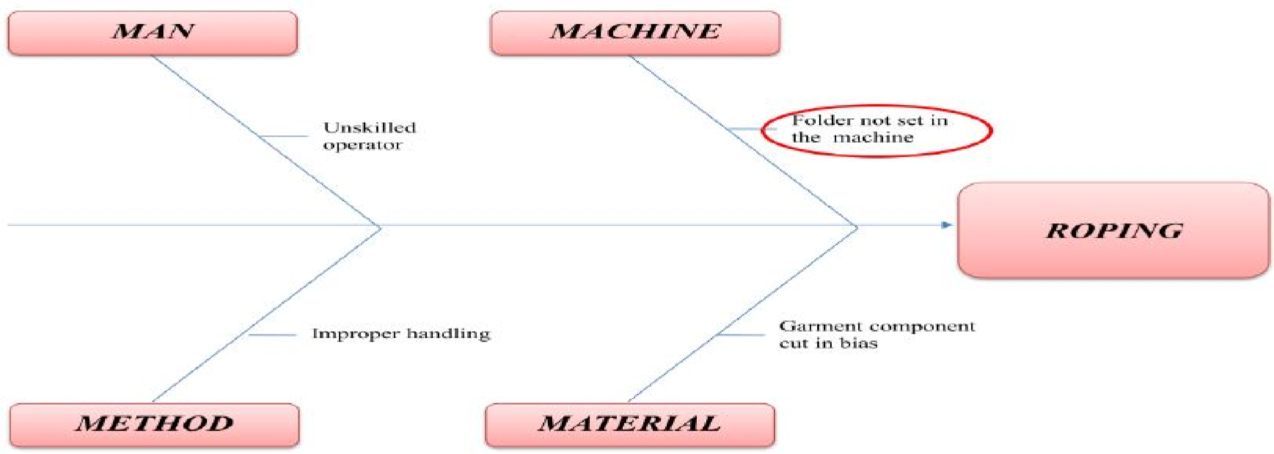

Figure 2.2: Cause & Effect Diagram (Islam, Khan and Khan 2013)

Another research shows that a conventional pareto analysis was used in a printing industry to find out the major reasons to behind identified problem & therefore, doing further WHY-WHY analysis on the major contributor from pareto analysis, provided the main problem to solve for better productivity (Jie, Kamaruddin and Azid 2014). Examples has been given below-

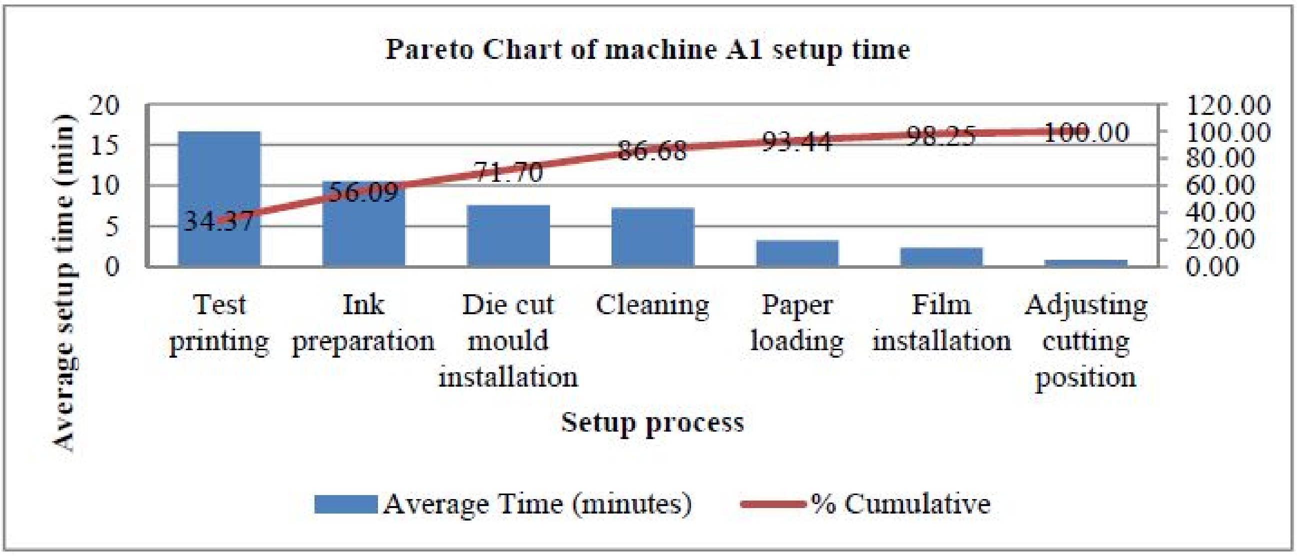

Figure 2.3: Pareto Analysis (Jie, Kamaruddin and Azid 2014)

Main cause	•Hard to find die-cut mold
Why 1	•Die-cut mould is not arranged properly in a drawer
Why 2	•Hard to arrange and not suitable for certain amount
Why 3	•The arrangement system is not sustainable
Why 4	•The existing method is not convenient to find and keep the die-cut mold
Why 5 / Root cause	**•There is no proper slot to keep the die-cut mold**

Figure 2.4: WHY-WHY Analysis (Jie, Kamaruddin and Azid 2014)

Another research showed benefits of quick change over time in the route of lean manufacturing & it was achieved via adhering to Single-minute exchange of die (SMED) technique. SMED allowed a particular process to be broken down into many individual processes, which ultimately helped the owners to examine unnecessary acts or acts that can be done in parallel mode. It also showed balancing load in the cell level to increase productivity as a part of commitment to lean manufacturing (Lee-Mortimer 2006)

It has been observed that some assessment tools was developed for guiding lean implementation in steel industry for engineering managers. It shows that process industry shows similar characteristics which make it possible to execute lean practices but with different variables on the specific industry. (Abdulmaleka, Rajgopalb and Needy 2006).Some assessment of lean tool is given below-

Table 2.2: Assessment of Lean Tools (Abdulmaleka, Rajgopalb and Needy 2006) (Pettersen 2009)

Lean Tool	**Applicability**	**Why/How/Where**
Cellular Manufacturing	Very Difficult	Layout reconfiguration is generally difficult for permanent infrastructure. For temporary set up, it can be done. However, it may require huge amount of money to do so.
Set up reduction	Partially Applicable	Analyze of set up time to move from internal to external operation
5S	Universally Applicable	Basic principles, can be implemented in any process industry
Value Stream Mapping	Universally Applicable	Identify major value adding process, can be used as first step to shift to lean manufacturing
Just in time	Partially Applicable	Material needs to be pulled only when there is a certain demand for it
Production Smoothing	Partially Applicable	Final product demands to be considered for various grades to develop smooth schedules
Total Productive Maintenance	Partially Applicable	Development of cyclic or periodic rigid maintenance plan
Visual systems	Universally Applicable	Easily applicable to all stages in manufacturing

Virtual Kanban system is found to be effective in some manufacturing units which has multiple stages of processing & highly customized products. One of the key characteristics of this system is to transfer signals to upstream processes, which are correspond to bottleneck processes. So if there is shortage of material, there will be no signal This system was analyzed through simulation and found to be very effective reducing lead time & inventory level among processes (Junior and Filho 2010). A study in an automotive manufacturing unit with three different managers reveals that inventory management, links between two consecutive processes, employee & top management commitment to lean plays a vital role in successive implementation of kanban system (Rahmana, Sharif and Esa 2013).

A research of standardized work in an Malaysian industry showed that different kaizen activities can be used to eliminate waste & reduce cycle time which includes simplifying process, work load balancing, removal of unwanted quality checking etc (Halim, et al. 2015). Some companies even tried routine kaizen work to find out the transgression of the process & through this step, both management & shop floor employees were also connected to collaborate across the boundary (Miller, Pawloski and Standridge, A case study of lean, sustainable manufacturing 2010)

2.4 Performance Measurement

Productivity has long been the only parameter manufacturing performance. It's a measure of manufacturing performance which reflects industries efficiency in transforming inputs into outputs. Along with productivity, flexibility & quality is also considered as performance measurement parameters (Son and Park 1987). Many researchers proposed different kinds of methodology to capture the performance of lean manufacturing. It has been observed that one of the proposed methodologies is to continuously monitor & record previous and after performances of lean implementation. The current state needs to be measured in terms of productivity, efficiency & defect rate. The after effect data needs to be measured in same order and evaluate to get the performance measurement (Karim and Arif-Uz-Zaman 2013) (Ng, et al. 2010) Another research shows similar types of approach by comparing current state mapping & future state mapping of an apparel industry of Bangladesh to measure the performance of lean implementation (Sultana and Islam 2013).

It is vital to measure things, which are important to organizations. It can be cash flow, organizational growth, KPI evaluations, empowerments, or even outer parameters like- customer satisfactions etc (GELDERS, MANNAERTS and MAES 1994). But whichever it is, the focus has to be firm on targets. It has been seen that approximately 60 percent companies are using a scorecard to measure performance though the real benefits of lean is found to be difficult to quantify (Bhasin 2008). The author has presented a table of performance template in his research, which is given below-

Table 2.3: Performance Template (Bhasin 2008)

Financial	Profit after interest and tax Rate of return on capital employed Current ratio Earnings per share
Customer/market measures	Market share by product group Customer satisfaction index Customer retention rate Service quality Responsiveness (customer defined) On-time delivery (customer defined)
Process	NPD lead time Cycle time Time to market for new products Quality of new product development and project management processes Quality costs Quality ratings Defects of critical products/components Material costs Manufacturing costs Labour productivity Space productivity Capital efficiency Raw material inventory WIP inventory Finished goods inventory Stock turnover
People	Employee perception surveys Health and safety per employee: Accidents Absenteeism Labour turnover Retention of top employees Quality of professional/technical development Quality of leadership development
Future	Depth and quality of strategic planning Anticipating future changes New market development New technology development Percentage sales from new products

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2.5 Concluding remark

After studying the literature review, it has been found that there are very limited researches, which have been conducted on labeling & packaging industry & very few of them showed practical implementation of lean manufacturing. In most cases it was shown via simulation. Besides that it has been observed that VSM was used intensively in most of the scenarios but a detailed step by step analysis of waste generation in highlighted process of VSM & practical methodology of waste reduction solution for packaging & labeling industries is not available in most reviews. UEE & CCR along with UPLH has been chosen to analyze the after effects of lean manufacturing tools. These parameters were chosen because no studies have been done on it for this particular type of industries. The main focus of this study is to lead time improvement of packaging & labeling company by reducing waste generation.

Chapter 3 Methodology and Development of New Processes

3.1 Introduction

The scope of this chapter is to establish a new process in die cutting & finishing which will eliminate waiting, motion & defects related waste by introducing different lean approach. For identifying the bottleneck in the process we need to conduct value stream mapping. It will show wip or raw material flow with all value adding & non value adding process. With the help of problem solving tools, different new processes can be introduced. New process needs to be easily applicable & properly visible to the machine operator. Different layout with more effective layout has been arranged to establish a new motion in finishing. With the help of all these tools, improved UEE, UPLH & CCR can be achieved.

3.2 Concept

Lean manufacturing is actually implemented to increase productivity without sacrificing any quality. Productivity improvement can be measured in terms many KPI such as UPLH, UEE etc. In this case the manufacturing process is segregated in few processes like- printing, cutting, finishing. VSM will be carried out throughout the process to understand the slow moving process with it's value to customer. All highlighted processes in the VSM needs to be furthered studied to visualize the main root cause for the problem. WHY-WHY analysis can be applied to find the underlying cause of the case. Die cutting UEE is entirely dependent on number of set up, where set up is the time between one job's end time & next job's start time. So the time here can be limited with the help of new process to make set up more faster. Previous output per hour & UEE will be compared with the new output per hour & UEE to observe the difference in result. Defects is directly related to quality of the product & almost every industry is generating defects. Good quality defines limited amount of defect & deteriorating quality means more defects than expected. CCR is the measureable unit for customer complain for which company has to bear additional processes, cost & time. It is a common practice in our industry to be negligible of quality perspective of a product in the root level, which is actually coming back to the manufacturer as a claim issue. So working in the root level & monitoring quality can actually give us better output. A comparison between previous CCR & CCR after implementation will be introduced to visualize the improvement. There is again a problem related to motion in the finishing area. It's slower than conventional processes. In the finishing area, UPLH is the defining factor. It is used to get the actual output in that process. We will introduce an entirely new finishing set up to eliminate any bottlenecks in the finishing. So by recording the output per person & providing comparison we can establish a result. Set up time will be recorded with the help of a stopwatch and VSM readings will be taken from the front sheet, which will be filled up by operators. Each & every steps will be approached with the help of lean tool.

3.3 Problem Identification Methodology

At the very beginning, VSM has to be carried out to get the problematic processes inside an operation. Based on that other lean tools like Why-Why analysis & Time study needs to be conducted to get better idea regarding the issue. It is very important that practical approach needs to be taken to arrest the issue & participation of shop floor employees is necessary in this case.

3.3.1 Application of VSM

VSM is one of the basic lean manufacturing tools. It is used to map the entire process from supplier to customer, in which information & process flow is properly visualized, value adding & non value adding processes are segregated & every kind of delays are clearly highlighted which are happening in the industry.

In this case, VSM was applied only to production processes. To map a VSM, each job was attached with a front sheet to get the vital information regarding time consumption in each particular steps. Production planner was assigned to attach it with customer order sheets. Randomly five hundred different orders were selected of different criteria's to conduct the research & get the exact timings. After the order is being dispatched to the warehouse, the front sheet with all the details are collected from the production floor & recorded. Different WIP areas of many processes are identified in the production floor & recorded status of current raw material & WIP to get the maximum WIP capacity per process

Table 3.1: Time Capturing Sheet Example

Digital					
Job No	24960223			Ref	HM68364-B
Time Taken in Processes					
	Received		**Released**		
Steps	**Date**	**Time**	**Date**	**Time**	**Total Time Taken**
Pre Coating	23-Jun-18	11:05 AM	23-Jun-18	11:45 AM	40 Min
Printing	25-Jun-18	5:00 PM	25-Jun-18	5:30 PM	30 Min
Post Coating	26-Jun-18	2:00 AM	26-Jun-18	2:45 AM	45 Min
Die Cutting 1	26-Jun-18	6:00 AM	26-Jun-18	7:15 AM	65 Min
UV	26-Jun-18	12:20 PM	26-Jun-18	3:30 PM	190 Min
Die Cutting 2	28-Jun-18	2:05 PM	28-Jun-18	3:10 PM	65 Min
Polar	29-Jun-18	9:00 AM	29-Jun-18	9:25 AM	25 Min
Finishing	29-Jun-18	11:35 AM	29-Jun-18	2:35 PM	180 Min
Inspection	29-Jun-18	9:00 PM	29-Jun-18	9:20 PM	20 Min
Dispatch Team	30-Jun-18	1:45 AM	30-Jun-18	2:20 AM	35 Min

All individual steps are categorized in value adding & non-value adding process based on the conception of value as per customer's point view. Figure 3.1 shows VSM of digital products in present state.

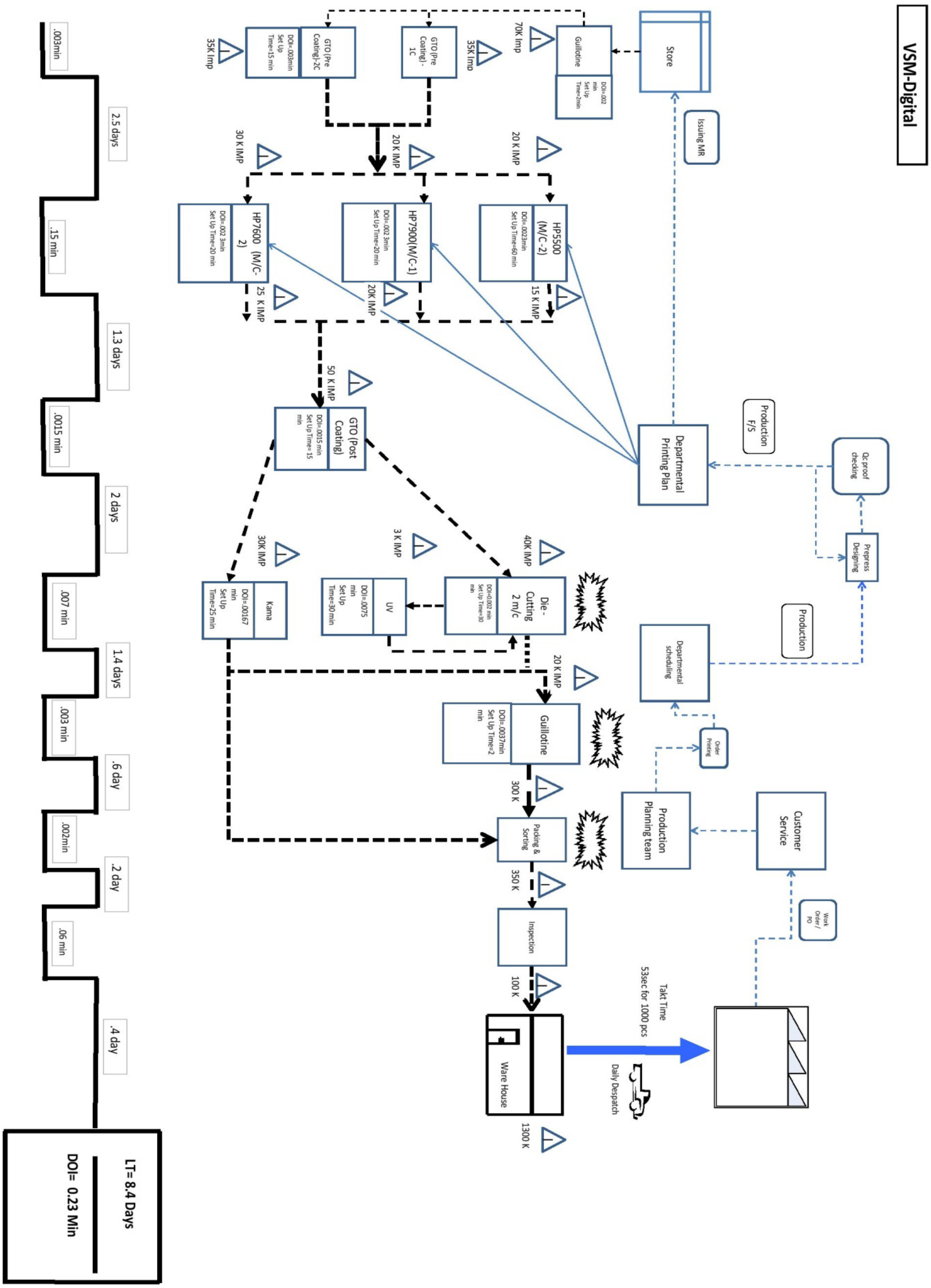


Figure 3.1: Initial VSM

3.3.2 Die Cutting Area

Based on the VSM, it can be seen that, one of the highlighted stages is die cutting where considerable time is being wasted. In this stage, every order has to be placed inside the machine with its own die as per customer requirement. Now setting up a new die cutter by removing the previous die, takes a lot of time. It has been observed by doing further Why-Why analysis in Figure 3.2 that set up time is even maximized with the addition of unavailability of the right die in the right place.

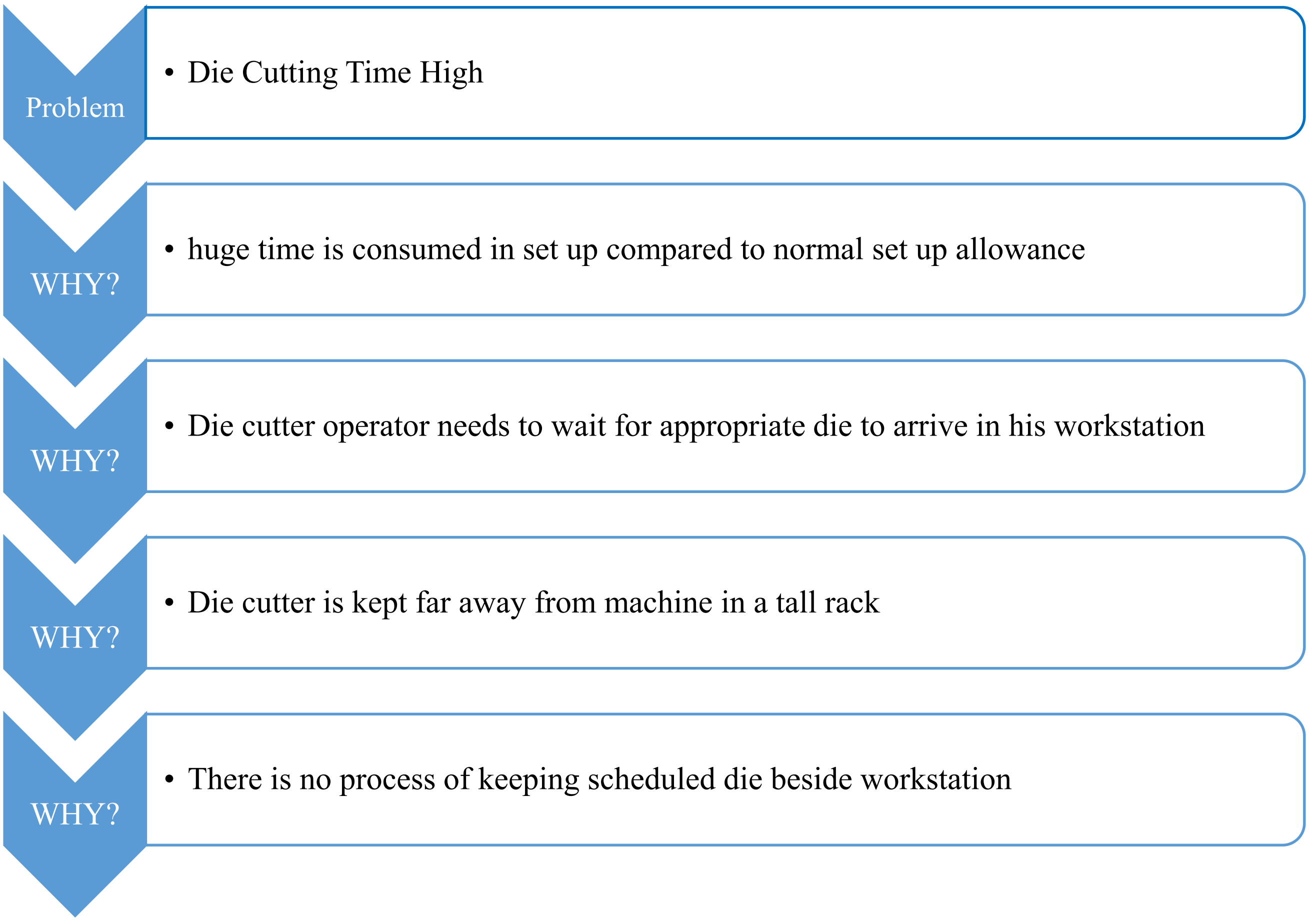


Figure 3.2: Why-Why Analysis of die cutting waiting time

A die cutter is a tool, which is used to give the printed sheets many customized shapes based on customer requirement. It needs to be installed into machine by the operator to cut the sheets. At present, department has approximately 2000 different types of die cutters. Each job requires separate kind of dies to process the goods. Some examples of dies has been given in Figure 3.3 -

Figure 3.3: Different kind of Die cutters

So until the die arrives, operator has to wait until the actual set up can be done. Therefore, it generates waiting time in this step for almost every job. In addition, an increased amount of WIP stock has been seen in the die area due to slow speed of cutting. Present storing system of die cutters has been shown in Figure 3.4-

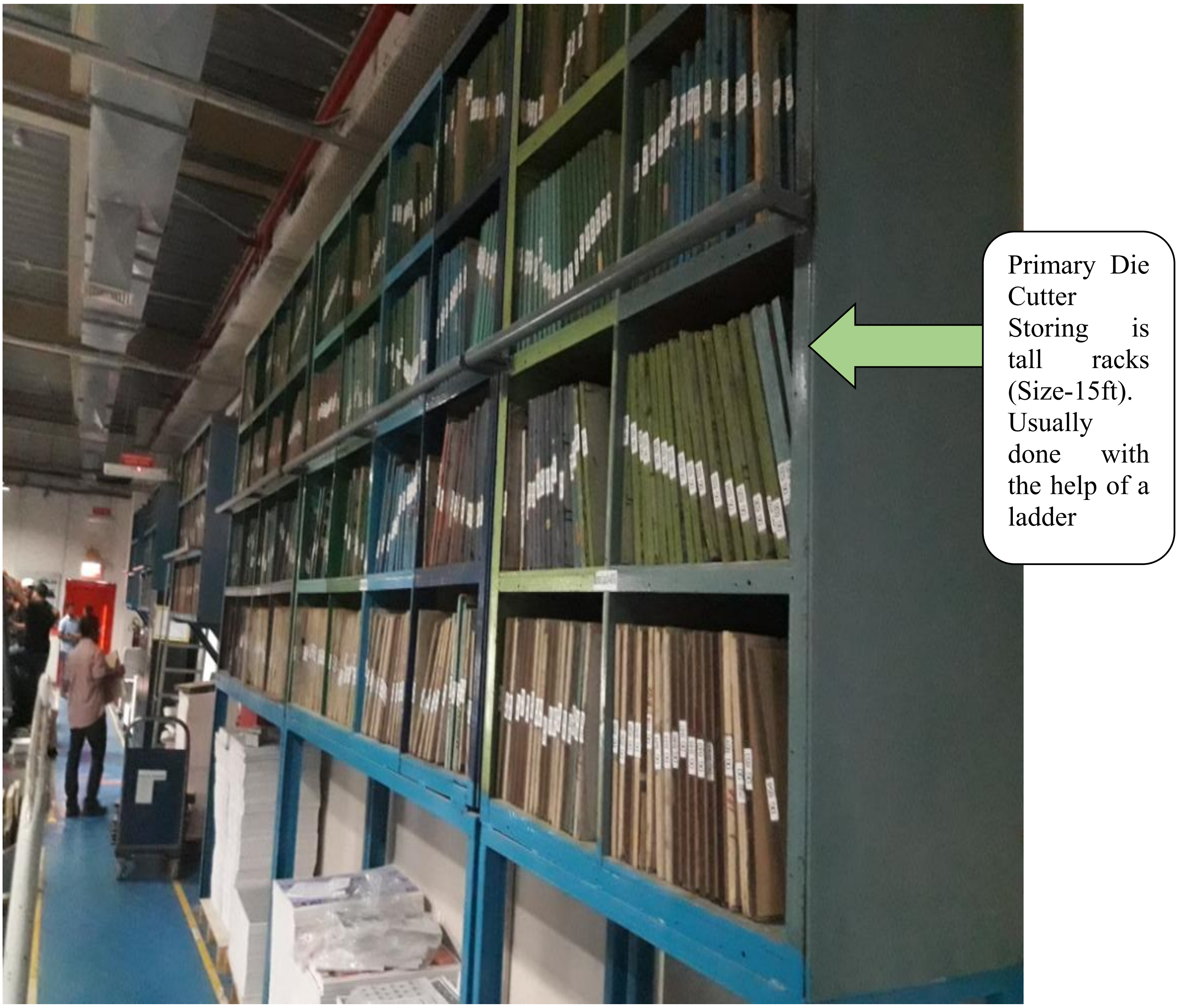


Figure 3.4: Current Die Rack

There are five types of die cutting & experiment has been carried out on every style so that actual scenario can be seen. That's why set up time in minutes for 500 different jobs are recorded and calculated.

Table 3.2:Average set up time in die cutting

Details of die cutting type	**Count of Order**	**Average Set up Time(min)**
Punch Hole	77	30
Crease Cut	70	32
Kiss Cut	92	45
Normal Cutting	189	42
Emboss Cutting	72	38
Total	500	37.4

3.3.3 Finishing Area

From VSM, it has been identified that huge no of semi finished products are getting pile up due to slow moving process. The current finishing process is the combination of 3 secondary processes which are polar cutting, rubber adding & sorting. So we have conducted why- why analysis to find out the bottleneck in the process which is shown in

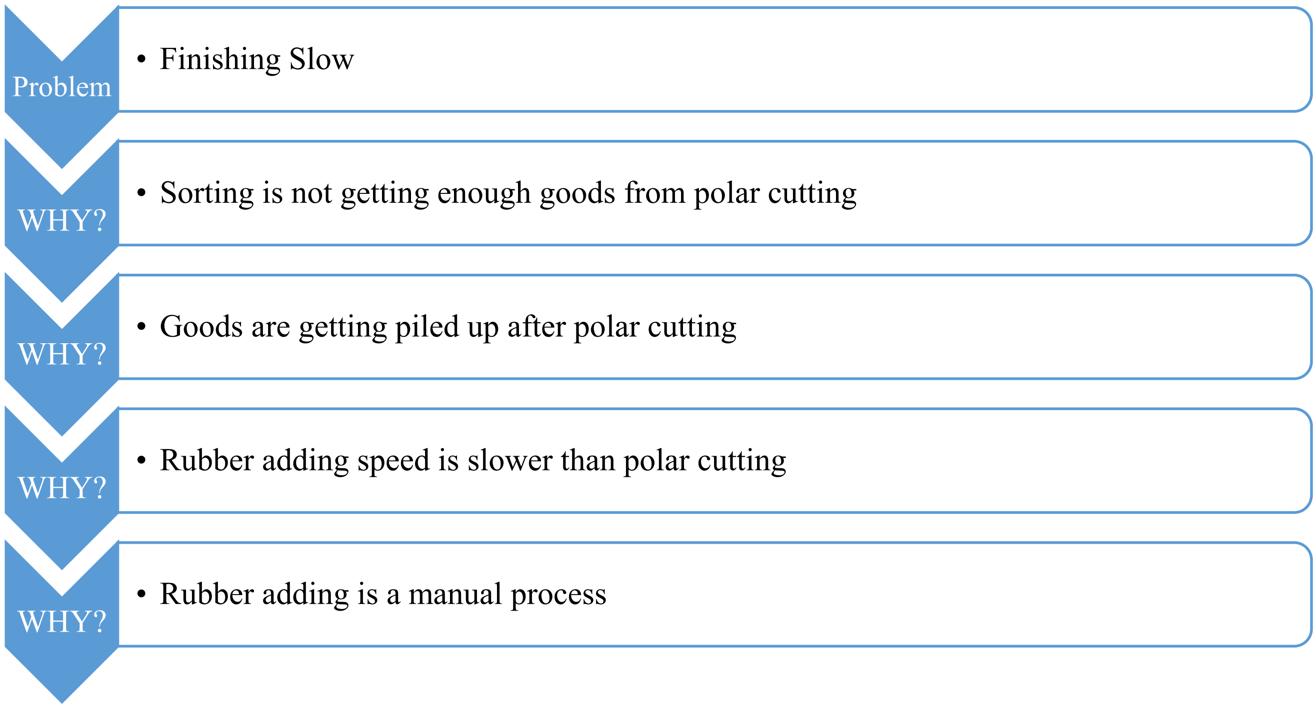


Figure 3.5. Why-Why analysis is another kind lean tool where each & every step is thoroughly investigated until the last answer receives no further question on it.

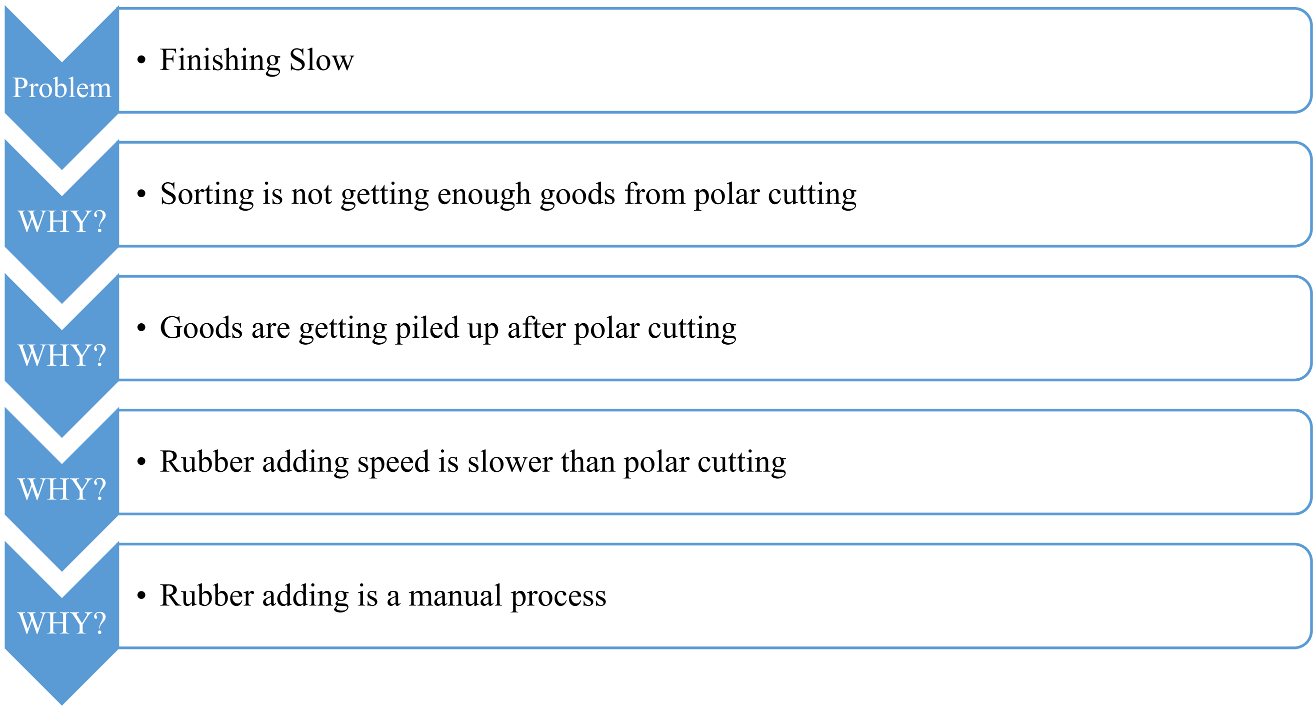


Figure 3.5: WHY-WHY analysis on finishing

In Figure 3.6 the present set up of finishing zone is shown where one operator is seen standing beside the polar machine for rubber adding. Figure 3.7 represents the schematic diagram where red lines are showing the motion that needs to be covered after rubber adding.

Figure 3.6: Current State Finishing Set up

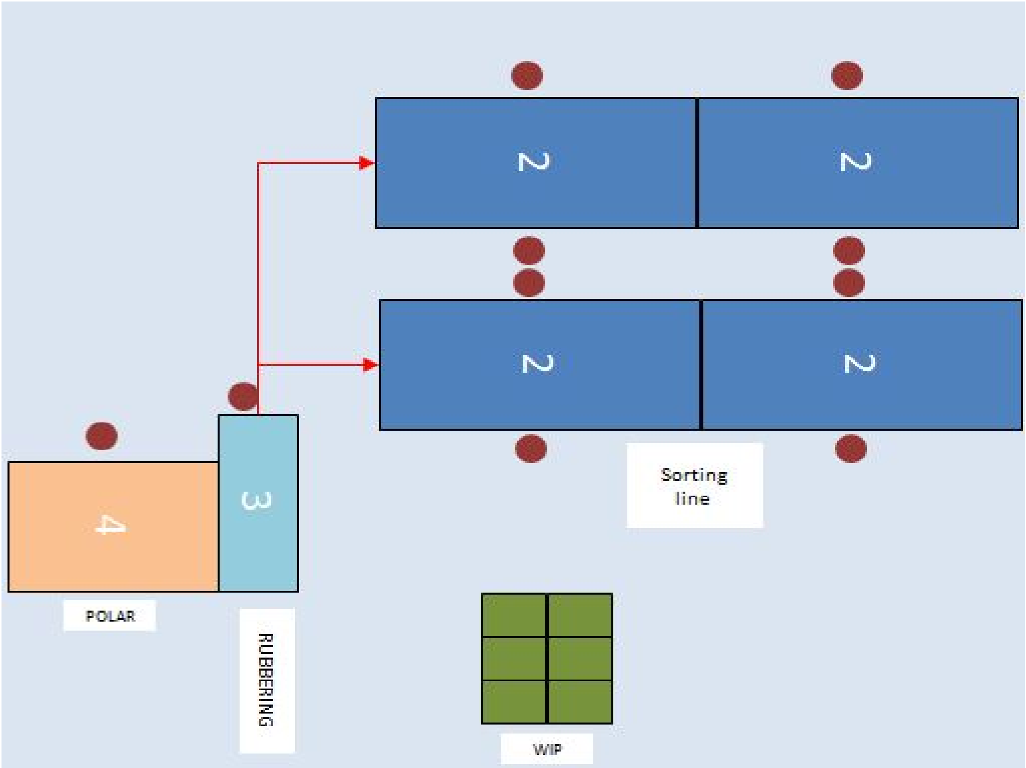


Figure 3.7: Current Finishing set up schematic diagram

It has been observed that rubber adding process can be leveled as non value adding process as it is not adding any value to product & customer will not pay any money for this process, which makes this step a burden to the manufacturer as not only it is making the process slow but also it needs manpower to attach rubber. Besides that, goods has to be carried to sorting tables in a box for further processing which generates extra motion of the operator. 40 different dispatch quantities with UPLH in the initial finishing condition is recorded & shown in Table 3.3. Also it has been noticed that a considerable amount of defects were being generated on the process which are making the process even slower & mainly the accountable factor for reprocessing.

Table 3.3: Daily Dispatch Quantity (M Pcs/Day)

May'18				June'18			
Dispatch/Day (Million)	**Manpower**	**Working Hours**	**UPLH(Pieces)**	**Dispatch/Day (Million)**	**Manpower**	**Working Hours**	**UPLH(Pieces)**
1.3	59	10	2199	1.1	57	10	1972
1.1	58	10	1933	1.2	59	10	2047
1.2	59	10	2054	1.1	56	10	1983
1.2	57	10	2115	1.1	57	10	1956
1.0	59	10	1720	1.0	58	10	1736
1.1	59	10	1874	1.2	59	10	2056
1.2	58	10	2078	1.2	57	10	2108
1.1	58	10	1910	1.1	59	10	1873
1.1	57	10	1967	1.2	59	10	2051
1.3	57	10	2283	1.0	58	10	1766
1.2	59	10	1957	1.0	58	10	1759
1.1	59	10	1906	1.0	56	10	1830
1.3	57	10	2284	1.0	57	10	1790
1.3	59	10	2210	1.0	57	10	1779
1.3	59	10	2230	1.0	58	10	1802
1.2	58	10	2072	1.2	59	10	2049
1.1	56	10	1972				
1.1	59	10	1872				
1.2	57	10	2109				
1.2	57	10	2141				
1.2	57	10	2142				
1.3	58	10	2262				
1.2	59	10	2053				
1.3	58	10	2276				

3.4 Details of the new process

In this research work, two kinds of experimental set up & one innovative process was used to conduct the new implementation & it's result. One of them will be in die cutting section of the process & the other one in finishing area.

3.4.1 Die cutter rack

In this industry, many kinds of die machines are in use. But all of them have one thing in common, which is all of them require a particular shape die to cut products into customer required shape. Every order has their own die to process in this step. A kanban die rack can solve the problem. Not only it can ensure on time die delivery but also it enhances the visibility of the floor. An example of kanban die rack has been shown in Figure 3.8. In here die operator needs to use & keep die in this die rack. It has two portion. Upper portion of the die rack will be used for future orders & lower portion of the rack needs to be used for already utilized dies. The whole idea of establishing this process with a new rack was to remove any die related waiting time in die cutting area.

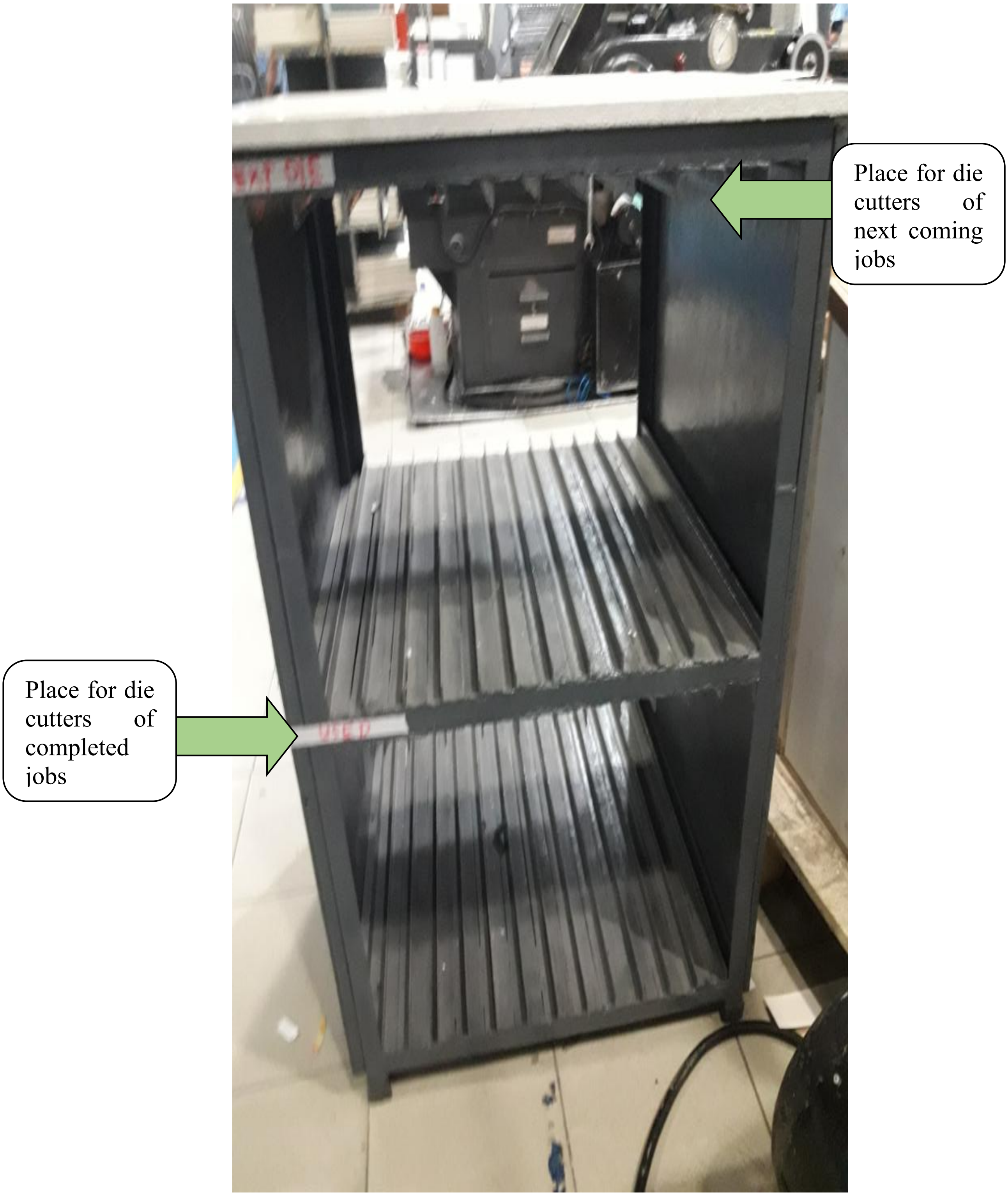


Figure 3.8: New Die Rack

3.4.2 New Finishing Table Line

Finishing stage is one of the key focus point of this entire research. A new finishing line set up is designed which is shown in Figure 3.9. In here sorting tables are connected by supporting tables with polar machine, which is another type of cutting machine. It provides goods in ultimate piece form. Each polar machine is connected with three long tables, which are again aligned with another three sorting tables where finishing operators will do their work. So it eliminates the requirement of rubber stage with the manpower itself as goods can be sent to the appointed table just by pushing it on the table surface. There is no need of rubber adding to the piece bundle which are being generated in the polar machine. So there is always be a flow of goods from machine to the table. This eliminates both waiting time of operator & mainly the motion of the goods.

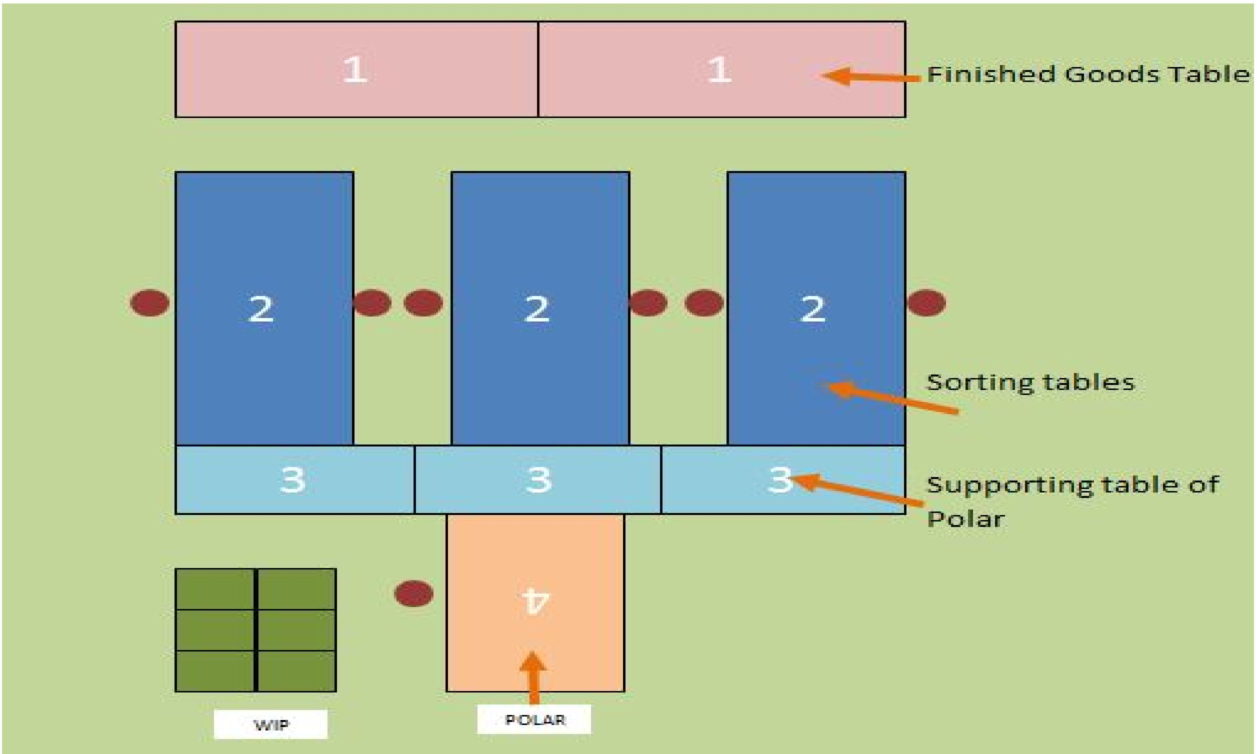


Figure 3.9: New Finishing line schematic diagram

For eliminating defects related wastage, the first step requires a quality visibility process & making accountability in the root level. For the new process, two different kind of color sticker has been arranged which needs to be attached on the top of the product which in this case is paper sheet. On top of the sticker, an alphabet is written mentioning the stage name. Two kind of color sticker- green sticker for indicating good quality & yellow sticker for indicating bad quality & requires further checking for quality assurance. So with the help of this not only the information of quality will be passed but also accountability will improve as stage name is mentioned on top of it. There are some basic stages of printing industry which are- printing, Emboss, UV, die cut & finishing. Each process has their own defects. So every operator has to take accountability and attach it.

3.4.3 Printing color sticker combination

For defect minimization, color sticker adding process can be adhered to every sub processes. It gives great visualization to process owners with the help of almost no investment. Two type of color sticker can be added- Green (For good quality), Yellow (For Bad quality). This new process can be a great tool to make the process much more faster than before. Also it makes the process owner more accountable because quality is now measured in each step. For printing two kind of probable attachment is possible which is shown in Figure 3.10-

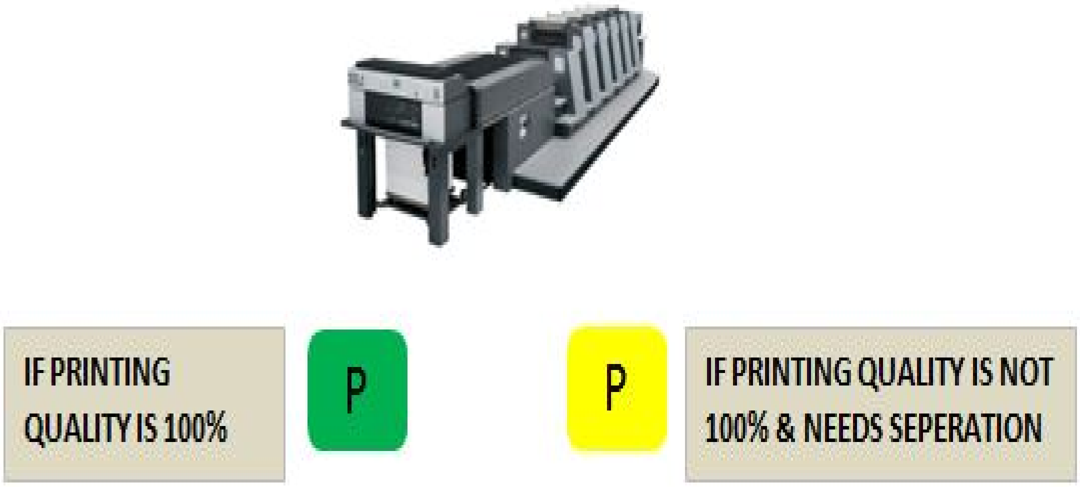


Figure 3.10: Color Sticker in Printing

3.4.4 Emboss Sticker combination

After printing, it comes to emboss. So in this stage, depending on quality, total 4 types of probable sticker can be attached which has been represented in Figure 3.11-

Figure 3.11: Emboss Sticker

3.4.5 UV printing sticker combination

After emboss, it goes to UV printing. So as usual, this step generates defects of its own. So again color sticker is added on it. Some examples of possible outcomes is given in Figure 3.12-

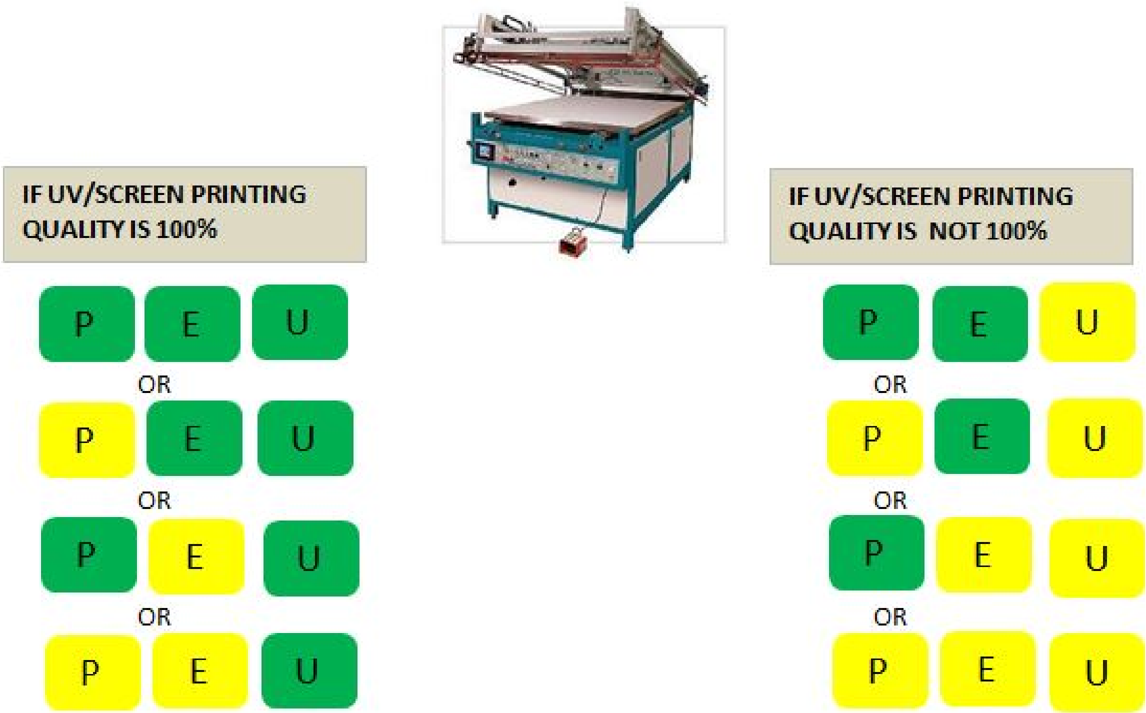


Figure 3.12: Color sticker combination in UV stage

3.4.6 Die Cutting Sticker combination

Die cutting is the last stage before the product goes to finishing. Figure 3.13 shows some of the probable combination of sticker, which can be expected after adding die cutting sticker. Based on the added sticker combination in the die cutting, the finishing operators will check the goods. All green will be given without any further checking. Any type of yellow sticker of any process requires further checking.

Figure 3.13: Die cutting stage combination

So if any sorting operator receives the highlighted combination than he or she will not check any defects related to UV but all other defects need to be checked. So it is actually giving the proper information to the sorting operators to make their work more comfortable.

3.5 Process Implementation Methodology

Based on the conception of the new processes, following methodologies were adopted & implemented in the production floor-

3.5.1 Waiting time elimination in Die cutting Zone through Kanban die rack

A kanban die rack can be used to arrest this waiting time. Kanban die rack is used to stock die cutter for next jobs, which is shown in Figure 3.14.Also it has separate place to put die cutters, which have already been used. One material handler is given the job to check and manage all die machines. So any usage of dies from the next cutter slot gives the visualization of the need to refill cutter supplies immediately. Besides that, as now operator know where the next job’s die is placed, so there will be no more waiting for cutting tools to arrive at the place rather it will allow him to start the new job faster than before by reducing set up time. Kanban rack also allows to keep the area as per 5S standard.

Figure 3.14: New Die Rack

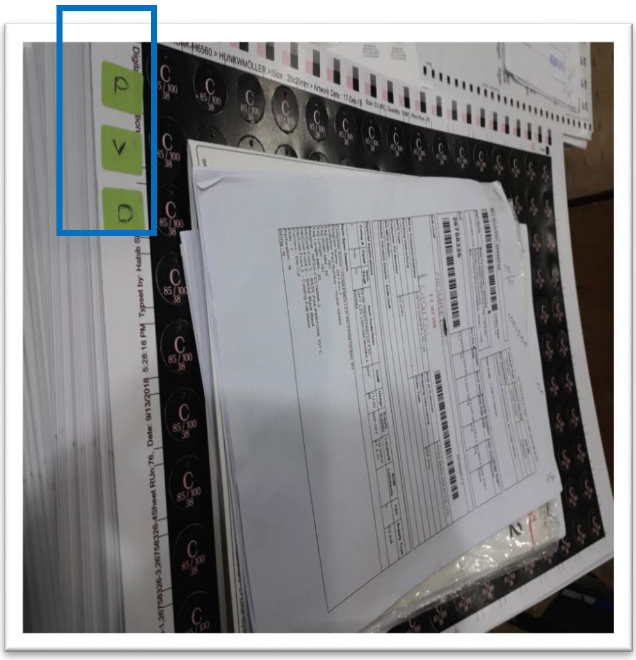
3.5.2 New finishing line implementation

A new finishing table set up which is shown in Figure 3.15, has been prepared according to new schematic diagram which will eliminate rubber adding stage complexly & also by doing so, it will streamline entire finishing process.

Figure 3.15: New finishing line set up

3.5.3 Color Sticker implementation

As per new process, every operator is now attaching color sticker based on the quality of the process output. Some examples is given from the production floor in Figure 3.16-



Color sticker added on top of the goods so that even after cutting it can go along all the way to the sorting table & give finishing operator the correct information regarding defects.

Figure 3.16: Practical implementation of color sticker

3.5.4 Output parameters

There is a common goal of every experiments and that is result. If the outcome of any experiment is not as expected then the entire experiment is worthless. Therefore, output parameters of any experiments should be chosen cautiously because the victory is entirely dependent on that. So, to make this research successful, output parameters are selected carefully so that input parameters have major effect on the results. In this experiment, the selected output parameters are given below:

- UEE
- UPLH
- CCR
- Delivery/Day

These readings are taken in both prior to any lean implementation & after implementation to compare with each other.

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3.6 Concluding remark:

Waste reduction through lean manufacturing tools will generate better productivity & quality. Most of these outcomes largely dependent on the sustainability of the lean processes & it's proper application. It has been found through literature study that lean tools have great impact on the improvement of productivity. First the entire process is covered by a VSM to highlight all the non value adding areas from the value adding processes so that based on that process proper lean tool can be selected & applied. Then die cutting area was selected to arrest waiting time due to die & a new kanban die rack has been arranged to reduce set up time. Also finishing area was chosen to eliminate entire non value adding stage of rubber adding and for that new schematic diagram with optimum motion of operator was designed & implemented. Also entire new process of color sticker was put into practice to produce more quality products, therefore deducting defects. All key KPIs like UPLH, UEE, CCR & daily output is calculated before implementation of lean tools to visualize the bottlenecks in the process.

Chapter 4 Effect of the lean tools in production

4.1 Introduction

This chapter discusses about the effect of lean manufacturing tools. process parameters. Every research has to be result orientated & to prove it both conditions like before implementation & after implementation & their comparison has to be showed. This chapter will show that how lean tools helped the manufacturer to eliminate waste from different processes & therefore improved their performances.

4.2 Experiment results

After implementing all the necessary steps, it has become obvious that lean tools can significantly improve manufacturing process through eliminating waste. The results are shown below-

4.2.1 Die Cutting Set up time reduction

In die cutting, new kanban die cutter rack provided the operator with better visibility & efficiency by providing the tools just in time of need. So no more waiting related wastes in the die cutting. We have observed another 500 different orders to track down the change in set up time & it is significantly improved. The results can be properly shown below for all kind of die styles for better visibility-

70 recordings carefully chosen like before for crease cut orders were recorded after implementation & there comparison is given below-

Table 4.1: Crease Cut Set up time comparison

Crease Cut jobs	Previous Set up Time(Min)	Present set up time(Min)	Crease Cut jobs	Previous Set up Time(Min)	Present set up time(Min)
1	35	32	**36**	33	31
2	32	32	**37**	30	28
3	33	31	**38**	33	31
4	33	32.5	**39**	30	28
5	37	35	**40**	32	30
6	36.5	33	**41**	30.5	28.5
7	31.5	29.5	**42**	30	28
8	31	29	**43**	32	30
9	34.5	31	**44**	34	32
10	32	31	**45**	34.5	32.5
11	30	28	**46**	32	30
12	32	30	**47**	32	30
13	32	30	**48**	33	31
14	30.5	30	**49**	32.5	30.5
15	30	28	**50**	32	30
16	29.5	27.5	**51**	30	28
17	29.5	28	**52**	30	28
18	32.5	30.5	**53**	33	31
19	32.5	30	**54**	34	32
20	29	27	**55**	34.5	30.5
21	29	27	**56**	35.5	32
22	29	27	**57**	33	31
23	30.5	30	**58**	34.5	32.5
24	33	31	**59**	33	31
25	31	30.5	**60**	32	29
26	30.5	28.5	**61**	32	30
27	30	28	**62**	31	28
28	34.5	32.5	**63**	31	29
29	33	31	**64**	32	31.5
30	32.5	30.5	**65**	31.5	29.5
31	32.5	30.5	**66**	30.5	28
32	29.5	27.5	**67**	32.5	31
33	29	27	**68**	30	29
34	32.5	30.5	**69**	33	31
35	33	31	**70**	33	30

Graphical representation-

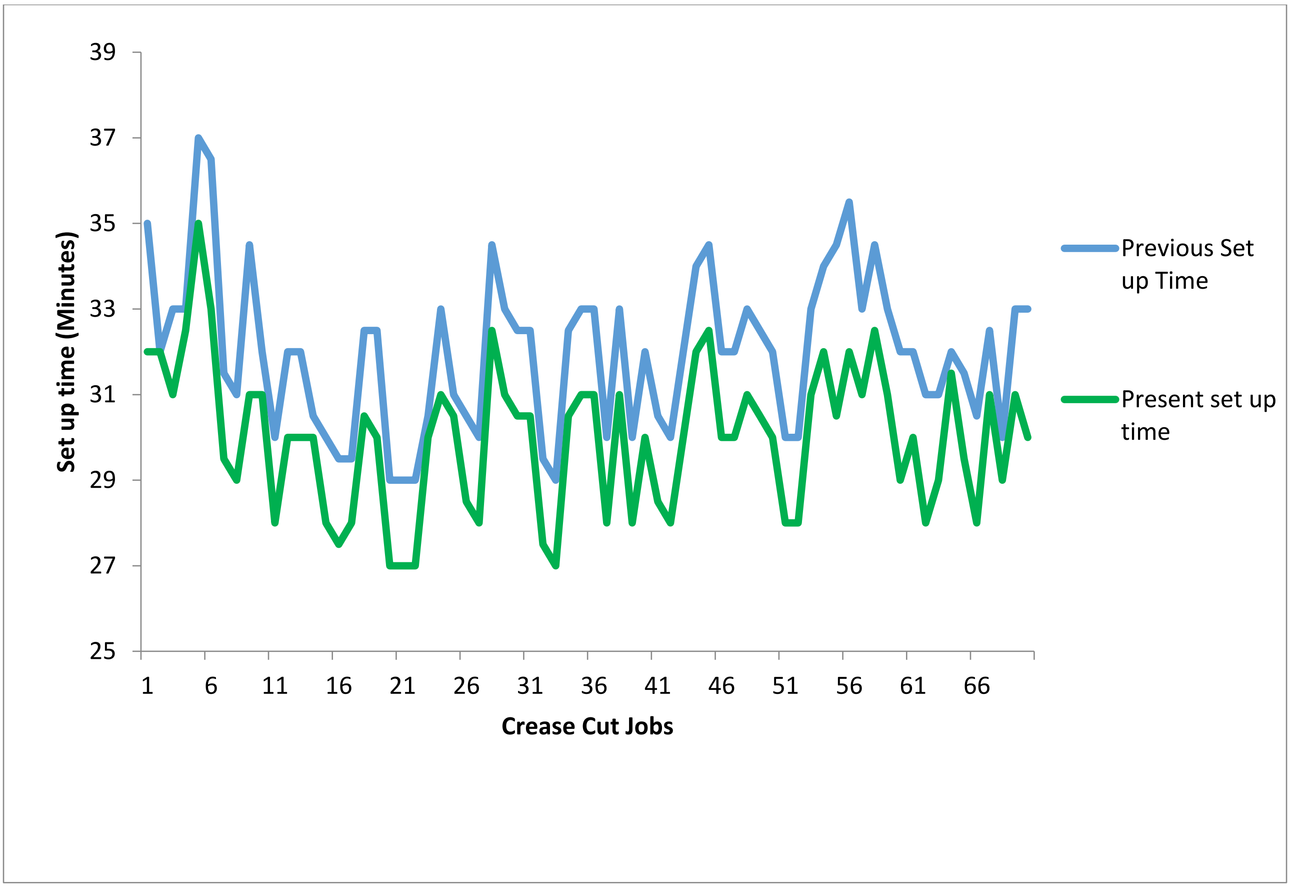

Figure 4.1: Crease Cut Set up Time Comparison

Figure 4.1 represents the reduced set up time after implementation of lean tools

Equation for % of improvement-

$$\frac{Previous\ average\ set\ up\ time(\text{min}) - Present\ average\ set\ up\ time(\text{min})}{Previous\ Set\ up\ time\ (\text{min})} \times 100$$

Equation 4.1: Die cutting Set up time improvement

Improvement (%) = $\frac{32-30}{32} \times 100$

= 6.2

72 emboss cut jobs like before was chosen to get the results of implementation. Results –

Table 4.2: Emboss Cut Set up time Comparison

Emboss Cut Jobs	Previous Set up Time (Min)	Present set up time(Min)	Emboss Cut Jobs	Previous Set up Time (Min)	Present set up time(Min)
1	35	31	**37**	36	30
2	40	38	**38**	38	37
3	42	38	**39**	38.5	34.5
4	40	37.5	**40**	38.5	36
5	38.5	34	**41**	40	36
6	42	39	**42**	36	32
7	36	32	**43**	38.5	34.5
8	36	33	**44**	37	32.5
9	38	34	**45**	36.5	32.5
10	36.5	32.5	**46**	36	32
11	36.5	34	**47**	40	36
12	36.5	32.5	**48**	36.5	32.5
13	37	34	**49**	37	35
14	40	36	**50**	38.5	34.5
15	37	33	**51**	38	32
16	41	37	**52**	35	30.5
17	35	32	**53**	39.5	35.5
18	40	36	**54**	40	36
19	42	38	**55**	38.5	34.5
20	40.5	36.5	**56**	39	33.5
21	35.5	31.5	**57**	38	31
22	38	35	**58**	38.5	34
23	36	31	**59**	35	31
24	37.5	33.5	**60**	40	35.5
25	36	30	**61**	34	30
26	40	36	**62**	37	32
27	38	34	**63**	34.5	30
28	37.5	33.5	**64**	35.5	30
29	38.5	35	**65**	37.5	33.5
30	40.5	36.5	**66**	40	37.5
31	40	34	**67**	38	34
32	37	33	**68**	38.5	34.5
33	40	35	**69**	36.5	32.5
34	38.5	36	**70**	38	34
35	40	36	**71**	37	33
36	38	34	**72**	40	35

Graphical Representation-

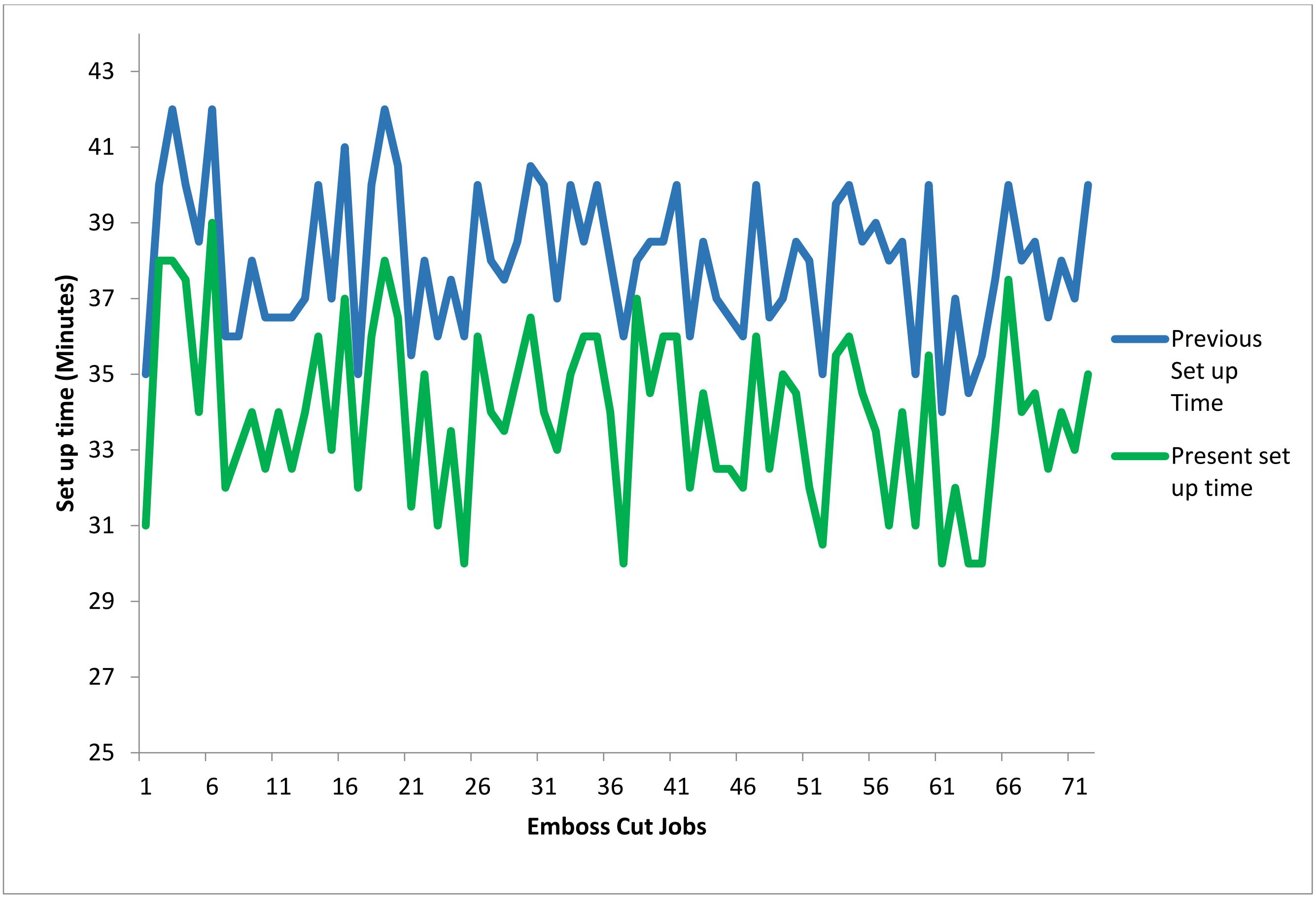

Figure 4.2: Emboss cut set up time Comparison

Figure 4.2 shows the improvement trend of set up time for emboss jobs.

Using Equation 4.1: Die cutting Set up time improvement for emboss type of jobs can be determined,

Improvement (%) = $\frac{38-34}{38} \times 100$

= 10.6

92 similar types of kiss cut jobs were chosen like previously to visualize the results-

Table 4.3: Kiss cut set up time comparison

Kiss Cut Jobs	Previous Set up Time (Min)	Present set up time(Min)	Kiss Cut Jobs	Previous Set up Time (Min)	Present set up time(Min)	Kiss Cut Jobs	Previous Set up Time (Min)	Present set up time(Min)
1	40	38	**38**	45	41.5	**76**	47.5	42.5
2	41	36	**39**	45	40	**77**	45	40
3	45.5	42	**40**	47.5	40.5	**78**	44.5	40
4	44	40	**41**	42	36	**79**	42	37
5	47.5	42.5	**42**	47	41.5	**80**	47	40
6	47	40	**43**	45.5	40.5	**81**	45	40
7	45.5	40	**44**	46.5	41.5	**82**	45	40
8	46	40	**45**	46	42	**83**	43	38
9	42.5	38	**46**	47	42	**84**	45	40
10	45.5	40.5	**47**	45.5	40.5	**85**	42.5	37.5
11	45	38	**48**	46.5	42	**86**	45	38
12	47	42	**49**	42.5	37.5	**87**	46.5	42
13	46.5	38	**50**	42.5	35	**88**	45.5	40
14	42.5	37.5	**51**	42	36.5	**89**	47	41
15	43	40	**52**	48	42	**90**	47.5	42.5
16	45.5	40	**53**	46	42	**91**	46.5	42
17	42	37	**54**	43.5	38	**92**	42.5	36
18	42.5	38	**55**	45	40			
19	46.5	41.5	**56**	47	42			
20	47	42	**57**	46.5	41.5			
21	42.5	37.5	**58**	47.5	43			
22	42	38	**59**	42	37			
23	45	41	**60**	47.5	41			
24	42	38	**61**	45.5	40.5			
25	45.5	42	**62**	43.5	38.5			
26	45.5	40.5	**63**	46.5	41.5			
27	45	41	**64**	44.5	39			
28	46.5	40	**65**	45.5	42			
29	43	38	**66**	45	40			
30	44.5	39	**67**	45	42			
31	42.5	39	**68**	46.5	40			
32	47.5	42.5	**69**	45	40			
33	45.5	40.5	**70**	42	37			
34	45.5	41	**71**	43.5	38.5			
35	46	41	**72**	47.5	42.5			
36	47	42	**73**	46.5	41.5			
37	46.5	41.5	**74**	45	40			

Graphical Representation-

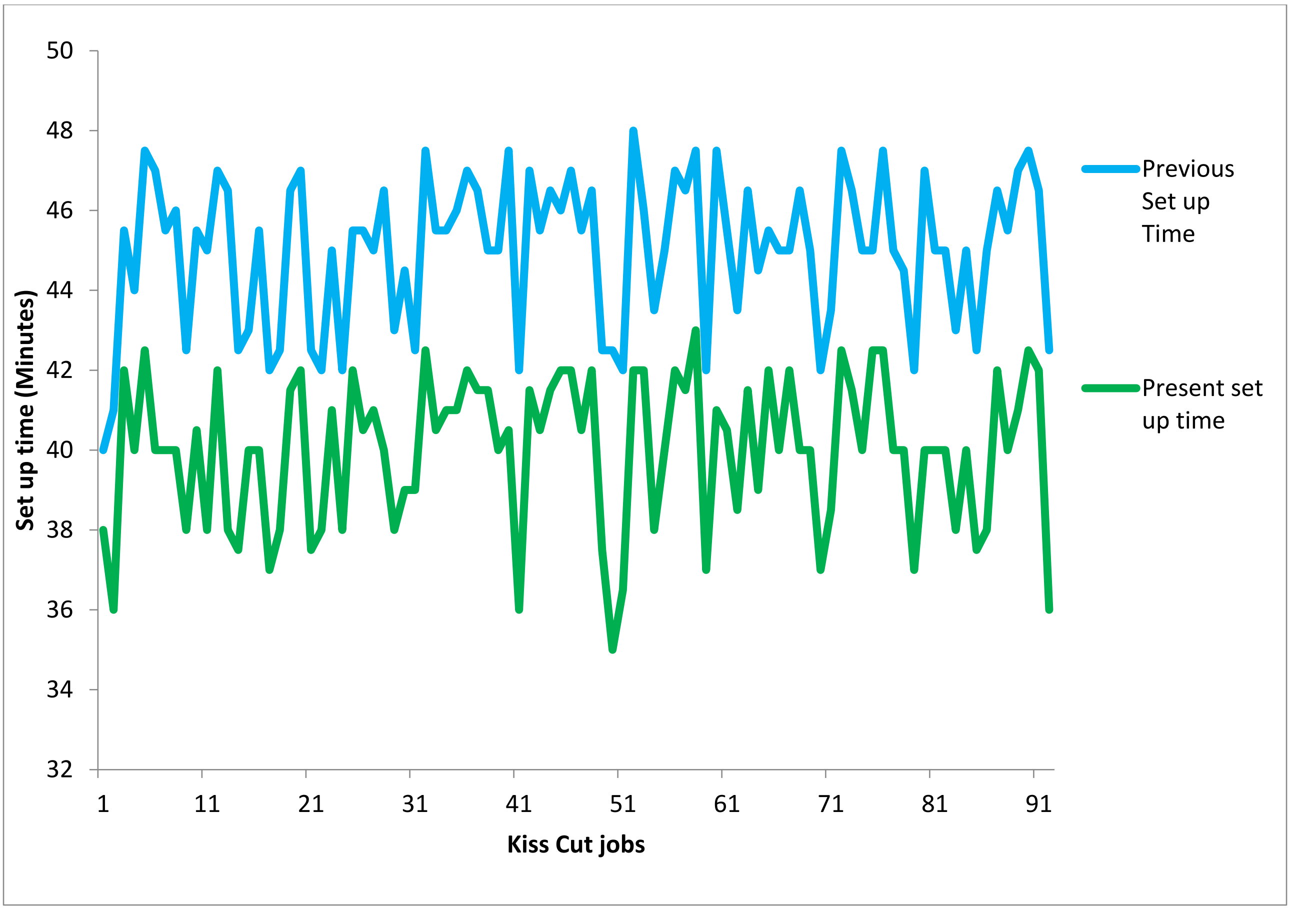

Figure 4.3: Kiss Cut Job set up time comparison

Figure 4.3 clearly shows improvement in set up time.

Using Equation 4.1: Die cutting Set up time improvement for Kiss type of jobs can be determined,

$$\text{Improvement (\%)} = \frac{45-40}{45} \times 100$$

$$= 11.2$$

189 normal type of die cutting jobs were chosen like before to do the study. Results-

Table 4.4: Normal Cut Set up time comparison

Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)	Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)	Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)
1	42	40	**36**	42	37	**71**	42	37
2	43.5	40	**37**	42	35	**72**	44	39
3	42	37	**38**	44.5	39	**73**	44	38
4	42	35	**39**	40	35	**74**	42	37
5	40	37	**40**	42	37	**75**	41	35.5
6	40	35	**41**	44	40	**76**	42	37
7	42	37	**42**	41	40	**77**	41	36
8	43.5	38.5	**43**	44.5	40	**78**	41	35
9	42	37	**44**	41	36	**79**	42	37
10	44.5	39.5	**45**	42	37	**80**	44	40
11	41	36	**46**	40	35	**81**	44	39
12	43.5	38.5	**47**	40	35	**82**	44	42
13	42	37	**48**	44	40	**83**	42	37
14	42	36	**49**	44.5	39.5	**84**	40	35
15	44.5	39	**50**	41	36	**85**	40	34
16	42	37.5	**51**	42	36	**86**	40	34
17	43.5	38	**52**	44	38.5	**87**	44.5	39.5
18	42	36.5	**53**	42	37	**88**	41	36
19	44.5	39.5	**54**	41	35	**89**	42	37
20	42	37	**55**	41	36	**90**	41.5	36.5
21	40	37	**56**	42	36	**91**	42	38
22	42	37	**57**	42	37	**92**	44	39
23	43.5	38.5	**58**	41	35	**93**	41.5	36
24	40	35	**59**	41	36	**94**	42	37
25	42	35	**60**	42	35	**95**	41.5	35
26	44.5	39.5	**61**	42	37	**96**	41.5	36.5
27	44.5	40	**62**	44.5	40	**97**	41.5	36
28	43.5	40	**63**	41	35.5	**98**	42	36
29	42	37	**64**	42	37	**99**	44	40
30	40	38	**65**	42	37	**100**	40	38
31	42	36	**66**	44	39	**101**	40	35
32	43.5	38.5	**67**	41	34	**102**	40	39
33	42	38	**68**	41	35	**103**	41.5	36.5
34	40	35.5	**69**	44	40	**104**	41.5	38
35	44	38	**70**	42	37	**105**	42	38.5

Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)	Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)	Normal Cut Jobs	Previous Set up Time(Min)	Present set up time(Min)
106	40	35	**141**	42	35	**176**	43	38
107	40	33	**142**	43	35	**177**	41	36
108	42	37	**143**	42	37	**178**	43	37
109	42	35	**144**	42	38.5	**179**	43	38
110	42	37	**145**	43	38	**180**	42	37
111	41	35.5	**146**	40	35	**181**	40	35
112	41	36	**147**	43	37.5	**182**	40	36
113	42	37	**148**	42	37	**183**	42	37
114	44	40	**149**	44	39	**184**	41	36
115	41	35	**150**	42	37	**185**	40	35
116	42	37	**151**	42	37	**186**	41	35
117	44	36.5	**152**	44	38.5	**187**	42	37
118	42	37	**153**	44	39	**188**	43	38
119	42	37	**154**	43	38	**189**	40	35
120	44	38	**155**	40	34			
121	42	37	**156**	40	34			
122	41.5	36	**157**	43	38			
123	42	39	**158**	40	35			
124	41.5	36.5	**159**	40	36			
125	42	37	**160**	40	35.5			
126	44	38.5	**161**	43	38			
127	42	37	**162**	43	37.5			
128	40	33	**163**	44	39			
129	40	34	**164**	41	37.5			
130	42	36.5	**165**	42	37			
131	43	38	**166**	42	37			
132	43	38	**167**	43	38			
133	44	39	**168**	41	35			
134	42	40	**169**	43	38			
135	42	37	**170**	41	36			
136	43	40	**171**	42	37			
137	43	38	**172**	43	36			
138	40	35	**173**	41	36			
139	40	34.5	**174**	43	37.5			
140	40	35	**175**	43	38			

Graphical Representation-

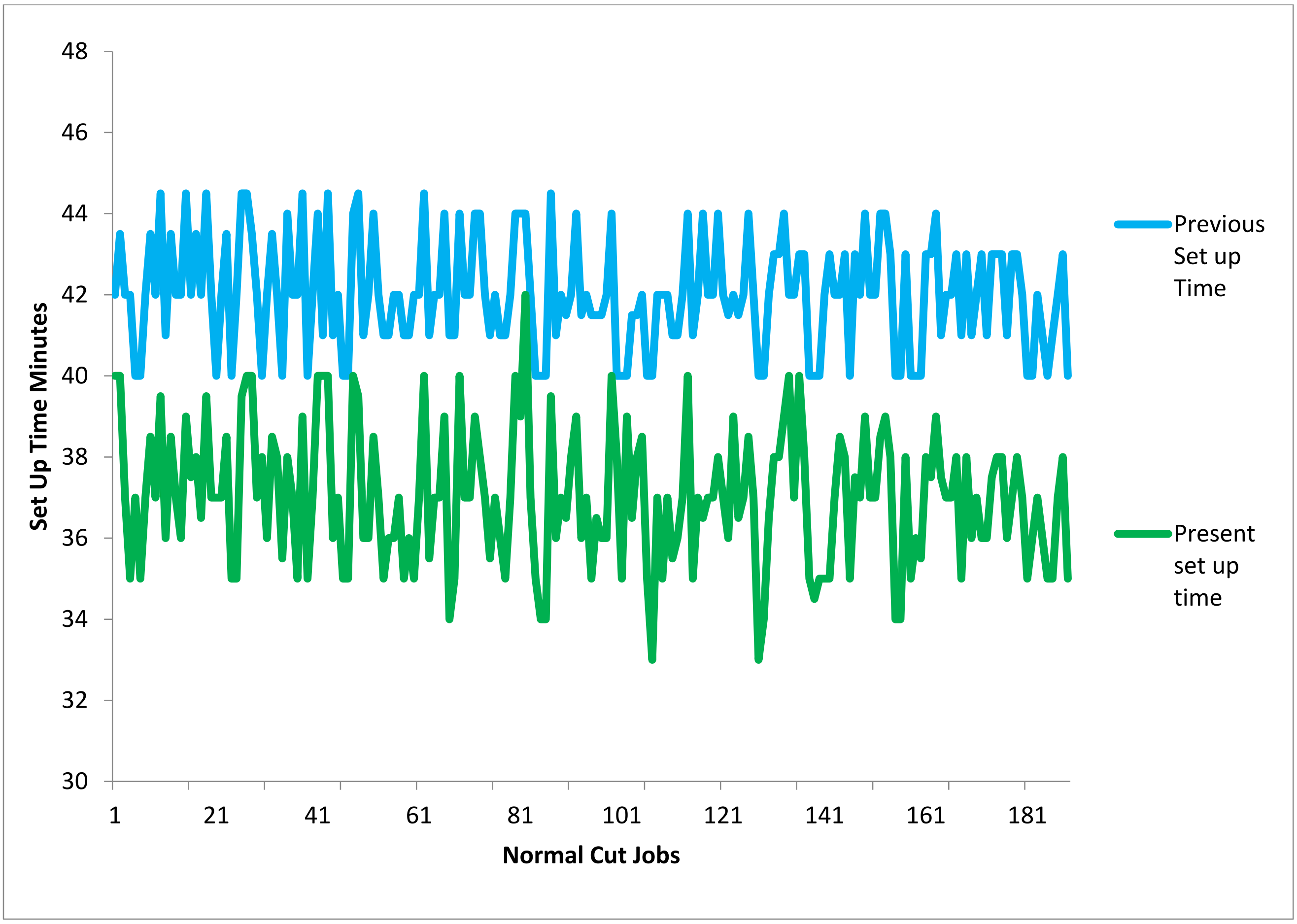

Figure 4.4: Normal cut set up time comparison

So through Figure 4.4, it can be observed that set up time has been reduced.

Using Equation 4.1: Die cutting Set up time improvement for normal cutting jobs can be determined,

Improvement (%) = $\frac{42-37}{42} \times 100$

= 11.9

Similar types of 77 punch hole jobs were chosen to see the effects of lean tools. Results-

Table 4.5: Punch hole jobs set up time comparison

Punch Hole jobs	Previous Set up Time (Min)	Present set up time(Min)	Punch Hole jobs	Previous Set up Time (Min)	Present set up time(Min)	Punch Hole jobs	Previous Set up Time (Min)	Present set up time(Min)
1	30	26	**31**	29.5	27.5	**61**	27	25
2	32	30	**32**	28.5	26.5	**62**	27	25
3	34	30	**33**	30	28	**63**	29.5	27.5
4	33.5	32	**34**	28.5	27.5	**64**	27	25
5	32	31	**35**	30	28	**65**	31	30
6	33	31	**36**	30	28	**66**	27.5	25.5
7	31	30	**37**	31	29	**67**	27.5	27
8	33.5	31.5	**38**	30	28	**68**	27.5	26.5
9	33.5	32	**39**	30.5	28.5	**69**	27.5	25
10	33.5	31.5	**40**	30.5	29	**70**	30	26
11	31	28	**41**	32	30	**71**	31	26
12	32	29	**42**	33	31	**72**	27.5	25.5
13	30	28	**43**	32	30	**73**	32	30
14	29	27.5	**44**	31.5	30	**74**	28.5	26
15	30	28	**45**	31.5	29.5	**75**	29	27
16	32	30.5	**46**	30	28	**76**	32	29.5
17	32	30	**47**	30.5	28.5	**77**	28.5	25
18	32	31	**48**	30.5	30			
19	30	27	**49**	30.5	28.5			
20	29	27.5	**50**	29	27			
21	30	28	**51**	29	26.5			
22	29	27	**52**	30	28			
23	30	28	**53**	29.5	27.5			
24	29	27	**54**	28	26			
25	28	27	**55**	28	26.5			
26	28.5	26.5	**56**	28	26			
27	28.5	27	**57**	29	27.5			
28	28.5	27	**58**	30.5	28.5			
29	28.5	26.5	**59**	28	26.5			
30	30	28	**60**	28	26			

Graphical Representation-

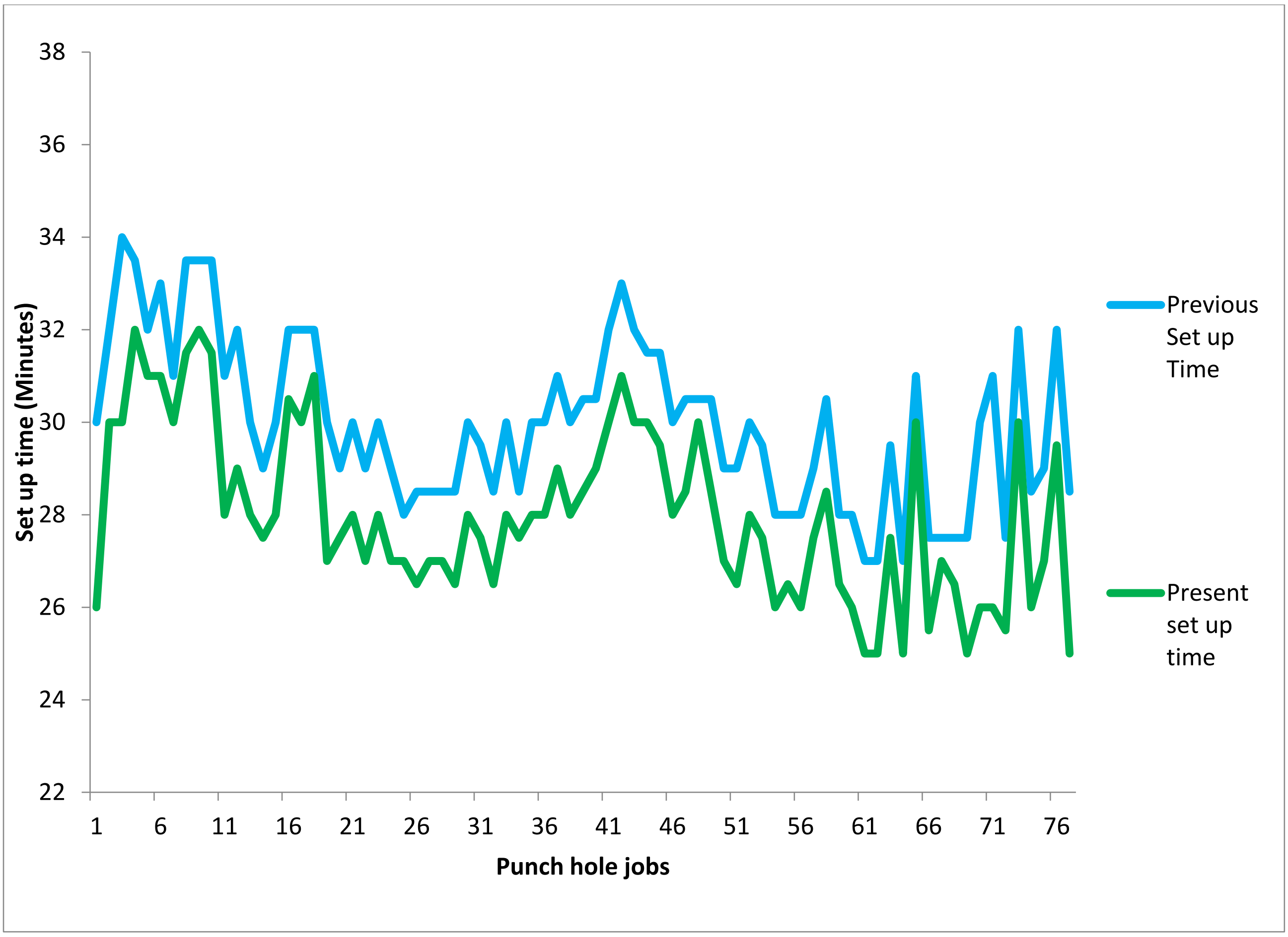

Figure 4.5: Punch hole set up time comparison

So through Figure 4.5, it can be observed that set up time has been reduced for punch hole jobs.

Using Equation 4.1: Die cutting Set up time improvement for punch hole jobs can be determined,

$$\text{Improvement (\%)} = \frac{30-28}{30} \times 100$$

$$= 6.7$$

So summing up whole type of die cutting styles-

Table 4.6: Comparison of Set up times

Row Labels	**Average of Previous Set up Time (Minutes)**	**Average of Present set up time(Minutes)**
Crease Cut	32	30
Emboss Cut	38	34
Kiss Cut	45	40
Normal Cut	42	37
Punch Hole	30	28
Average Set Up time	**37.4**	**33.8**

Overall improvement can be determined by using Equation 4.1: Die cutting Set up time improvement.

So, waiting time reduction (%) = $\frac{37.4-33.8}{37} \times 100$

= 9.6

So with the help of lean tools, we were able to reduce set up time by reducing waiting related wastage by 9.6%.

4.2.2 Die Cutting UEE improvement

Reduced set up time, results in better UEE that provides the manufacturer with improved productivity.

$$\text{UEE(\%)} = \frac{Achieved\ quantity\ in\ total\ scheduled\ run\ time}{Total\ scheduled\ hour \times standard\ speed}$$

Equation 4.2: UEE for Die cutting machine

There are total 3 die cutting machine in the production. Among 3, 2 of the die machines are cylinder type & other one is flat plate type. Standard speed for machines varies. For cylinder type KSBA machines, the standard output per hour is 1200 imp & for flat plate type KAMA machine, the standard output per hour is 1800 imp.

So for cylinder type daily standard output= $Total\ scheduled\ hour \times Standard\ speed \times No\ of\ Machine$

= 19 hours × 1200 imp × 2

= 45,600 imp/day

And for Kama flat type die machine daily standard output= $Total\ scheduled\ hour \times Standard\ speed \times No\ of\ Machine$

= 19 hours × 1800 imp × 1

= 34,200 imp/day

So for getting the UEE(%), total standard output which needs to be considered= (45,600 + 34,200) =79,800 imp/day

A comparison between UEE in before & after lean tools implementation case is shown in Table 4.7.

Table 4.7:UEE Comparison

Before Implementation						After Implementation					
Date	Imp/Day	UEE	Date	Imp/Day	UEE	Date	Imp/Day	UEE	Date	Imp/Day	UEE
2-May	63,335	79%	2-Jun	51,720	65%	1-Jul	69,091	87%	1-Aug	41,322	52%
4-May	22,740	28%	3-Jun	58,032	73%	2-Jul	59,125	74%	2-Aug	43,446	54%
5-May	75,366	94%	4-Jun	53,400	67%	3-Jul	65,234	82%	4-Aug	68,563	86%
6-May	49,398	62%	5-Jun	44,245	55%	4-Jul	73,255	92%	5-Aug	51,020	64%
7-May	29,978	38%	6-Jun	51,822	65%	5-Jul	41,107	52%	6-Aug	57,847	72%
8-May	54,711	69%	7-Jun	44,233	55%	7-Jul	62,849	79%	7-Aug	76,961	96%
9-May	44,589	56%	9-Jun	48,758	61%	8-Jul	63,410	79%	9-Aug	60,265	76%
10-May	51,938	65%	11-Jun	47,590	60%	10-Jul	60,754	76%	11-Aug	71,884	90%
12-May	71,185	89%	12-Jun	68,348	86%	11-Jul	42,607	53%	12-Aug	72,231	91%
13-May	63,885	80%	13-Jun	45,186	57%	12-Jul	64,411	81%	13-Aug	78,929	99%
15-May	44,997	56%	21-Jun	40,260	50%	14-Jul	59,767	75%	18-Aug	55,610	70%
16-May	62,014	78%	23-Jun	53,300	67%	15-Jul	79,212	99%	19-Aug	53,574	67%
17-May	49,685	62%	24-Jun	38,849	49%	16-Jul	62,475	78%	26-Aug	63,742	80%
19-May	59,834	75%	25-Jun	55,894	70%	17-Jul	41,861	52%	27-Aug	60,908	76%
20-May	50,739	64%	26-Jun	52,737	66%	18-Jul	51,158	64%	28-Aug	48,725	61%
21-May	53,016	66%	28-Jun	33,755	42%	19-Jul	57,076	72%	29-Aug	52,570	66%
22-May	49,297	62%	30-Jun	62,367	78%	21-Jul	68,060	85%	30-Aug	56,255	70%
23-May	55,955	70%				22-Jul	60,465	76%			
24-May	60,243	75%				23-Jul	56,225	70%			
26-May	56,635	71%				24-Jul	64,363	81%			
27-May	55,170	69%				25-Jul	62,478	78%			
28-May	60,424	76%				26-Jul	55,142	69%			
29-May	70,540	88%				28-Jul	58,372	73%			
30-May	45,175	57%				29-Jul	47,864	60%			
31-May	43,870	55%				30-Jul	51,410	64%			
						31-Jul	72,205	90%			

Graphical Representation-

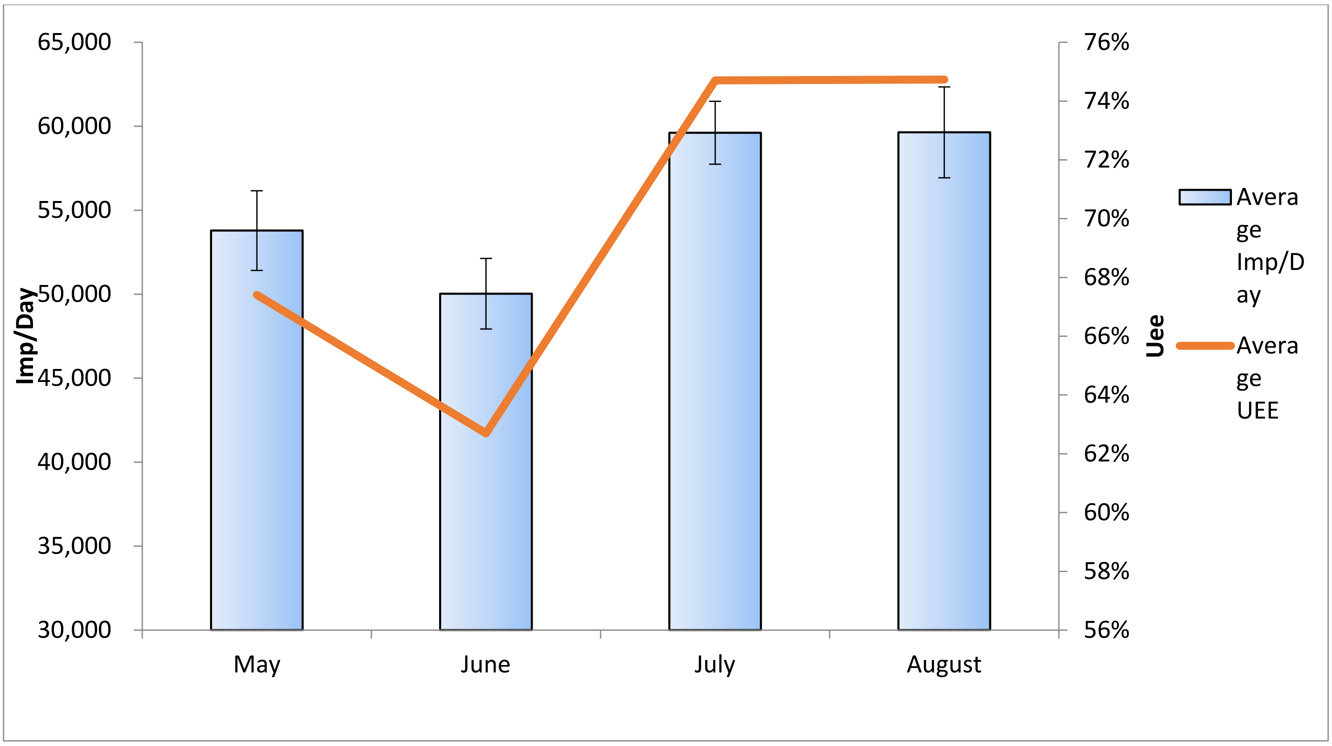

Figure 4.6: UEE(%) comparison in Die cutting

In the graphical chart, it has been clearly shown that, not only the productivity in the later months has been increased but also it is sustaining. As set up is also largely dependent of operator skill & also machine run time along with surrounding environment plays a role in set up time, so there can be some variation in the output which has been represented through error bar in the graph.

UEE Improvement (%)= $\frac{Current\ average\ UEE - Previous\ average\ UEE}{Previous\ Average\ UEE} \times 100$

Equation 4.3: UEE improvement

$$= \frac{75-65}{65} \times 100$$

$= 15\%$

4.2.3 Quality Improvement by minimizing defects

Implementation of color sticker process made everyone accountable & also defects in the products properly visualized. So less chances of defective products delivery to customer. In production, 2 types of quality recordings are captured- ICR & CCR. ICR is the count of defects, which are found in the production floor before delivery, and CCR is the count of defects, which are found in customer's place after delivery has been completed by manufacturer.

ICR recordings for four months are given below-

Table 4.8: ICR comparison

Before Adding color Sticker		After Adding color sticker	
May	June	July	August
30	27	21	17

More Details of ICR is represented in Figure 4.7-

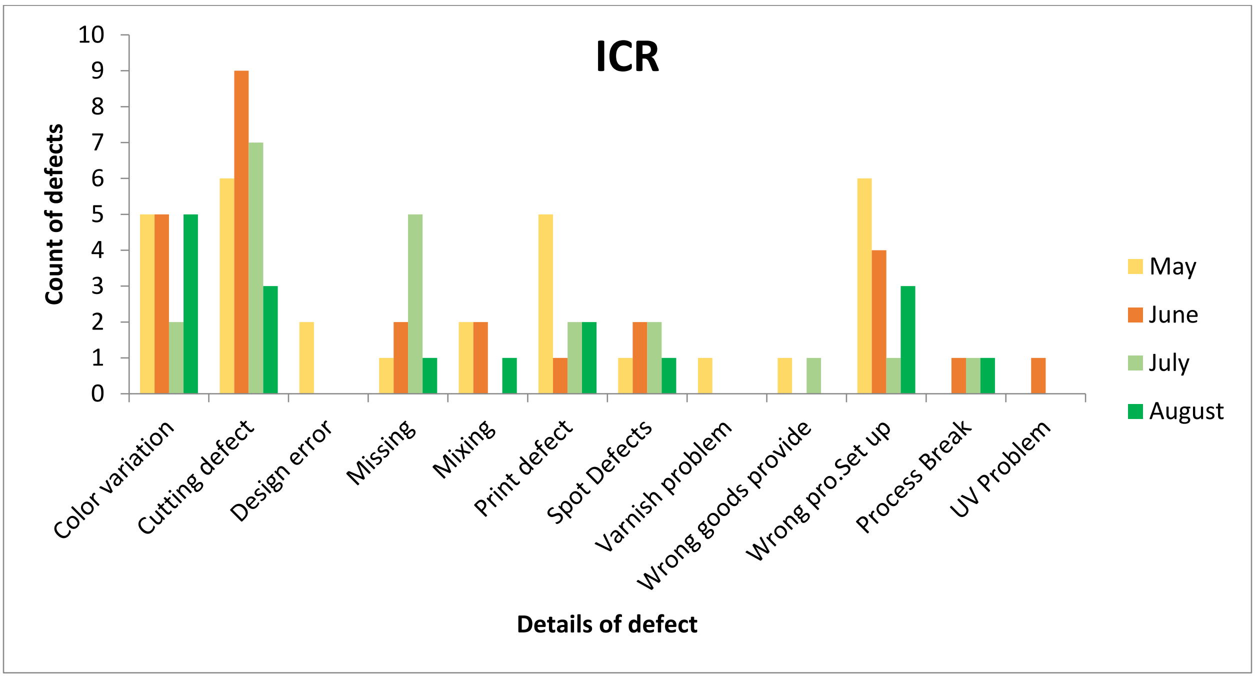

Figure 4.7: Details of defect

Similarly, four months of CCR data has been captured which is shown below-

Table 4.9; CCR Comparison

Before Adding color Sticker		**After Adding color sticker**	
May	June	July	August
11	7	3	2

It has been observed that, CCR has been tremendously reduced with the help of lean tools. Details of CCR is given in the below graph (Figure 4.8)-

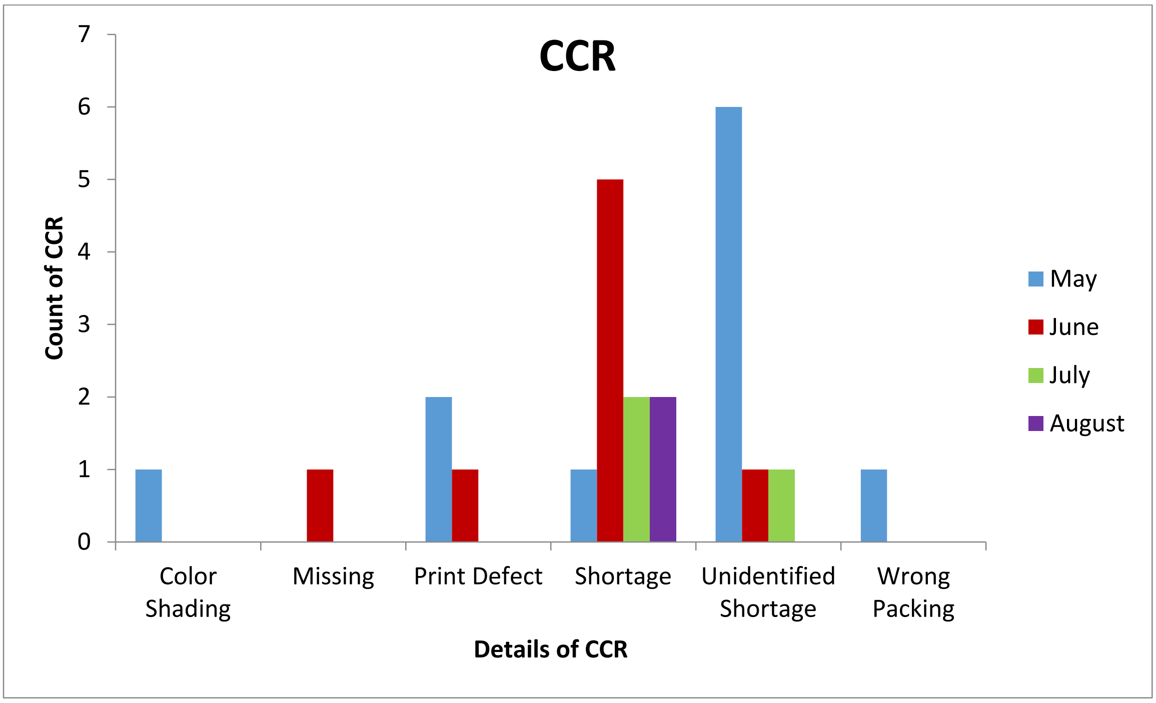

Figure 4.8: CCR Details

From this chart, we can see that, in August, there was no CCR logged without shortage, which is huge improvement from previous months.

CCR Improvement (%)= $\frac{Previous\ Average\ CCR - Current\ Average\ CCR}{Previous\ Average\ CCR} \times 100$

= 72%, So a massive improvement in defects generation has been noticed.

4.2.4 Finishing capacity improvement through motion elimination

New finishing line set up entirely eliminated rubber adding process & also transferring goods to the sorting section in a bucket. Thus it helped to continuously maintain goods flow to the operators, eliminating any idle time, therefore boost productivity. After implementing new finishing lines, another 44 readings are recorded to visualize the progress.

Table 4.10: Finishing output/ Day after process improvement

Date	Dispatch/Day (Million)	Date	Dispatch/Day (Million)
1-Jul	1.2	29-Jul	1.33
2-Jul	1.3	30-Jul	1.36
3-Jul	1.3	31-Jul	1.31
4-Jul	0.8	1-Aug	1.33
5-Jul	1.2	2-Aug	1.35
7-Jul	1.3	4-Aug	1.41
8-Jul	1.3	5-Aug	1.41
9-Jul	1.3	6-Aug	1.32
10-Jul	1.1	7-Aug	1.52
11-Jul	1.3	8-Aug	1.49
12-Jul	1.2	9-Aug	1.32
14-Jul	1.3	11-Aug	1.40
15-Jul	1.4	12-Aug	1.41
16-Jul	0.8	13-Aug	1.44
17-Jul	1.3	14-Aug	1.52
18-Jul	0.8	16-Aug	1.53
19-Jul	1.3	17-Aug	0.87
21-Jul	1.4	18-Aug	1.37
22-Jul	1.5	19-Aug	1.30
23-Jul	1.4	20-Aug	1.02
24-Jul	1.4		
25-Jul	1.4		
26-Jul	1.2		
28-Jul	1.3		

Average Output/ Day (Million)
1.30

From the output/day, it can be easily understood that, lean tools improved the finishing capacity of the entire process to 1.35 million pieces.

Output Improvement (%) = $\frac{Current\ average\ output\ per\ day - Previous\ average\ output\ per\ day}{Previous\ average\ output\ per\ day} \times$

100

Equation 4.4: Finishing capacity improvement

$= \frac{1.30-1.15}{1.15} \times 100$

= 13%

4.2.5 Finishing UPLH Improvement

Unit Produced per Labor Hour (UPLH) can be determined using the following equation

$$\frac{Total\ dispatched\ quanity\ in\ a\ day}{Total\ number\ of\ manpower\ on\ that\ day \times Total\ amount\ of\ working\ hours(including\ over\ time) in\ a\ day}$$

Equation 4.5: UPLH calculation

In Equation 4.5, Total number of work force is a variable data as not everybody remains present in the production. Total amount of working is generally fixed. Normal working hour is 8 hours & with overtime, it becomes 10 hours. After lean tools implementation another 44 recordings were captured and for UPLH calculation from it, attendance record for those days were collected from Human resources with working hours. And with the help of these data, the following UPLH calculation were done-

Table 4.11: UPLH comparison after lean tools implementation

July'18				Aug'18			
Dispatch/Day (Million)	Manpower	Working Hours	UPLH(Pieces)	Dispatch/Day (Million)	Manpower	Working Hours	UPLH(Pieces)
1.2	57	10	2,094	1.33	59	10	2,258
1.3	59	10	2,219	1.36	58	10	2,347
1.3	59	10	2,189	1.31	57	10	2,290
0.8	55	10	1,496	1.33	57	10	2,342
1.2	57	10	2,114	1.35	58	10	2,334
1.3	57	10	2,315	1.41	59	10	2,393
1.3	59	10	2,241	1.41	58	10	2,427
1.3	59	10	2,228	1.32	56	10	2,361
1.1	55	10	2,018	1.52	59	10	2,579
1.3	59	10	2,218	1.49	58	10	2,568
1.2	59	10	2,037	1.32	57	10	2,318
1.3	56	10	2,322	1.40	58	10	2,412
1.4	57	10	2,449	1.41	59	10	2,396
0.8	56	10	1,491	1.44	57	10	2,523
1.3	57	10	2,262	1.52	58	10	2,623
0.8	57	10	1,463	1.53	58	10	2,635
1.3	57	10	2,299	0.87	56	10	1,547
1.4	57	10	2,412	1.37	57	10	2,410
1.5	59	10	2,480	1.30	59	10	2,210
1.4	58	10	2,354	1.02	56	10	1,822
1.4	56	10	2,517				
1.4	58	10	2,424				
1.2	57	10	2,062				
1.3	57	10	2,272				

UPLH Improvement (%) =

$$\frac{Current\ UPLH - Previous\ UPLH}{Previous\ UPLH} \times 100$$

Equation 4.6: ULPH Improvement (%)

So with the recordings of prior to lean process implementation, we can easily get the Previous UPLH value which is 1989 Pieces.

From the 44 recordings, which were captured after lean process implementation, the average UPLH value is easily achieved= 2253 Pieces.

Therefore, UPLH Improvement (%)= $\frac{2253-1989}{1989} \times 100$

= 13.2%

So it can be easily proved that, simple lean tools have helped the finishing processes to run 13.2% faster than before.

4.3 Value Stream Mapping After Implementation & Sustainability

After all the process improvement in die cutting, quality & finishing, several readings has been taken on jobs to get the overall process..Figure 4.9 represents VSM after implementing lean tools .A significant improvement in lead time is captured along with the inventory reduction in die cutting & finishing stage, which allowed the process to run smoothly & more faster.

Lead time improvement (%) = $\frac{Previous\ average\ lead\ time - Current\ average\ lead\ time}{Previous\ average\ lead\ time} \times 100$

$= \frac{8.4-7.8}{8.4} \times 100$ = 7.1%

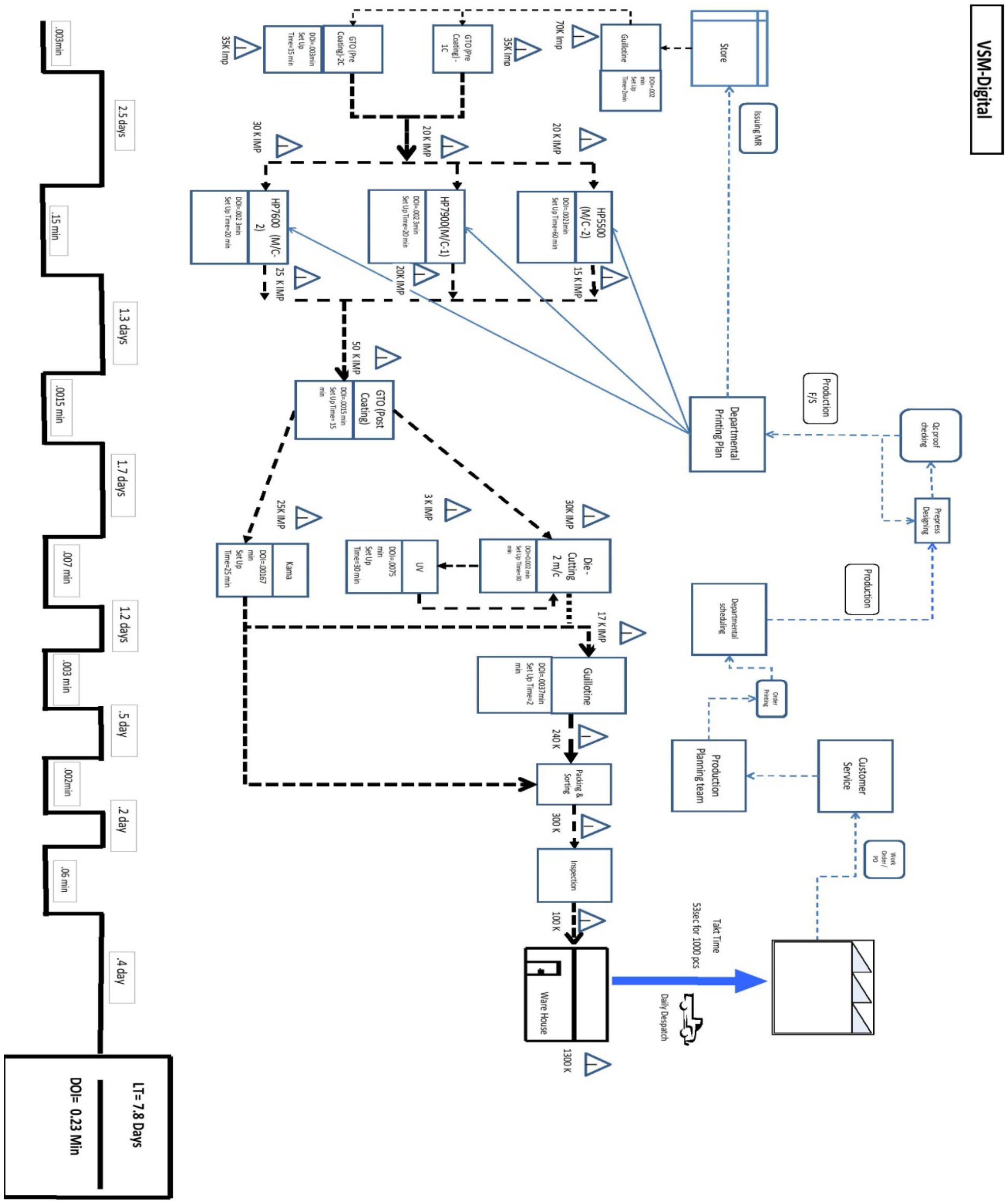

Figure 4.9: VSM after implementing lean tools

4.4 Concluding remark

From the above discussion, it can be easily said that waste elimination of waiting time in die cutting stage, color sticker adding process throughout the entire process & motion elimination of finishing, helped the entire manufacturing process to become faster, flexible & competitive. Every graphical representation of die cutting stage, clearly highlighted 9.6% improvement of the process which is a phenomenal outcome compared to the previous situation. Color sticker adding process made the operators much more accountable & therefore presented the manufacturer with quality goods by reducing defects. An improvement of 72% was recorded while sustaining color sticker adding process. Elimination of rubber adding process gave the finishing an innovative opportunity to boost the productivity by 13%. This study of all process outcomes in different periods defines that all the lean processes are not only contributing to the progress of the production but also it is sustaining. So in a nutshell, it can be established that, waste elimination through lean tools implementation enabled the manufacturer to improve their lead-time by 7.1%.

Chapter 5 Conclusions, Contributions and Recommendations

This chapter summarizes the conclusion of the experiment (section 5.1) and discusses research contributions of this work (section 5.2). Limitations of the present work and suggestions are discussed in (section 5.3).

5.1 Conclusion

Lean manufacturing is the way of producing quality goods in the shortest lead-time by minimizing waste generation. It's a continuous process. The experiment was conducted in a packaging & accessories company where lead time is always a challenging issue. For solving, this problem lean manufacturing needed to be established first. To visualize the problematic area, VSM has been carried out to highlight the bottlenecks & their affects on the related process. Based on that further studies has been carried out to figure out the wastage that was the reason behind it. After comprehensive study & recordings of present state situation, solution was suggested. One of the main step in printing industry is die cutting & it has been found that ample amount of time is getting wasted due to waiting. So to get rid of this problem, user friendly & easily understandable Kanban die rack has been introduced. Kanban die rack allows the manufacturer to get the visualization of next prepared jobs in line. So no more waiting for appropriate tools for the job & by doing so, an amazing improvement in die cutting stage inventory & set up time is achieved. Another highlighted process in the mapping was sorting process in finishing area which is largely dependent on quality on the products. Better quality means faster delivery & bad quality generates different kind of wastages in the process, which can even create claim issue. For increasing the sense of better quality, it was necessary to develop a process to make everyone accountable for it. So an innovative idea of adding color sticker was developed for it. In which every person is the controller & at the same time communicator to the next process handler regarding produced quality. It is done by adding different color sticker to the products. This color sticker carries information regarding product quality & also from which step the product has come. As a result of it, operators become more responsible & internal complain rate has started to reduce, which actually helped the manufacturer to serve customers with better quality goods. So ultimately the customer complain rate which is the organizational KPI, was improved significantly. Lastly, there was non-value adding process with extra motion in finishing stage and to solve this case, a new flow set up was introduced in the floor with the entire elimination of rubber process & less motion inside the process. This new finishing set up helped the process to cater 13% more goods than before. So it can be said that, lean manufacturing has improved the process to be more streamlined & flexible, which helped the business to become more competitive & made lead time even faster.

5.2 Research Contributions

- Productivity can be improved through defects elimination with the help of color sticker adding process is truly beneficial for any manufacturer, as it does not include any additional huge investment to carry and visualize information (type of defects).
- Elimination of an entire process through controlled flow of goods with streamlined set up in finishing
- It can be extremely useful in competitive packaging & accessories companies.
- Practical benefits of VSM application.

5.3 Limitations and recommendations

There is no experiment, which has no limitations but overcoming the limitations with carefulness is necessary. The limitations of this experiment are given below:

- Every person has their own capacity & it's very natural that it will not match with one another. Also output of the process may vary depending on the job type. So output needs to be measured for similar type of jobs, only then results can be compared with each other. Recording of different types of job may give wrong idea.

- Set up time in die cutting stage was measured using a stopwatch. So the watch has to be precise & the counting has to be done carefully. Careless time study will provide faulty data.

- As VSM were done with the help of live order readings, so every process owner needs to capture the entering timing & processing timing accurately. There is always a high chance of not recording receiving dates properly as each timing has to be captured manually.

- VSM was applied only in production processes. Information flow of other supply chain processes or customer service communications can create difference in the mapping timings

- There are other non-value adding process which may have impact on the process lead time, due to lack of opportunities, these options were not explored. But it is suffice to say that with the help of lean manufacturing process lead time can be dramatically improved by systematically eliminating different types of wastes in the process.

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March 14, 2018 ADHR-2018/006

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He is doing research on Productivity Improvement through Waste Management. The Company does not have any objection on his research work for educational purpose.

This certificate is issued on his request.

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