Hafiz Javid

Waste Reduction of Composite Film Line in Process Industries

Helsinki Metropolia University of Applied Sciences

Master's Degree

Industrial Management

Master's Thesis

25 May 2015

Preface

I like to express my appreciation to my supervisors Dr Thomas Rohweder and Dr Marjatta Huhta for their unlimited support and guidance throughout this research, with their cool minded temperament and unlimited experience which allowed me to utilize my productivity to complete this research. A big thanks to Zinaida Grabovskaia, PhL, for her responsible attitude and readiness to help in terms of transforming the research into an impressive paper.

I also wish to express my obligation to the stakeholders of the case the company who participated in research and showed positive attitude towards my calling and interviews during the study

I would like to thank Allah, my lord for giving me strength, courage and patience to complete this research. I would also like to thank my Country Pakistan and Helsinki Metropolia University of Applied Sciences for opportunity to pursue my degree in higher education.

Unlimited thanks go to my mother, Bushra Javid, who encouraged me with biggest of heart in life to move ahead and allowed me to stay abroad and live without her for completion of my study. Nothing is possible without her help in every stage of my life, who strengthen me to make progress by leaps and bounds in studies and professional life. I wish to thank my Father, Muhammad Javid, too, who taught me to take risks to move step further. As the starting of this study was a bit risk to adopt but my dad encouraged me to take this risk.

I dedicate this thesis to my parents for their unlimited support, providing me a positive thinking environment in home to be a self-confident person. May they live long.

Helsinki, 25th May 2015
Hafiz Javid

Author(s) Title Number of Pages Date	Hafiz Javid Waste Reduction of Composite Film Line in Process Industries 67 pages + 10 appendices 06 May 2015
Degree	Master's Degree
Degree Programme	Industrial Management
Instructor(s)	Thomas Rohweder, DSC (Econ), Principle Lecturer Marjatta Huhta, DSC (Tech), Head of Master's Program in Industrial Management

This research focuses on the waste reduction of polymeric material in a chemical process plant during the manufacturing of film composite line. The case the company is a manufacturing the company where continuous throughput and quality of product plays an important role for the profitability of the company. The new scheduling of maintenance and new techniques were needed to be introduced to reduce waste during the manufacturing of the product.

This study is conducted as a case study, divided into theoretical and empirical parts. Theoretical part begins with the overview of lean manufacturing techniques and then discusses other approached and tools to reduce waste and increase the overall operating efficiency of the production film line. Just-In-Time tool was used to control the inventory, developed the good relationship between suppliers and consumers, improve quality of the product by supplying the short lot sizes of the raw material. Lean 5 S's tool is used to eliminate waste in the production area of film line. In order to reduce the breaks during the manufacturing of film, SMED technique is considered. Finally, scheduling of the preventive maintenance rather than corrective maintenance is proposed to make manufacturing in the film composite line more cost effective and result oriented.

In the empirical part, semi-structured interviews were conducted with the stakeholders of the case the company. Seven interviews were conducted with the production engineers and quality assurance workforce to collect data in three different rounds. The preliminary proposal was built with the collaboration from the stakeholders and incorporated also the findings from the theoretical part. Later, the final proposal was developed in four sections and focused on quality improvement, small breaks reduction, scheduling of maintenance, and introducing the Lean 5S's tools.

The final proposal then presented to the higher management to discuss and put it into implementation. The outcome of the thesis is to reduce waste during the manufacturing of the product, in order to increase the profitability through the application of preventive maintenance and some lean tools and techniques.

Keywords	Waste reduction, composite film line, process industries, Lean, Just-In-Time

Contents

List of Figures

List of Tables

Acronyms

PP	Polypropylene
BOPP	Bi-axial Oriented Polypropylene
CPP	Cast Polypropylene
MDO	Machine Direction Orientation
TDO	Transverse Direction Orientation
OS	Operation Side
DS	Drive Side
AK	Air Knife
OOE	Overall Operations Efficiency
ISO	International Standard Organizations
CSA	Current State Analysis
CFW	Conceptual Framework
JIT	Just-In-Time
TPS	Toyota Production system
SMED	Single Minute Exchange of Dies
PM	Preventive Maintenance
OEE	Overall Equipment Efficiency
MHI	Mitsubishi Heavy Industries

1 Introduction

Process industries produce a huge waste during the operations that it is necessary to reduce and control the wastage of polymeric material in order to get smooth process. However, in the processing of the already processed material (Thermoplastic), there is a need to have more energy, maintenance of recycler and labour cost. Therefore, it is necessary to introduce some methods to minimise the wastage of polymer.

There are several kinds of films such as Composite film, Metallised Film, Plane film and pearlized film but Composite film. In this study, focused on the process of manufacturing of film, the research is considered as a case study due to its huge demand in food packaging industries. The phenomenon of manufacturing of film occurs in the southern city of Pakistan named Karachi, a corporate city of the country. There are two types of materials used in Polymeric process industries: a) *Thermoplastic materials* can be heat softened and thus can be recycled, while b) *Thermosets* can neither be heat softened nor they are possible to recycle. This is due to formation of chemical cross-links by covalent bonding.

The Film Production line where packaging films are being manufactured is called BOPP (Bi-axially Oriented Poly Propylene). During the processing, there are two orientations occur, the first one is in Machine direction (MDO) and the second one is Transverse direction (TDO). Since Polypropylene is being used as core material during operations, that is why this plant is known as Bi-axially Oriented Poly Propylene.

Silo is a structure storing bulk material, this structure is used in many places like to store grain in agriculture and in process industry to store raw material. Extruders make part of the main film line where the material is being pushed by a screw which is inside the extruder, and this process is called extrusion. Die is a specialized tool used in manufacturing industries used to cut or shape the material, mostly using a press. The process by which film is stretched to reduce thickness and to increase width by heating up to softening point is called Orientation.

Several Chilled roles are used in the whole process of film line to maintain the temperature and the circulation of chilled water circulated inside the rolls. The Corona treatment is carried out in the corona station immediately after BOPP film is produced and just passed through the stretching process in the transverse direction orientation.

Tri-Pack Films Ltd is a leading the company in terms of manufacturing of different grade films such as Composite, Metalized, Plane and Pearlized film. The case the company is a large sized industry to supply packaging films to food processing industries which operates according to the ISO Standards.

The business challenge of this study, in the case the company Tri-Pack Films Ltd, is to control the wastage of polymeric materials without interrupting the production process and to maintain the quality of food graded films. The action plan to minimise the polymer in a lower price and to get the improved process is a challenging task in a process industry.

1.1 Case Company Background

Tri-Pack Films Limited is a joint venture between Mitsubishi Corporation of Japan and Packages Limited of Pakistan which was launched as a public Limited the company on April 29, 1993 to produce Bi-axially Oriented Polypropylene (BOPP) in Pakistan. The head office located in Karachi and its regional offices are in Lahore and Hattar Industrial State. The focus is to provide the quality, dependable films to the customers backed with strong customer Services Support. The company is continuously growing and reached the country's ever highest production of BOPP in the year of 2013 through commissioning of BOPP Line-4. The project of Cast Poly polypropylene (CPP) was successfully executed in March 2014 and raised the Production rate.

1.2 Business Challenge

Bi-axially Oriented Polypropylene (BOPP) is an extruded Polypropylene sheet subjected to two types of stretching orientations i.e., machine and transverse directions. This film is carried out the corona treatment before winding as a roll in which three types of electrodes allowed to face within 2 mm corona gap where 2.04 KJ /m^2 corona energy is delivered to the film to generate the gravure printing capability. As the case the company produces a huge amount of film in order to fulfil the requirements of customers, the wastage of film increases due to the increase in production. There is a need to generate the strategy and methods to lower down the production waste and apply new mechanism to utilise the wasted film more efficiently.

Currently, the case the company produces 6% waste per month and there are several reasons by which this situation is unprofitable for the company. The reasons and sources for that huge amount of waste will be discuss in the current state analysis from the perspectives of determining the reasons and sources of waste of polymer materials during manufacturing of film line. Therefore, the business challenge of the study is to eliminate the unacceptable level of production waste in BOPP composite film line.

1.3 Objective and Outcome

The objective of this study is to propose an action plan to eliminate the waste of polymeric materials by 10% and develop practical recommendations for the improvement of the composite film process. This is done by analysing the whole process of the film line manufacturing in terms of quality assurance, reducing the small breaking in the line, and regarding the scheduling of maintenance in different unit operations such as die, MDO and TDO and the main extrusion line where polypropylene material is processed by heating up to its softening point.

The outcome of the thesis is to obtain the process with improved quality of product, reduce the waste and obtain the desired mechanical and optical properties of the film which includes barrier strength of UV and oxygen. The optical properties include the Haze, gloss, refractive index etc.

1.4 Scope of Study

This scope of the study is analysed by the negative factors in the composite film line for defective waste and reasons and sources, which affect the performance of the company. These issues are resolved by adapting the lean concepts of waste elimination, scheduling the maintenance, reducing the small breaks in plant and quality improvement.

The study is written in seven sections in which Section 1 describes the business challenges and research objective of the study. Section 2 illustrates the method and material used in the study, research design, data collection techniques and methods of data analysis and validation. Section 3 describes the current state analysis which shows the challenges in the production line that are the core hindrances in the performance of the company.

Section 4 illustrates the lean principles in order to overcome the challenges in waste elimination by applying different techniques and tools which are needed to be implemented. This section generates the conceptual framework of the study as a whole. Section 5 presents the preliminary proposal to eliminate the waste, improve the throughput, increase the quality and raise the standard of maintenance. Section 6 shows the validation by the key stakeholders of the company and lead to the final proposal. Section 7 is dedicated to conclusions of the study, next plans to be implemented, managerial implications, analysis of research reliability and validity.

2 Method and Material

This section illustrates the research design, data collection and data analysis and validity and reliability plan.

2.1 Research Design

The research design of the study is described in the Figure 1 below.

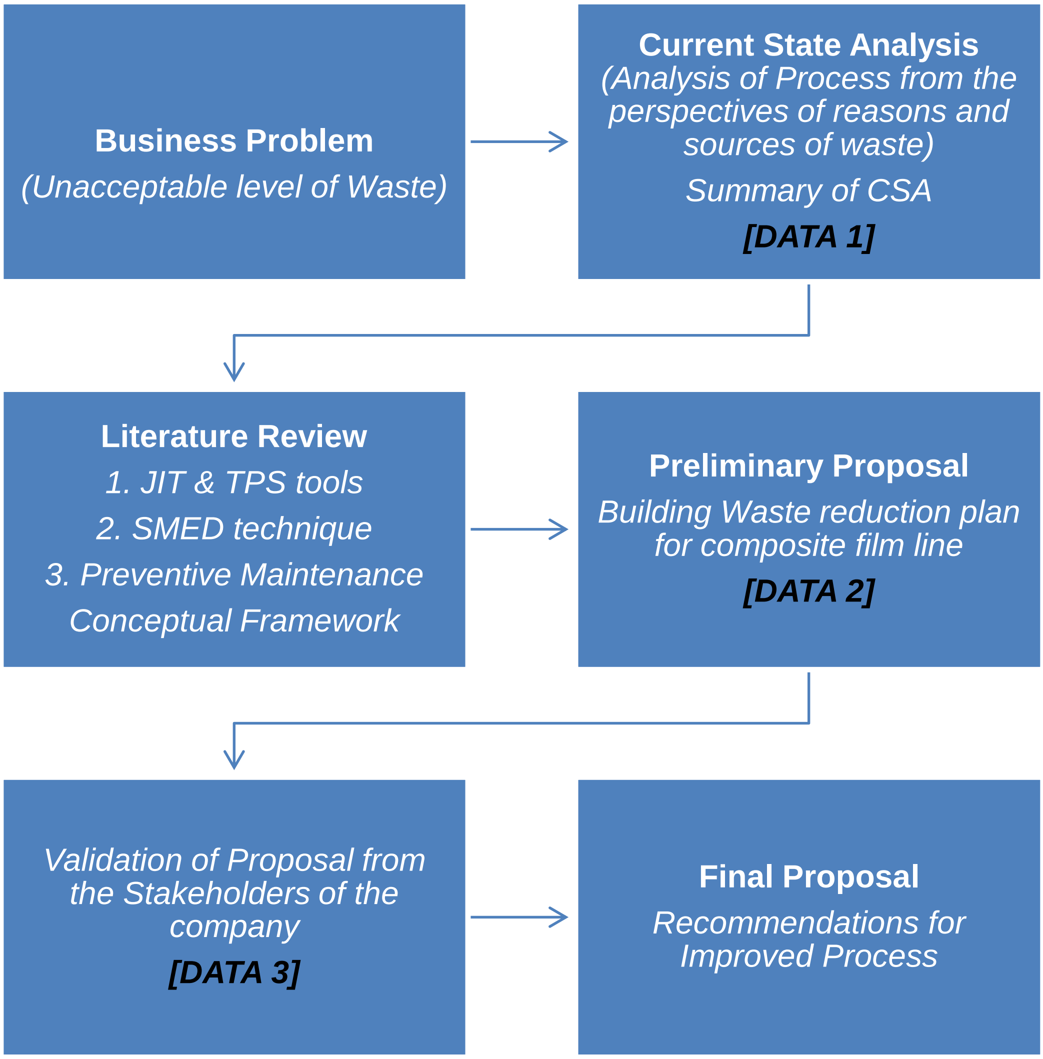


Figure 1. Research design of the study.

This study contains several steps which include business challenge, the current state analysis of the case the company focused on the issues of the wastage of polymer during the operation of composite film in the different sections of the film line (Data 1). In the next step, there is search for best practice from the literature review to build the conceptual framework. In this section, the waste management principles are introduced from the literature related to the issues found from the current state analysis of the case the company. In the next step, a preliminary proposal is built with the formation of the conceptual framework from the literature and the analysis of the case the company (Data 2). That proposal is then moved to the piloting step and then get the feedback from the key stakeholders of the company (Data 3) after which there are some changes to be made (if needed) in the preliminary proposal according to the data collected from the company. After that, the final proposal for the waste reduction of the polymeric material is made for the manufacturing of composite film.

2.2 Data Collection and Data Analysis

The data for this thesis is collected in several rounds. The foremost source of collecting data are interviews of Quality assurance officers from R & D and personnel's of film line department for Current State Analysis (Data 1). In the second round, the data from key stakeholders for building the preliminary proposal to eliminate the waste of polymeric material composite film line (Data 2). In the third round, the feedback from the management of the company to generate the final recommendations (Data 3).

Data 1

Table 1 illustrates the details of data collected from the stakeholders of the company, theme of interviews, designation and source of contact. This data is used for the current state analysis.

Table 1. Interview respondents for Data 1 (Current State Analysis).

Respondent	Interview Theme	Designation	Duration	Date	Source
A	Reasons to avoid the small breakage of different units of plant.	Shift Engineer	2.0 hours	13.02.2015	Video call (Skype)
B	Scheduling and Maintenance of Main units of plants.	Line Shift Manager	45 minutes	15.02.2015	Video call (Skype)
C	Effect of temperature parameters on optical and Mechanical properties.	Quality assurance officer	1.30 hours	21.02.2015	Video Call (Skype)

Data 2

Table 2 shows theme interviews with the stakeholders of the case the company related to the film line production department. These interviews are the sources to build the preliminary proposal for waste reduction in regards the challenges from the current state analysis.

Table 2. Interview respondents for Data 2 (Proposal building).

Respondent	Interview Theme	Designation	Duration	Date	Source
D and E	Lean management (Lean 5S's tool, Single minute exchange of dies and its five principles for quick changeover, Preventive maintenance to avoid the small breakage.)	Shift Engineer 1 and 2	2.0 hours	17.04.2015	Video call (Skype)
F	JIT features to reduce the space for inventory, quality improvement of product. Toyota Production system and its features. Scheduling and maintenance of the line to reduce the small breaks.	BOPP film Line Manger	1.00 hour	18.04.2015	Telephonic conversation

Data 3

Table 3 represents the feedback from the Manager Operations of the company to get the feedback from the preliminary proposal and this conversation leads to the final proposal in the form of recommendations to attain the improvements in the composite film line in the form of elimination the waste of material.

Table 3. Interview respondent for the validation of proposal (Final Proposal).

Respondent	**Interview Theme**	**Designation**	**Duration**	**Date**	**Source**
G	Discussion about the preliminary proposal and lead this conversation into final proposal for the improved process.	Manager Operations	1.00 hour	18.02.2015	Telephonic Conversation

2.3 Validity and Reliability Plan

Validity of the study measure its correctness and credibility. Four types of validity are described by Quinton et al (2006) which are internal validity, external validity, construct validity and reliability. In this section, validity and reliability plan is discussed and later this plan will be reviewed against the actual results of the study in the last section of the thesis.

Internal validity is an inductive estimation of the degree to which results can be made. Internal validity is used a strength and in order to assure the internal validity described by the Quinton et al. (2006), questionnaire to be made to raise internal validity and describing the theme of the study in a correct manner. External validity measures the usage of results in other context and it can be consigned and the outcome transformed into another context.

Reliability addresses the consistency of the study and if the research was conducted by others, results and outcome of the study obtained, which was conducted originally (Quinton et al. 2006). Therefore, the issue of reliability is to be addressed in qualitative research. In this study, the reliability is supported by the clear business challenge, the method to collect the data from the case the company, and the selection criterion for the respondents. In this study, reliability is secured to conduct the interviews from the respected workforce in the relevant department of the case the company.

The following section describes the current state analysis of the case the company for manufacturing of composite film line to find out the challenges in the case the company to proceed further.

3 Current State Analysis

This section analyses the Production line for composite film to acquire the major reasons and sources for wastage of polymeric materials.

3.1 Description of the Current BOPP Process

In this part of the study, the process comprises the following sequential steps to obtain the bi-axially oriented Polypropylene film. i.e., feeding, extrusion, quenching, MDO, TDO, trimming, corona treatment, winding up.

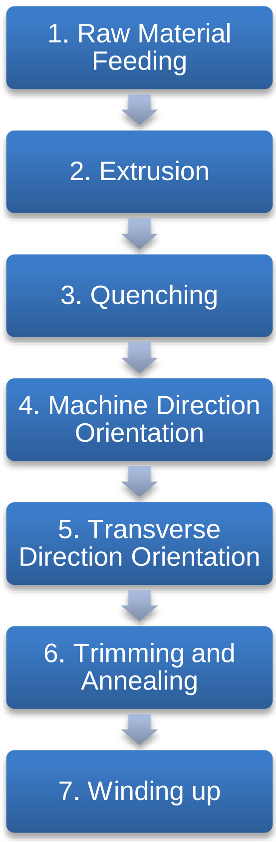


Figure 2. Current BOPP process.

As seen from Figure 2, the current Bopp process which is used for producing composite film in the case the company, includes seven steps. These steps are specified below.

Step 1. Feed Materials

Poly propylene homopolymer (PP) is used in BOPP film line to manufacture any type of film as a core material. This material is used in the form of pallets / grains which are filled in silos and later it moves to the main hoppers of the extruders. The film manufactured by BOPP film line is a three layered film in which PP material is used as a core component while the upper and bottom layer is made up by a copolymer of poly propylene. Copolymers of propylene in the film provide increased toughness at the cost of tensile strength. Random copolymers represent the major changes like increased elasticity and decreased melting point. Copolymers having different structures like a block, in which ethylene is distributed in some of molecules, gives the good compromising properties between strength and toughness. Antistatic agent is used to avoid the static charges in the final product which in turns to the shrinkage of film.

Step 2. Extrusion Process

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed or pulled through a die of the desired cross-section. The apparatus used for this process is called extruders. The polypropylene feed material is extruded through conventional extrusion process at a temperature of softening point. There are three extruders used for this process in order to manufacture three layered PP sheet. The main extruder which is used to process homopolymer PP contains the huge capacity and the remaining two extruders which are being used to process the copolymer of polypropylene are caller satellite extruders 1 and 2. The extrusion process is carried out at 230 to 250ºC in the extruders and the same temperature in the die lips under the pressure of 1000 to 1500 pounds per square inch. Usually, the difference between the inlet and outlet pressure of molten material is 25 to 30 bar which is the ideal ratio to run the plant smooth. As the pressure difference increases, the flow of material from the main filter is not continuous due to which operations of the film line plant is unable to run smooth and the breaking of sheet takes place at the exit point of TDO section, where transverse direction stretching is to be happened which in turns the wastage of plastic sheet, which must be controlled and this is the core issue of the thesis.

Step 3. Quenching and Drying

In materials science, quenching is the process where rapid cooling of material takes place to obtain certain properties and phase transformations. The extruded polypropylene is then quenched by passing through water and the distance between die lips and water is being maintained to about 2.0 inches. If the gap is less than the required distance, haziness in the product of polypropylene sheet is appeared as a result while the greater gap of 2.0 inches fails to melt properly in the extrusion process line and ultimately, the chances of breaking the film during the machine direction section or transverse direction orientation increased and thus wastage of polypropylene film happens. If the melting of PP material is not sufficient, it is impossible to achieve a commercially accepted PP sheet at the end of whole process. BOPP film line is synchronized with the speed of chilled roll in quenching process. Once there is changing in speed in the chilled roll, there is automatically changing speed in MDO and TDO and as a matter of fact, the speed depends on the production rate of the film at the winding. The purpose of this step is to draw the melt down over a sharp distance and cool quickly before thermal disorientation can take place.

Step 4. Machine Direction Orientation

The machine direction orientation or stretching is the section of the BOPP plant where extruded quenched PP sheet is stretched about 60% in the longitudinal direction by preheating up to the softening point. The extruded film is subjected to a first stretching operation where longitudinal direction orientation is achieved. The machine direction orientation process is carried out at the temperature range 92 to 150^{0}C and the stretching ratio 1.2:1 to 1.6:1 in the machine direction orientation. In the MDO section, there are arrangement of slow and fast horizontally disposed, closely spaced, parallel driven. The rolls are maintained in the case the company by circulating oil at the optimum temperature of about 92 to 150^{o}C. Other methods of heating these rolls and internal system may be employed like steam boiler and hot water. The film is being stretched in MDO in such a manner that there is combination of slow and fast rolls to control the film during the longitudinal stretching and to obtain the required degree of orientation without distorting the film and if the distortion of film happened inside the MDO, there is huge wastage of film as the whole plant from extrusion cannot stop and thus the manufacturing is taking place continuously from the previous sections. The temperature of polypropylene sheet varies at the stretching point in the range of 100 to 150^{o}C and the film rate is equal to the speed of the whole film line ranges from 150 to 350 rpm. The rate of the film production depends on the several major mechanical and optical properties at the desired level.

Step 5. Transverse Direction Orientation

This is the section of BOPP film line in which the lateral stretching of PP sheet takes place to obtain the desired width of the sheet. In this section of the BOPP film line, the tenter frame apparatus is employed for transverse direction stretching. The entire length of tenter frame consists of the parallel chains with clamps for gripping and moving forward of polypropylene film through the transverse direction of the frame. The longitudinally stretched polypropylene sheet is clamped by the clips from both sides of the frame and moves in the transverse direction through the frame of TDO. The film is released at the end of the frame and the chains of the clamps return back to get the longitudinally extruded film. The transverse direction stretching section is divided into four zones include preheating zone, first stretching zone, second stretching zone and annealing zone. In the pre-heating zone, the film is heated by circulating the hot air ranging from 160 to 180^{o}C but no stretching takes place in this zone. The PP sheet attains its softening point for orientation in the coming first and second stretching zones.

Step 6. Trimming and Annealing

In the annealing step, the film is cooled down around 50^{o}C for stability and allows shrinkage of film but no stretching in this section. The longitudinal and transverse oriented film move to the next process while the clamps at both OS and DS returns back at the starting point of tenter frame to engage with the longitudinal stretched film for transverse orientation. The term slackness used in the film production, not to have the desired tension at the outlet of TDO. The temperature parameters in the transverse stretching zones are critically important in order to obtain the quality film and thus the shift engineers and the responsible crew are unable to adjust the parameters for the film to get the required mechanical and optical properties of the PP sheet in the later sections. Due to this reason, the production under this circumstances is not acceptable by the customers and ultimately, that production is counted as waste.

Step 7. Corona Treatment and Winding

The capillary action is the process in which a liquid flows in the narrow spaces in the film without external gravity force. The longitudinal and laterally oriented film is then provided corona treatment to enhance the capillary properties either in one side or both sides, depends on the customers' requirement. In the corona section of the BOPP line, the high energy beta rays bombarded to the surface of PP sheet. The treatment is provided by electrodes with high energy of 2.4 KJ /m^2 to the film. The corona treatment is necessary for the manufacturing and to generate the adhesiveness for printability. After treating in this manner, the commercially accepted ink is applied to PP sheet. Finally, the processed film enters in the winding section where tension of the sheet plays important role to wind up properly and air intact value of the manufactured film is being calculated by the given formula to avoid air bubbles in the final roll of the produced film of PP.

3.2 Scheduling and Maintenance Issues

Based on the responses from the respondents 'A' and 'B' during the theme interviews with the production personnel, there is a core issue of maintenance scheduling of the production line, due to which the breaking of films during the manufacturing take place. The management take the decision of maintenance only when a failure of a certain component of the film occurs. The maintenance at the time of failure of components or stoppage of plant is called corrective maintenance.

Corrective maintenance is an expensive, less result oriented and time taking decision but unfortunately, the top management takes the decision then, when this incident happens. There is another maintenance known as *preventive maintenance* instead of corrective maintenance, which is more result oriented, cost effective and can perform during the operations of the product. According to respondent 'A', it takes longer time to clear the small breaking of film often when plant needs to have maintenance or some other scheduled operations. But the management are unable to make the decision due to having the production load from the customers.

There are several steps which are needed to take into account in order to make the maintenance of plant. a) Cleaning of extrusion barrel. b) Change over the main filter of the main extrusion line. c) Adjustment of heating adjustment to avoid the breaking of film in the TDO frame.

The first step is the cleaning of extrusion of barrel. The cleanliness of extrusion is a necessarily important to make the operation continuous and quality improvement. In order to make the extrusion barrel clean, the Shift Engineer need to have a decision to purge the material through a special nozzle made for the specified purpose. The purging is the process in which material is allowed to move through special nozzle in the extruder, which cleans the processing material for the manufacturing of film. The purged material is included in the waste (scrap) and to increase overall operations efficiency.

The second step for the maintenance of film line plant is the change over the main filter present in the extrusion line. Changing the filter is critical step to run the operation in a continuous throughput and improved quality film. There are certain points that need to keep in mind in order to change over the main filter during the maintenance. Firstly, the temperature of the filter that need to install in the line must meet the temperature requirement of the extruders. Since the temperatures of the three extruders are up-to the softening point of processed material, so the temperature of the filter need to have the same as that of extruders. Secondly, the speed of the composite film line have to be reduced but the company does not allow to shut down the plant as a whole. To restart the film line is a challenging task with quality production and without the small breaks because that is the main reason of wasting the polymer material. That is why, the company does not allow the shut down the plant as a whole during the changeover.

The selection of workforce for this critical task is done by the higher management to control the trouble shooting of the film line, make the changeover smoothly and run the production line in an efficient manner. The workforce in changing the main filter includes the production personnel and the experienced maintenance personnel to avoid the small issues being raised in the line.

The third step is the adjustment of heating adjustment to avoid the breaking of film in the TDO frame. In order to meet the requirement of temperatures with the main line of extruders, a special oven is being used which can accommodate the particular part. The changing filter has several plates with different meshes that provides the clean path to material which are being processed in extruders. Once a filter is changed, the previous one is disassembled in order to make the maintenance of each part (Plates, meshes, rings etc.) and the operators are assigned to complete the required job within the specified time period and make sure that the new filter is ready with the required temperature before the scheduling of operation filter. There are inlet and outlet point connected to the extruders and die of the production plant. The pressure difference of inlet and outlet material is critically necessary to run the process smoothly and get the continuous throughput of the produced film.

The adjustment of heating temperatures in the transverse direction orientation (TDO) is a challenging job in order to run the production plant in an efficient manner, quality improvement, and to avoid the small breaks during the tenter frame of TDO. The temperatures of TDO gets disturbed at the time of changeover of main filter in the extrusion line.

3.3 Lack of Remote Measurements

The remote measurements of the properties in the produced film is necessary in order to make sure the quality assurance and reduction of waste. There are two types of film lines are operating in the case the company. One is BOPP and the second one is CPP (casting polypropylene); this thesis is based on the BOPP film line. The consumption of BOPP film is more than the CPP film due to tensile strength, UV light barriers, and oxygen barrier. In the BOPP production line, there are lacking of online measurement of different properties. Measurement of thickness of the film is necessary to measure as required by the customer but unfortunately, case the company does not have the online measurements of film. Whereas, the CPP film line in which no orientation is taking place, this film line has the online measurement of thickness of the produced film. This is, because of technological enhancement by leaps and bounds.

The reasoning of not measuring the thickness of producing film in BOPP is the outdated technology being used in the manufacturing of composite film. Since there are two types of orientations taking place (MDO and TDO), that is another reason of not providing the online measurement of thickness because it changes in different stages of production unit. In CPP, only one step is included in the film production process. This is the easier to measure the thickness continuously during the manufacturing process.

The other mechanical properties (tensile strength, barrier properties) are unable to measure during manufacturing process. This is only possible when the required length of film would have completed. Apart from the mechanical properties, there are some other optical properties (transparency, UV light barrier, Haze etc.) necessary in order to make sure to meet the quality control requirements. The produced film is colourless in order to act like a capillary action for printing according to the requirements of customers. The capillary action is the process by which quality assurance officer examines the quality of film in terms of printability. This action is being done by the help of corona treatment after those two orientations (MDO and TDO). The corona treatment is the bombardment of beta particles on the film and the side of the film mainly depends on the customers’ need.

Tension of the film measures the quality of wrapping in the winding as the speed of the film is 450 meter per minute and during this speed, there is more chances to loosen the film in the winding step. This property is controlled by the experienced workforce in the production department. Air bubbles are easily trapped during the winding and this makes the produced film is included in the scrap. Tension of the film and air bubbles are connected to each other as the air bubble could avoid only when tension of the produced film would be on acceptable level.

3.4 Manual Raw Material Feeding in Silos

Raw material is the core component in the process industries. Each process starts from the raw material. Several processes contain different raw materials in order to attain the desired properties (Mechanical or optical). Compositions of the produced film in terms of material is an essential calculation and the chance of error raises if the calculation is being done on manual basis.

In the case the company, this process happens on a manual basis and since the company uses several material to obtain the required properties such as brittleness, transparency and other optical and mechanical properties. In the silo section, different hoppers are installed in order to make sure the availability of silos. Since there is one main extruder and two secondary extruders in the production process and in the same way, there is one main hopper and two secondary hoppers on respected extruders. In the main hopper, homopolymer is used and in the remaining two hoppers, copolymer is included. In order to add those materials, proper composition is needed for the quality controlled product. This composition is calculated manually which may contain error and might create the disturbance during the manufacturing of film. This disturbance leads to the breaking of film either in MDO or TDO frame, which includes in the scrap. Apart from homopolymer and copolymer, there are some other types of material in a minor quantity such as slipping material to generate the smoothness in the film and one material except from those core materials, the anti-static material, during the manufacturing.

Anti-static material is used in order to avoid the friction during the winding of each layer of the film. The composition of homopolymer, copolymer, slipping agent material, and anti-static material is being calculated by the personnel on the silos which often contains error and as a result, the waste of polymeric material happens.

3.5 Limited Methods Applied to Reuse the Wasted Material

There are different methods applied to utilise the waste of polymeric material. Case company produces 6% of waste on a monthly basis. The handling of this huge amount of waste of polymeric material is critical and challenging task. There are several methods available to reuse or utilise the wasted material in the process industries and the recycling is a common method in terms of costing, handling the material, and storage. Case company uses the mechanical recycling to utilise already wasted polymeric material to produce the plastic pallets.

Recycling is possible when thermoplastic material is used for the manufacturing of product while for the thermosets, the recycling is impossible due to certain properties of thermosets. Almost every process industries use recycling due to easy handling, storage and costing view point. There are several other possible ways to utilise the plastic material like chemical recycling and conversion of plastic material into transport fuel by applying a proper set up. This method for further development for the case the company is being discussed in the Section 7.4.

The conversion of transport fuel contains several steps by which the company could get the reasonable profit and save the time and cost. A simple set is need to be installed in order to start this profitable development.

3.6 Summary of the Findings

Table 4 summarizes the challenges in the case the company were obtained on the basis of the current analysis and data from the stakeholders of the company. As a summary of current state analysis, it is clear that there are several stages were identified where wastage of PP sheet may occur.

Table 4: Challenges based on current state analysis

1. Scheduling and Maintenance Issues
2. Lack of Remote Measurements of Properties (thickness etc.)

3. Manual Raw Material Feeding in Silos
4. Limited Methods Applied to Reuse the Wasted Material

Based on the current state analysis, the case company is suffering many major issues in terms of scheduling, outdated technology, and limited considerations on the expected results of the manufactured good. Firstly, Scheduling the maintenance is a major issues due to which plant efficiency lowers down and quality issues take place and production of waste material increases. Several parts of the film line need to be maintained in a specific period of time in order to run the film line smooth and defect free production. Mechanical parts of the plant such as filters, extrusion line and moving rolls are included in the maintenance parts need to be serviced in a fixed span of time.

Secondly, the Remote measurements of different characteristics of the produced film are necessary to maintain the desired properties (mechanical or optical) according to the customers' requirement. The foremost property to be measured during the manufacturing is the thickness of the film by which the company may save material as the whole film line is synchronised with the material coming from the die. If die allows the extruded material more frequently, then more material accumulates on the produced film and as a result the manufactured product would be thick than the required thickness and vice versa.

Thirdly, Manual feeding in the silos for the main extruders and secondary extruders which raises the chances of getting error higher. In order to run smooth process in Bi-axially oriented polypropylene film line, the extruded material must be dust free when extruded film is being stretched in longitudinal and transverse direction section of the film line. Throughput of extruded material depends on the pressure difference of the main filter at the end of extrusion process line. This is the major reason of film breaking at the outlet of TDO due to stretching the film as 8:1 ratio. These obstacles are due to inappropriate maintenance of the main filter in the extrusion line and thus raises the pressure difference which causes the film breaking at the time of transverse direction orientation.

Finally, the case the company uses the limited method (recycling) to reuse the wasted film and the rejected product by the customers. The rejected product is due to not having the required the mechanical and optical properties of film. Several other advantageous practices are available by which case company can increase the process efficiency in terms of producing the transport fuel by setting up a small procedure which will be explained in the last section of the thesis under the heading of further development.

Next section discusses the best practice in waste management of polymers in terms of applying the scheduling of maintenance issues, which is the first challenge mentioned in the findings from the current state analysis and applying different lean tools to eliminate the waste and existing knowledge leads to develop the conceptual frame work of the study. Later, the conceptual frame work is used to build the proposal for the case the company to eliminate the waste of polymer.

4 Best Practice of Waste Management

This section overviews best practice in reducing the wastage materials of polymers. Several waste reduction and quality improvement techniques introduce like Just-In-Time (JIT), Toyota Production System (TPS) and lean manufacturing. A technique is introduced called single minute exchange of dies (SMED) to reduce downtime and to measure the overall equipment effectiveness. A planning and scheduling of preventive maintenance implements to boost the reliability and efficiency of the machines.

4.1 Lean Techniques in Process Industries

The elimination of waste is carried out through different lean techniques explained by Heizer and Render (2011) using JIT, TPS and Lean manufacturing philosophy (Rathore, 2015).

4.1.1 Just-In-Time (JIT)

Heizer and Render (2011) describes the term Just-In-Time approach to eliminate the waste, improve throughput and reduce inventory in a continuous process. JIT is an essential ingredient of lean management and specifically provides the support of rapid response and lower costing. According to this technique materials arrive only where they are needed and when they are required. The certain essential features which are included in Just-In-Time are given in the Figure 3.

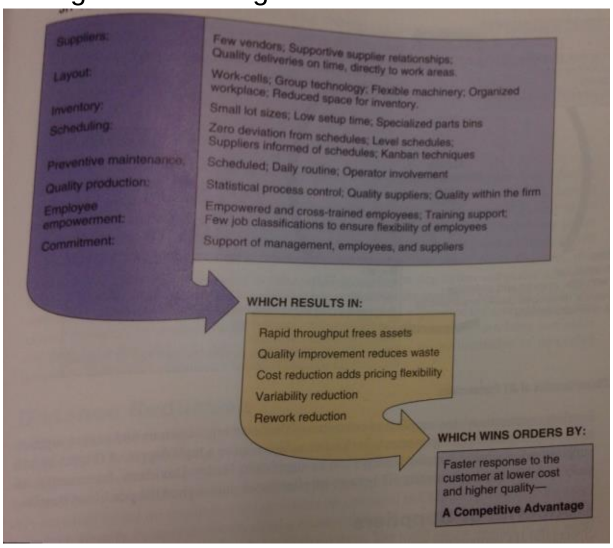


Figure 3. JIT Contributes to competitive advantage (Heizer & Render, 2011).

Figure 3 shows the different features which are to be explained in order to get the appropriate ideas about elimination of wastes in relation with suppliers, layout, inventory, scheduling and quality. JIT attributes a competitive advantage which results faster customer response at reasonable cost, quality improvement and reduces waste. Heizer and Render (2011) discussed several section such as partnerships, layout, inventory, scheduling and quality of JIT which are being explained in the following paragraphs.

Firstly, JIT partnerships exist when both supplier and purchaser work together with mutual understanding and trust. Some aims of JIT partnerships regarding removal of activities related to bidding, paperwork, inspection and payment. The removal of plant inventory by delivering small lots directly for use on workplace as necessary. The mutual relationship between suppliers and buyers in terms of nearby location, small lots supply etc. are shown in the Figure 4.

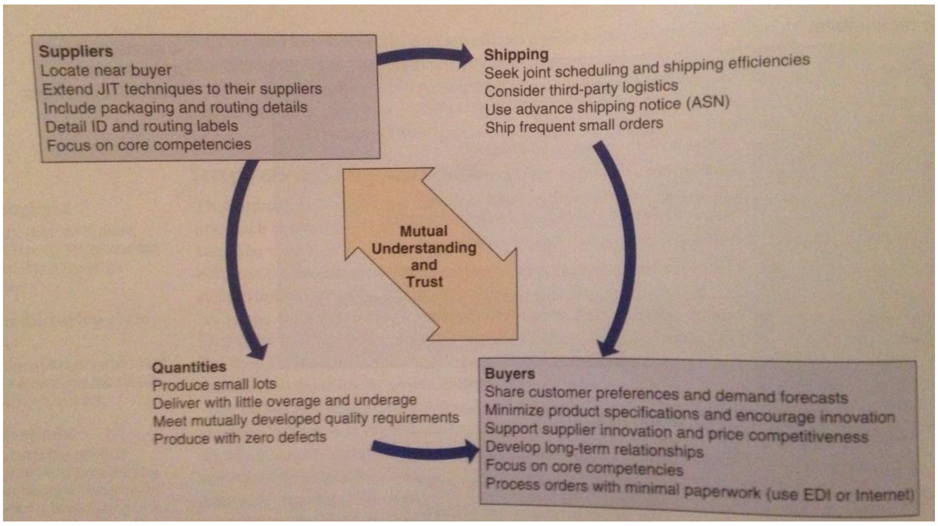


Figure 4. Characteristics of JIT partnerships (Heizer & Render, 2011).

Figure 4 illustrates the mutual understanding and trust between suppliers and buyers in which suppliers should be encouraged by the buyers to locate nearby workplace to ensure the delivery on time, supply small lots and encourage innovation.

The removal of in-transit inventory takes place by encouraging the supplier to locate nearby and deliver frequent shipments. Inventory can also be reduced by using the technique called consignment. Improvements in quality and reliability can be achieved through long commitment, communication and cooperation (Heizer & Render, 2011).

The concerns of successful JIT partnerships that supplier is addressed and encouraged by diversification in which suppliers think they can reduce the risk of losing the customers to have variety of customers and suppliers may not want to tie themselves to long-term contract with only one customer. Secondly, most of the suppliers have a bit faith on the ability of purchaser to generate orders to a smooth and coordinated schedule. In continuation with lead time in which inadequate lead time for suppliers to apply the required changes can play havoc with JIT. The capital budget, processes or technology may set a limit to respond the changes in quality and product. Suppliers might see the frequent delivery in small lots as a way to supply buyers' holding costs to suppliers.

Secondly, JIT layouts reduce the waste of movement of material on the factory floor which does not add value by Heizer (2011). This tool is applicable in the factories and as a result, managers intends flexible layouts to reduce the movement of both people and material. According to JIT layouts, paper should be placed on the location where needed (Heizer & Render, 2011). When a layouts reduce distance, firms often save labour and space. The tactics of JIT layout describes in Table 5.

Table 5. JIT layout tactics (Heizer & Render, 2011).

Build work cells for families of products
Include a large number of operations in a small area
Minimize distance and design little space for inventory
Improve employee communication
Use poka-yoke devices and build movable or flexible equipment
Cross-train workers to add flexibility

Table 5 shows the layout tactics in JIT technique that how to implement these tactics in workplace to increase quality of the product and make sure to get continuous throughput of the required product.

According to the Heizer and Render (2011), the distance reduction is a major contribution of work cells, centers and certain factories. There are group technologies used in the firms instead of long production lines, huge economic lines and single operation machines. Group technologies help to identify the same type of components and same families, so it could built work cells for them.

Modern work cells are designed to rearrange to get the changes in bulk inventory, new designs and improvement of products. JIT layout idea is applicable to office environments as well. Layout flexibility allows the changes result from the process and product improvement which are inevitable with a technique of continuous improvement (Heizer & Render, 2011).

The impact on employee technique of layout allows trained workforce to bring elasticity and enhancements to the work cell. Employees working together may teach each other about opportunities, problems for improvements. The machines in work cells use verification itself by poka-yoke methods to identify defects and stops automatically when this happens. The deficient products were exchanged to the inventory before introducing this technique (Heizer & Render, 2011). As JIT layouts reduce distance of travel, it also reduce the inventory by arranging the space. Units of the inventory may be moved because of the shortage of space stated by Heizer and Render (2011).

Thirdly, Heizer and Render in operations management (Pearson Edition, 2011) states that the minimum inventory necessary to keep a perfect system running. Efficient inventory tactics need to have “just in time” not “just in case”. Some useful JIT inventory tactics are shown in Table 6.

Table 6. JIT inventory tactics (Heizer & Render, 2011).

Introduce pull system to shift inventory
Reduce a lot size
Develop JIT delivery methods with vendors
Deliver directly to the workplace
Implement the Schedule
Reduce set up time and use group technology

Table 6 illustrates different tactics of inventory in JIT that how to reduce inventory in the workplace or manufacturing line. These tactics are helpful to manage with the inventory with efficiently and in a better manner.

The pull technique which is included in JIT is the ideal to eliminate the variability in the production system hidden by inventory and reducing uncover inventory that represent the variability and problems directly being endured. With reduced inventory, the chips of management away at the exposed problems as shown in the figure 8 (Heizer & Render, 2011).

JIT has also come to mean the elimination of the waste by reduction the investment in inventory. In order to reduce the inventory and costing of inventory, the size of batches may be a great help. The reduction in lot sizes must be accompanied by reduced setup times. As the inventory reorder quantity and the ultimate level of inventory decreases and as result, inventory and holding cost both of them go down. Consequently, the method to drop down the lot sizes and reduce the average inventory is to reduce the setup cost, which in turns lowers the optimum size of the order.

The effective scheduling (Heizer & Render, 2011) is required for effective use of capital and personnel. Better scheduling improves the ability to meet the requirements of order fulfil of the customers setting down the inventory by allowing the reducing the lot sizes and reduce work-in-progress.

Table 7. JIT schedules tactics (Heizer & Render, 2011).

Communicate the schedules to the suppliers
Make scheduling levels
Freeze part of the schedule
Reduce waste
Generate in small lots and use Kanban
Each operation produces excellent part

Table 7 shows different tactics in scheduling in the JIT technique which are needed to implement in the production unit in order to increase throughput and quality of the manufactured goods.

Heizer and Render (2011) describes that schedule the products, so that each day's production meets the demand for that day. Scheduling process mostly small batches rather than the few large batches. This technique is called a jelly bean scheduling as it schedules many small lots that changing always.

The Japanese word for card which means "signal"; a Kanban system moves different parts through production via "pull" from a signal. The final assembly receives the scheduling from the office of dispatching and the scheduling is more or less same day to day. The other workers and suppliers get the production orders from the relevant work centres. In order to stop the line means there is no order from the work centres at all (Aswathappa & Shridharabhat, 2010).

Kanban system contains significant benefits as follows (Aswathappa & Shridharabhat, 2010): Reduced inventory level, less confusion over sequence of activities, less obsolescence of inventories in storage, reduced lead times, smaller floor space requirements for storage, elimination of waste, improved quality, higher system flexibility.

Finally, there is strong relationship between JIT and quality. JIT technique works in quality assurance in three ways. Firstly, JIT reduces the cost of acquiring the good quality. Inventory controls the bad quality and avoids the rework, scrap and JIT immediately exhibits it. Secondly, JIT improves the quality. This technique reduces the lead time and queues, it keeps the track record of sources of errors. In JIT technique, the feedback for quality control is immediate and this advantage accumulate within the firm and products received from the vendors. Finally, it allows the organization to reduce the costs correlate with inventory (Heizer & Render, 2011). The JIT quality tactics are shown in Table 8.

Table 8. JIT quality tactics (Heizer & Render, 2011).

Use statistical process control
Empower employees
Disclose poor quality with small lot JIT
Contribute Immediate feedback
Build fail-safe (poka-yoke) methods

Table 8 illustrates the different tactics to increase quality of the manufactured product and to get the continuous throughput of the product. Figure 3 illustrates the core components of Just-In-Time in which JIT contributed competitive advantage in terms of quality improvement and continuous throughput of the product by developing the partnerships with suppliers, inventory layout, scheduling, and quality improvement tactics.

The different tactics described in the JIT technique which are necessary to implement in the workplace to improve the quality of the product, to get the better scheduling and inventory which helps to increase the continuous throughput of the product. By implementing these tactics in the workplace and production premises lead to elimination the waste of the product.

4.1.2 Toyota Production System

The second component of lean management is Toyota Production System (TPS) which is utilized for enhancing quality, reduces waste and value for customer-driven. These benefits attain by continuous improvement of employees capabilities, adding value to the employees responsibilities and developing standard work practices. In the waste elimination of the manufactured product, Toyota Production System plays an important role by implementing the core three components explained in the following paragraphs.

The Toyota Production System defines the seven deadly wastes which are equally harmful (Wilcox, 2008).

Lewis (2005) describes the seven types of waste which relates to the Ohno: The waste which produces earlier than the customer orders is overproduction. The material that adds no value to wait for machine to complete the process is called queues. The material that moves between plant and workplace and it handles more than once is called transportation waste. The unnecessary raw material adds no value and excessive operative supplies which is called as inventory waste. The movement of equipment and people adds no value is waste is known as motional waste and the work which is performed on the product adds no value is over processing waste, while the waste which may be reusable, returnable, is called defective waste.

There are three core components described by Heizer and Render (2011) which is being followed in Toyota in order to make the process continuous, defect free and profitable. The first core component is continuous improvement. In TPS, continuous improvement means a building the organizational culture and diffusing in the people a system by which stressing the process can be improved and that improvement is essential part of the employee's job. This process and technique is introduced by Kaizen in TPS. The process of continuous improvement begins at the recruiting and continuous through considerable and continuing training. Another main reason is to respect people for continuous improvement of the Toyota.

The second one refers to respect for the people that described by Heizer and Render (2011) in the section of respect for the people that Toyota considers their employees as empowerment. TPS employs mentally and physically in the challenging task of improving operations. Toyota recognizes that employees know how to complete the task more than anyone else. Toyota Production system respects employees by providing the opportunities to enhance their lives and jobs.

The third core component which is being followed in Toyota is the standard work practice. The Work practice at Toyota emphasizes the following points (Heizer & Render, 2011): Specified work is done in terms of content, timing and outcome, customer-supplier connections are direct, services and goods are directed to the particularly person or machine and it is to be simple and direct, scientific methods used to make improvements in the system at the lowest possible level of the firm.

Furthermore, Bicheno's research (2008) argues that Toyota's problem-solving technique is successful as it employs the PDCA cycle and improves processes continuously by iterating the learning cycle. In 2004, the the company modified the name of 8-step process to Toyota Business Practices (TBP) which has used on a broader view that 8-step problem solving is applicable to all kinds of business. Toyota's philosophies have reshaped the TBP and is noticed by their "Drive and Dedication" points which is said to explain the the company's policies when completing each of the 8-steps.

Toyota 8 step process commonly refers to A3 problem solving (Liker, 2004). This term denotes the paper size that has been used before e-mail. Toyota's 8 steps process has produced much speculation and revised how problem solving is being applied and how it could be accepted commercially. Much of work suggests that Toyota's hands-on learning is the absolutely perfect combination that makes the problem solving a successful strategy. (Liker, 2004).

Toyota's methods is effective due to an influential properties of a lean system that aims to find the root cause of problems so those issues never appear again (Mann, 2005). The Toyota's 8 steps process as shown in Figure 5.

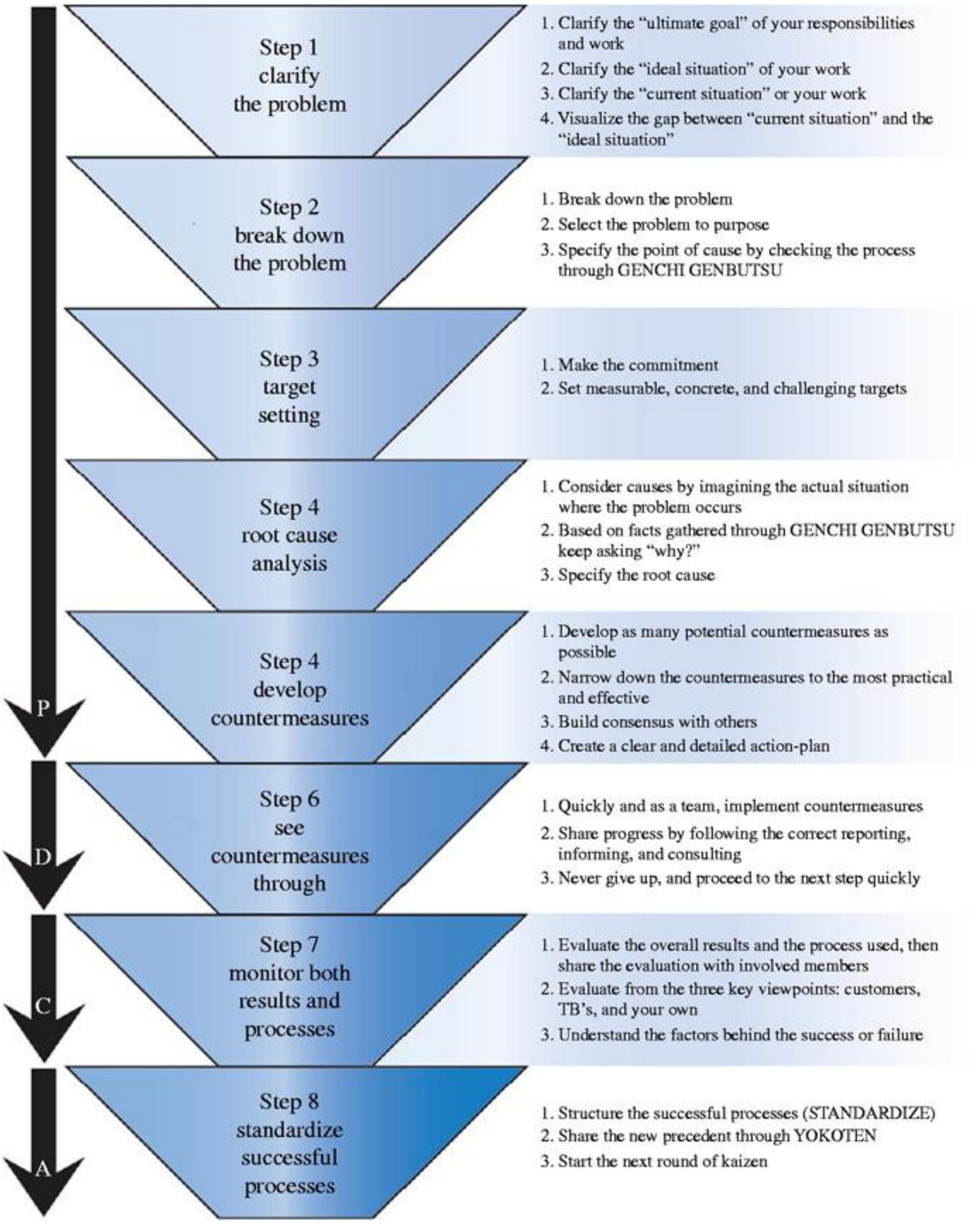
In Toyota's 8 step processes, each step needs to have an explanation in order to apply effectively in the manufacturing firm.

Step 1: Problem Clarification. Clarify the "ultimate goal" of your responsibilities and work. The "ideal situation" of your work should be clarified, the clarification of the "current situation" or your work, and hence Visualize the gap between "current situation" and the "ideal situation".

Step 2: Breakdown the Problem. In order to resolve the problem efficiently, the breakdown of the problem should take into account, select the problem to purpose, and specify the point of cause by checking the process through GENCHI GENBUTSU.

Step 3: Target Setting. The target setting is an essential element to resolve the problem in the industrial sector by making the commitment and setting the measurable and challenging targets.

Step 4: Root Cause Analysis. Knowing the problem from the origin helps a lot and based on the facts gathered through GENCHI GENBUTSU keep asking "why"?, and then specify the root cause of the issue.



.

Figure 5. Toyota's 8 step process (Phillip , et al., 2011)

Step 5: Develop Countermeasures. There should be generation of counter measures as many as possible, keep narrowing down the counter measures to the most relevant and practical, and build consensus with others to develop a clear and detailed action plan.

Step 6: See Countermeasures through. The countermeasures implementation should be as quickly as possible. Secondly, the progress report should be shared to make correction, informing and consulting, and never give up to proceed to the next step quickly.

Step 7: Monitor Results and Processes. Evaluate the overall results and the processes used, and then later share the evaluation report with the evolved members in the project. The evaluation from the three key points customers, TB's and one's own.

Step 8: Standardize the Successful Process. Structure the successful processes as standardize, sharing the new precedent through yokoten and start next round of kaizen, and understand the factors behind the success or failure.

It is speculated that Toyota is excellent in problem solving due to continuous training to assist the members of the team when they are attempting to solve their own problems. The way which human uses to solve the problems contain different ways. This is uncertain to know the step on which managers are expected to emphasize, corrections or which errors to avoid to obtain a successful problem-solving results (Phillip , et al., 2011)

The research of Bicheno (2008) suggests that Toyota's problem-solving methodology is prosperous as it utilizes the PDCA cycle, as shown in Figure 5, and improves the processes on a continuous basis. In 2008, the company named their 8 step process to Toyota Business Practices (TBP) which has adapted on a more general view that 8–step problem solving is applicable to all business operations.

4.1.3 Lean Operations

Lean is a manufacturing methodology that comprises activity which consumes resources but unable to develop value for end customer is wasteful and therefore should be reduced (Shah & Ward, 2003). Sohal (1996) described that lean manufacturing technique eliminates scrap processes, regulates the processes in a continuous flow and clarify the problems through continuous improvement. At production level, lean manufacturing is carried out through tools and techniques and eliminate the huge waste exist inside or along with the supply chain.

Why Adoption of Lean is Vital for Process Industries

According to Dennis and Meredith (2000), process industries are those which have processes like mixing, forming, separation and chemical reactions. Melton (2005) describes many of the other kinds of waste in the process industries that van be controlled by using lean manufacturing technique. Process industries have seasonal stock of raw material and huge equipment for processes. Therefore, it requires huge space for finished goods and materials. Lean helps to attain better utilization of space and equipments (Cox and Chicksand, 2005)

Furthermore, lead time is generally very high in process industries as it comprises cleaning and washing of equipments. Lean manufacturing philosophy such as lead time reduction and quick change over technique is effective. Zanoni and Zavanella (2005) describes that there are key processes depend on time and temperature. Dov (1992) proved that techniques of lean philosophy like ‘JIT deliveries’, ‘Kanban’ are very effective to maintain the quality of product in process industries.

Application of Lean Processes in Process Industries

Lyon et al. (2013) conducted a survey regarding the lean practices in UK and found that those are associated with elimination of wastes. Authors found the results that application of lean tools such as 5S, TPM, quality management, JIT, poka-yoke devices are widely used in process industries. Hodge et al. (2011) observed that those who have implemented lean showed symbolic use of tools such as 5S, kaizen, JIT whereas, lean tools like as cellular manufacturing, policy deployment, mistake proofing were rarely used.

Challenges to Implement Lean

Melton (2005) describes that difficulty to change and confusion of validity need to be conquered during the implementation of lean in process industries. Lack of training and knowledge about lean tools are core challenges and need to have a proper planning to implement lean concepts in process industries. Another challenge not to implement lean philosophy in process industries is the difficulty to find the experts who could lead (Kamakura, 2006).

The 5 S's of Lean

Heizer and Render (2011, p. 655) describes lean 5S's tool is frequently used to compensate in the industry of manufacturing and the 5S's are from Japanese given below:

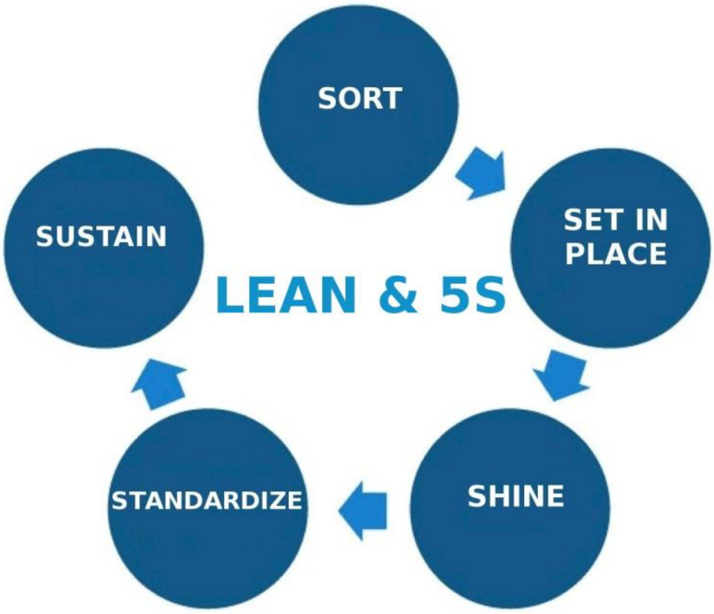


Figure 6. The 5S's lean tools (adapted from practical eloquence).

The removal of anything unnecessary from the work place. This makes space and usually improves work flow. The setting in order of tools improve the work flow and label the goods for easy use in the work area for immediate use. The elimination of all kinds of contamination, dirt and clutter from the work area makes work clean and sweep. The standardization of the equipment and tools to reduce time and cost. Train the workers to tackle the deviations. Sustaining the progress and communication by visually and review periodically to know efforts. U.S managers added two S's to maintain lean workflow which are included as constitute good practices into above five activities and reduce unplanned downtime, variability and costs.

Lean 5S's tool that is not necessarily one of the primary Lean tools but rather more of a supportive one that nonetheless plays a key role in establishing the continuous improvement culture. When utilized, this tool will ensure that the working environment is clean and clear of any encumbrances that would negatively affect continuous improvement.

Implementation of Japanese 5-S Practice

Management must be noticed to practice 5-S and to sustain the commitment. O'Eocha (2000) illustrates that breakthrough and practice revises in a small the company needs to have a strong leadership in a practical way. The situation is far complicated and to implement the usage of 5-S is not clear enough. Ho (1996) mentions that importance of lean 5S in the company from top management to everyone and the importance of having a 5-S expert lead to the leadership. He explains his roadmap in five steps: firstly, get commitment of top management and be prepared, secondly, design an advertising campaign, thirdly, make sure to keep records, fourthly, accomplish the training of 5-S practice and then evaluation.

Benefits and Barriers of 5-S

The benefit of adopting the lean 5-S includes the fast improvement of items, the involvement of staff improvement takes place, better housekeeping, elimination of waste, preventing pollution, materials and other stuff make storage safer, health and safety environment issues start to improve. The limitations to implement the lean 5-S includes as recognizing the loss of control by middle management, time, limited resources, lack of responses, communication gaps, low morale, low incentives and lack of planning. The research commenced will establish perceived benefits and barriers with the implications of 5-S presently in UK industry (O'Eocha, 2000).

4.2 Single Minute Exchange of Dies (SMED)

The second major technique to reduce the downtime in the manufactured line is single minute exchange of dies. This technique is used to reduce the small breaks in the production line as small breaks are the main reasons to produce the scrap waste. In this way, this technique is essential to implement in the production line to eliminate the scrap waste.

The single minute exchange of dies (SMED) technique refers to the improvement of operational activities has been preferred to eliminate the downtime loss and quick changeover during the production process (Moxham and Greatbanks, 2001). Challenges have also made to implement this technique due to involving the extensive use of information technology in such electronics industries (Trohvinger and Bohn, 2005). The SMED technique describes that the actual reason of downtime by machinery specification changes can be significantly reduced even if the frequency of the system cannot be reduced, and hence an increase in production capacity.

Shingo (1985) illustrated the development of the SMED technique took place in Hiroshima, Japan during the fifties. Initially, it was developed in the area of Mazda and Mitsubishi Heavy Industries (MHI). Though, it was only in the seventies, as part of the Toyota Production System, that the SMED technique was extensively acknowledged. Contrary, the concepts of quick changeover utilized in the US during the fifties. According to Shingo’s (1985) research, the methodology of SMED is responsible for widespread diffusion. The SMED methodology was introduced in order to eliminate and simplify the setup time during changeover (Shingo, 1985). SMED, a Japanese innovation, generates it possible to get a feedback on the variations which lead in time reduction in lead time. Furthermore, it reduces wastefulness during the changeover and abates lot sizes. The five principles for doing quick change over is as follows:

The first principle is to differentiate internal setup elements from external elements. Internal setup refers the activities which are needed to be performed during the stoppage of production line while external setup refers the activities that are needed to be performed during the operation of machines (Moxham & Greatbanks, 2001). The second principle is to separate the internal elements to the external elements. The set of operations divided into the internal and external elements in this step of SMED. The third principle is to convert as many internal elements as possible to external elements. In this step, many modifications are to be made in terms of technical aspects to convert internal elements to external elements. The purpose of this step is to analyse whether the required activity can be done during the operations of machines which results the reduction of downtime of the production line (Michels, 2007). The fourth principle is to streamline the remaining internal elements. In this step, the SMED requires to have alternative ways to reduce the internal elements downtime such as to reduce walking, searching and gathering the desired parts and materials required during the SMED (Conner, 2001). The fifth principle is to streamline the external elements. The external activities are accumulated to make it easy and efficient. Reducing in time to complete the external activities does not improve overall equipment efficiency but the efficient operators.

An important key factor of single minute exchange of dies (SMED) is the converting internal setup elements into external setup elements. External operations to prepare tools and methods should be routine and standardized. The internal setup elements should also be prepared in terms of documented and standardized for workers to view. Reducing the internal elements or eliminating affects directly on the setup time. Standardizing eliminates several types of activities, which is known for consuming time (Hunter, 2003).

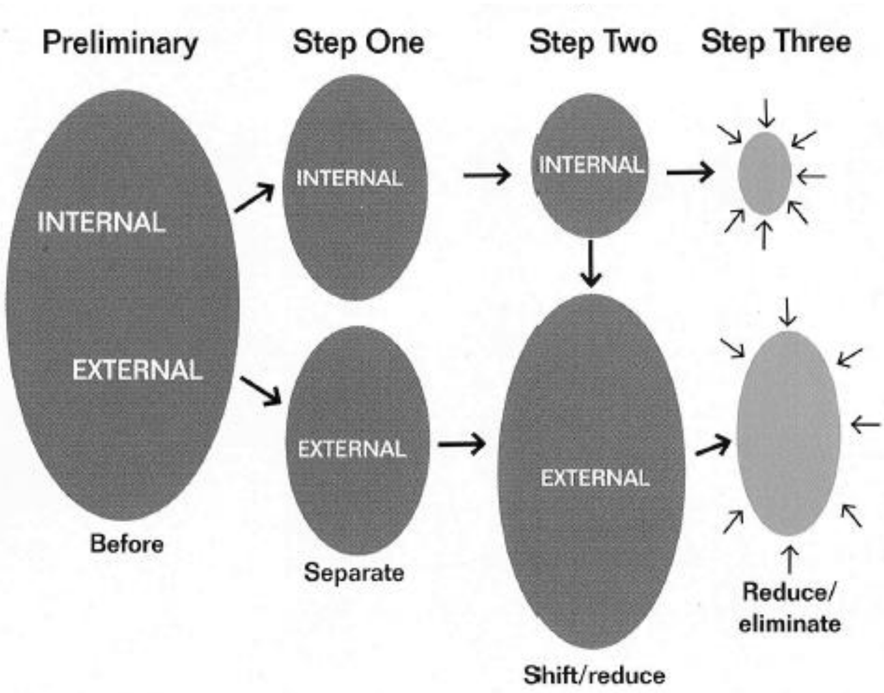


Figure 7. Implementation of SMED technique (Hunter, 2003).

Reduction or elimination of setup time is critical to convert into lean and flexible system in manufacturing environment. This practice usually the foremost which the company need to take as results are quick and effective (Hunter, 2003).

As the small breaks are the major reasons to produce and increase the scrap waste during the manufacturing process, so there is need to implement the technique by which small breaks during the production process could be reduced, so the SMED technique is clearly related to the production process to stop the small breaks which in turn the elimination of waste occurs.

4.3 Preventive Maintenance

Maintenance plays a major role to operate the machines continuously and produce the quality assured products. If the machines in the plant work in a continuous manner to manufacture the required product, there are less prospects to stop the machines during operation which in turn the elimination of waste.

Maintenance can be defined as the set of all activities related to technical and administration performed to avoid the shut down or to repair the damaged components of plant (Malamura et al., 2012). This step may have high impact on the profitability of the the company and choosing the suitable planning is integral part of the manufacturing the company. There are mainly two types of maintenance; Preventive maintenance and Corrective maintenance. Preventive maintenance is most effective way to perform than corrective maintenance in terms of effectiveness and cost. Preventive maintenance supports the reliability and performance of the machines. Implementing of a well planned maintenance reduces the cost of corrective maintenance (Richan Chouhan et al., 2013).

To relate the maintenance to the production, a classification scheme is described by Budai (2006) to support the maintenance tool to the production. The classification scheme shows that how maintenance related to the production which as a result to eliminate the waste and produced the quality assured product.

Classification Scheme

Gabriella Budai (2006) describes the classification scheme of maintenance. Maintenance is related to production in many ways. Firstly, In order to perform maintenance, production line has to be shut down as a whole. This effect of maintenance considers in planning and optimization and this effect directly related to downtime and costing. Secondly, the maintenance to be considered as a part of production that needs to be planned with respect to the production process. Thirdly, in this category, planning considers the integral part of production and maintenance, as maintenance has to be done either to eliminate the quality issues or of a failure of the system.

Maintenance planning and optimization

In order to implement the maintenance planning to the production premises, planning and optimization is required which consists of following steps. The planning and optimization of maintenance (Wang, 2002) has described the important maintenance decisions which are as follows: (i) Maintenance concepts and long term planning and strategy (ii) intermediate term planning, (iii) short term planning and scheduling and finally (iv) control and performance indicators.

The main strategic decisions regarding maintenance are taken in the systems of process that which type of maintenance is suitable and when it should be done. This idea concerns in the maintenance. The second core strategic issue is the organization of the maintenance section in the firm. Wang (2002) discussed the strategy that the maintenance completed by the workforce of production, in the way of TPM (Total Productive maintenance) and secondly, the location of specific type of task outsourced. Thus, the the company management more concerns of industrial organization than mathematical models.

Moreover, another core strategy concerns that the methodology of how a system can be maintained and it determines that whether specific equipment of personnel are required, determination ease of accessible of the personnel to the subsystem, the available information and it concerns also that which element might be easily replaceable.

In the tactical stage, management makes a plan for major maintenance of some important section of the plant within the certain span of time which has to be performed with the workforce of the production department. In this regard, some particular decisions needed to take into account. Secondly, the number of crews required to complete the mentioned task regarding maintenance and there should be appropriate number of employee to complete the required task to get the desired results (Wang, 2002).

In a short term scheduling stage, the workforce related to the maintenance in the company determines the order of execution and given an amount of corrective or preventive maintenance task in the manufacturing line. Firstly, it is carried out when a failure of core component of production line take place in a prescribed way. In order to prevent those issues, preventive maintenance work to be carried out. Although, this situation is usually happened, so it is likely observed that the difference is not clear enough and this is, because of the definition of failure. A component might be in a bad situation but still in functioning mood and one may consider this as a failure or vice versa. The corrective maintenance usually cannot be planned but preventive maintenance takes place in a certain period of time to avoid the failure of the main component in the production line.

The execution of maintenance can also be triggered by condition measurements, in other words, condition-based maintenance. This has often been speculated as more effective and efficient than time-based preventive maintenance. Since this is hard enough to anticipate the working condition in advance and if the failure of component has happened, condition based maintenance often unplanned.

Finally, inspections of different sections of the production line may carry out by using the sight and instruments using the laser operated (Infrared thermometer) that do not affect operation. They do not improve the state of a system however, but only the information about it. This strategy is essential for the production machines and this strategy can be important in case quality of product starts bad which is being produced. There are inspection-quality problems where inspection optimization is connected to quality control (Wang, 2002).

When to Do Maintenance in Relation with Production

The effect of maintenance on modifying production schemes are considered in three ways. In the first stream follows the cost of downtime that is necessary in maintenance planning. In the second stream that opportunities for maintenance are not necessary in the specific units and in the third stream, theories consider the effect of maintenance on production.

Firstly, the costing of downtime in an imperative step during the plant maintenance. The costing of downtime is easier in preventive maintenance than the corrective maintenance as there may have unexpected failures consequences (Gabriella , et al., 2006).

Secondly, the maintenance that is carried out that the units of the company are less needed to work normally. There may be several reasons for opportunity maintenance. Which are described as the preventive maintenance need to be carried out when failure of one component has happened especially when this failure causes the shutdown of the production process. The next reason for opportunity maintenance is to face interruptions in the production process other than the failure of the components. The other reasons may be the market interruptions, grade changing in the production line. This generates the opportunity of preventive maintenance in the plant (Gabriella , et al., 2006).

Maintenance Scheduling in Line With Production

In this section, the used models show the effect of production on maintenance is categorically taken into account. This model described the decisions of maintenance in the production workplace.

Charles et al. (2003) found that the effect of planned maintenance on semiconductor wafer fabrication lab. The objective of this practice was to improve the quality of maintenance practices by the implementation of the strategies regarding preventive maintenance and develops the scope of total productive maintenance strategy. The production of semiconductor gadgets is carried out in the lab and the breakdown of the equipment usually induces unplanned productions interruptions.

Cheung et al. (2004) studies on different types of plant with several units. There are many breakdown periods for maintenance and the task is to detect units to those periods in a way without the effect of production.

4.4 Summary of the Best Practice

Section 4 discussed tools and techniques for waste elimination in the process industries from the best practice. Lean manufacturing techniques are those that are most relevant tools to eliminate the several types of waste in the industries

Figure 8 shows the conceptual framework of the study which combines the tools of lean practices such as Just in Time (JIT), Toyota Production System (TPS), lean 5 S's tool, single minute exchange of dies and preventive maintenance implementation.

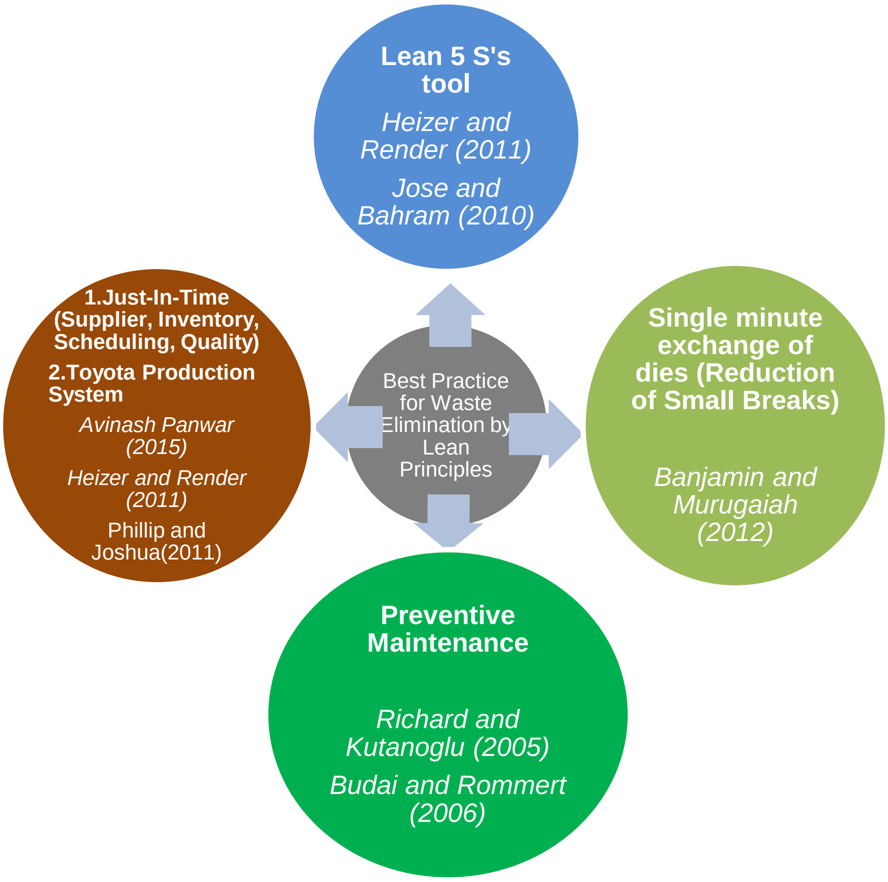


Figure 8. Conceptual framework of the study.

JIT technique is necessary to improve throughput of the manufacturing line, quality improvement which results as a waste reduction. The waste elimination of the defective product is possible by adopting the JIT principles in the process industries. Inventory control and rework reduction is the result of JIT inventory tactics by using the 'pull' system and hence reduce the scrap products. Toyota Production system brings the continuous improvement by kaizen formula, respect for the people in Toyota and standard work practices by improving good communication with customer-supplier.

Single minute exchange of dies (SMED) technique in a manufacturing industries reduce the small stop time loss. The SMED technique has been proved to be an effective approach to tackle the small stop and a loss which has been nominated the big among the six losses. The scheduling of preventive maintenance of production process is considered as a continuation of lean operations to eliminate the waste of material and improvement of production process.

Preventive maintenance is highly effective than the corrective maintenance as in the corrective maintenance, team has to wait until the stoppage of production line or some other major emergency with which the line stoppage would be take place. Preventive maintenance scheduling includes costing of downtime, opportunity maintenance in which failure of component or other interruptions such as market practice or catalyst changing.

Next section describes the proposal building for waste reduction by analysing the Current state analysis, findings from the literature and conducting the theme interviews with the stakeholders of the the company which turns as the improved process for the manufacturing of composite film line.

5 Proposal Building for Waste Reduction

Based on the conceptual framework, data acquired in the first round and the theme interviews of the stakeholders of the company, a preliminary proposal for waste reduction is built.

5.1 Overview of Data 1 Results

The data collection for current state analysis shows that there are several issues found to resolve the problem of waste. The Table 9 represents the mapping of current state analysis findings and conceptual framework elements.

Table 9. Mapping of CSA against conceptual framework elements.

Findings of CSA	Conceptual Framework
Scheduling and Maintenance Issues	Lean Tools and Techniques Just-In-Time Toyota Production System Single Minute Exchange of Dies Preventive Maintenance
Lack of Remote Measurements of Properties (thickness etc.)	
Manual Raw Material Feeding in Silos	
Limited Methods Applied to Reuse the Wasted Material	

As seen from the Table 9, the findings from the current state analysis shows the several challenges and the conceptual framework elements against the challenges from the current state analysis. The lean tools, Just-In-Time, Toyota Production System, Single minute exchange of dies and preventive maintenance are included in the conceptual framework.

The scheduling and maintenance issue considered to fix in relation with the elimination of waste in the manufacturing of film line. The tools and techniques are used to resolve in different areas of the film line to increase quality of product, increase the throughput and eliminate the waste of the product. Just-In-Time and Toyota Production system are used for quality improvement and continuous throughput in the production line.

The single minute exchange of dies is the technique to reduce the downtime during the small breaks in the film line and by implementing this technique, a quick changeover occurs and as a result, the downtime reduces which in turn reduces the waste of product. The scheduling of preventive maintenance is the method by which the overall operating efficiency increases and operation of the film production line makes smooth which in turn no downtime occurs and thus, no waste of product produces. The lean 5S's practice is used in the conceptual framework to setting the tools in order to make the process smooth and ultimate eliminate the waste in the production area.

5.2 Data 2 Results

Data 2 is the stakeholder's ideas in order to build the preliminary proposal and the details of the theme interviews with the stakeholder's are as follows:

During the second round of data collection from the core stakeholders of the case company in the production department. Two theme interviews with open discussion were conducted and presented the ideas from the current state analysis, the ideas from the literature and conceptual framework to build the provisional proposal for the waste elimination in the composite manufacturing film line. In the first interview, there were two shift engineers were included to develop the ideas for the preliminary proposal. The lean 5S's practices to eliminate the waste of scrap waste from the production unit, single minute exchange of dies and preventive maintenance techniques were discussed with the Respondents D and E. These topics were discussed to get the process smooth, quality improvement, continuous throughput and reducing the downtime during the small breaks in the film line.

The ideas of lean principles were presented to reduce the waste and improve the overall equipment efficiency. Both of them agreed to implement lean 5S's tool to attain the improvement in the overall operation of film line. The five principles of single minute exchange of dies (SMED) technique is efficient to reduce the changeover time during die exchange of the line. In the SMED technique, it is not possible to apply five principles immediately but four of them are possible and this agreed by both of the respondents.

Since small breaking of the manufacturing film is a major issue to generate the scrap waste in the production plant, so the SMED technique seems to be the right technique to implement in the production unit. Ideas related to the lean management including 5S's, single minute exchange of dies for quick changeover and the preventive maintenance scheduling were discussed to the respondents 'D and E' who have direct contact with the production affairs of the film.

According to the Respondent D, he continued the idea of SMED technique regarding the application in the manufacturing department in terms of differentiation of external and internal elements and as an expert of film line. His suggestion related to the external elements which are the operations could be performed during the operations of film line and no need to be stoppage of the production line to be worked on. In the production firm, the core department is production unit due to which the company generates the profit for the whole stakeholders and keeping in mind this view, the Respondent E continued his suggestion in the technique of SMED that the conversion of internal elements of the manufacturing line into the external ones, so the production operation runs thoroughly and every changeover could happen without the interruption of production of film line.

According to Respondent 'E', he continued the discussion about lean 5S's tool in order to reduce the waste in the production area to raise the throughput and quality improvement. Starting from the first step of lean that remove all the unnecessary tools in the pit (near quenching process) section of the plant and to make sure the cleanliness of that specified area. Secondly, the setting in order of the tools needed to be accessed on time and readily available and labelled them in a proper, so that everyone can put it in the right place after use. Thirdly, the sweep and shining the required tools are the also the necessary in order to find the necessary tool which should be ready to use. The cleaning environment produces the opportunity to visual inspection, tooling and work conditions. The continuation of the lean 5S's practice is the standardization as the standard work should be clear, understandable and easy to communicate. The next step in the lean 5S practice is to sustain and in terms of implementation the solutions to describe the root causes of the work issues and all the employees must be trained to use visual management techniques.

According to the researcher's analysis during working in the case the company, the small breakings in the manufacturing film line are the fundamental reasoning to raise the waste of material. In order to avoid these breakings, preventive maintenance idea presented by researcher to respondents D and E and of course, it is logical that the maintenance is essential to reduce the small stops. The management of case the company schedules the regular maintenance with the different intervals of time but since the preventive maintenance (PM) is a bit different from the regular maintenance and this idea is ready to implement immediately, agreed by both respondents (D and E).

The other lean technique such as JIT tools were discussed with the line manager of the case the company, who is responsible to implement the JIT techniques, Toyota Production System (TPS). The respondent F, the line manager of BOPP agreed to take care the JIT tools such as inventory, quality improvement, supplier's partnerships and the scheduling the preventive maintenance rather than the normal maintenance in the line. According to respondent F, JIT tools are not possible to implement immediately but lean 5S's, preventive maintenance scheduling and four principles of SMED and Toyota Production System techniques are possible to implement immediately. These suggested techniques, related to lean manufacturing, by the researcher to the stakeholders of the company are possible to implement to get the quality improvement and reduce the small breakings.

Summing up the results of the interviews with the stakeholders of the company, two shift engineers on the production line suggested that SMED technique and lean 5S's tools are the basic tools that are most appropriate to implement in the production line in order to lower down the downtime of the film line during the small breaks and smoothen the process to get continuous throughput. The BOPP line manager suggested that Just-In-Time and TPS techniques are the useful techniques but particularly with the BOPP production line, some of the tactics of JIT scheduling and JIT quality are applicable rather than JIT inventory and JIT layout.

5.3 Preparing the Preliminary Proposal

Based on the findings of current state analysis, conceptual framework from the literature, the researcher experience and the theme interviews (Data 2) of the stakeholders of the case the company, a preliminary proposal to eliminate the waste for the manufacturing film line for the case the company. The Figure 9 demonstrates the sources for proposal building.

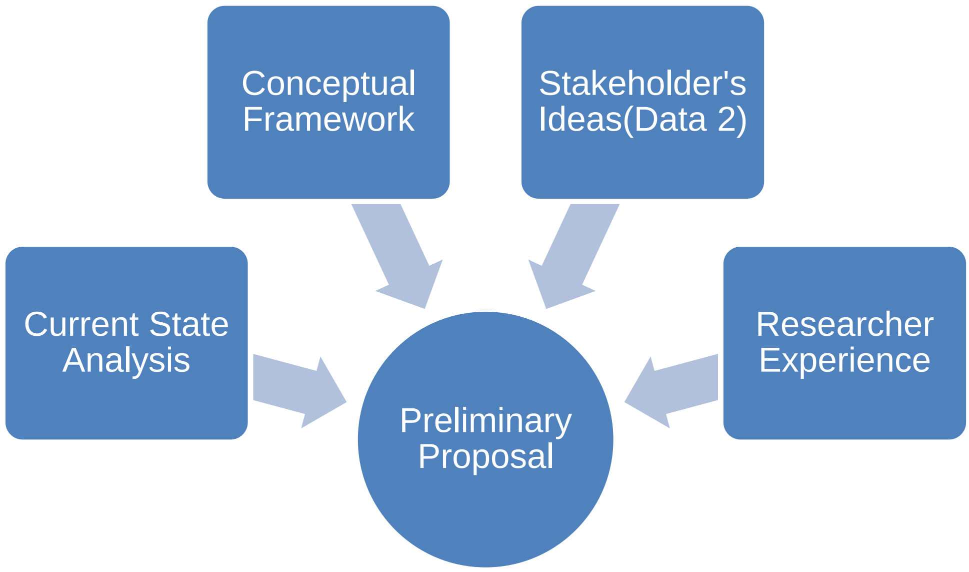


Figure 9. Sources of the preliminary proposal.

5.4 Preliminary Proposal

Table 10 shows the practical recommendations based on the theme interviews with the stakeholders of the case the company and the researcher's experience during the working in the company as shown in Figure 9. The precise recommendations in order to improve the production process of composite film line are shown in Table 10.

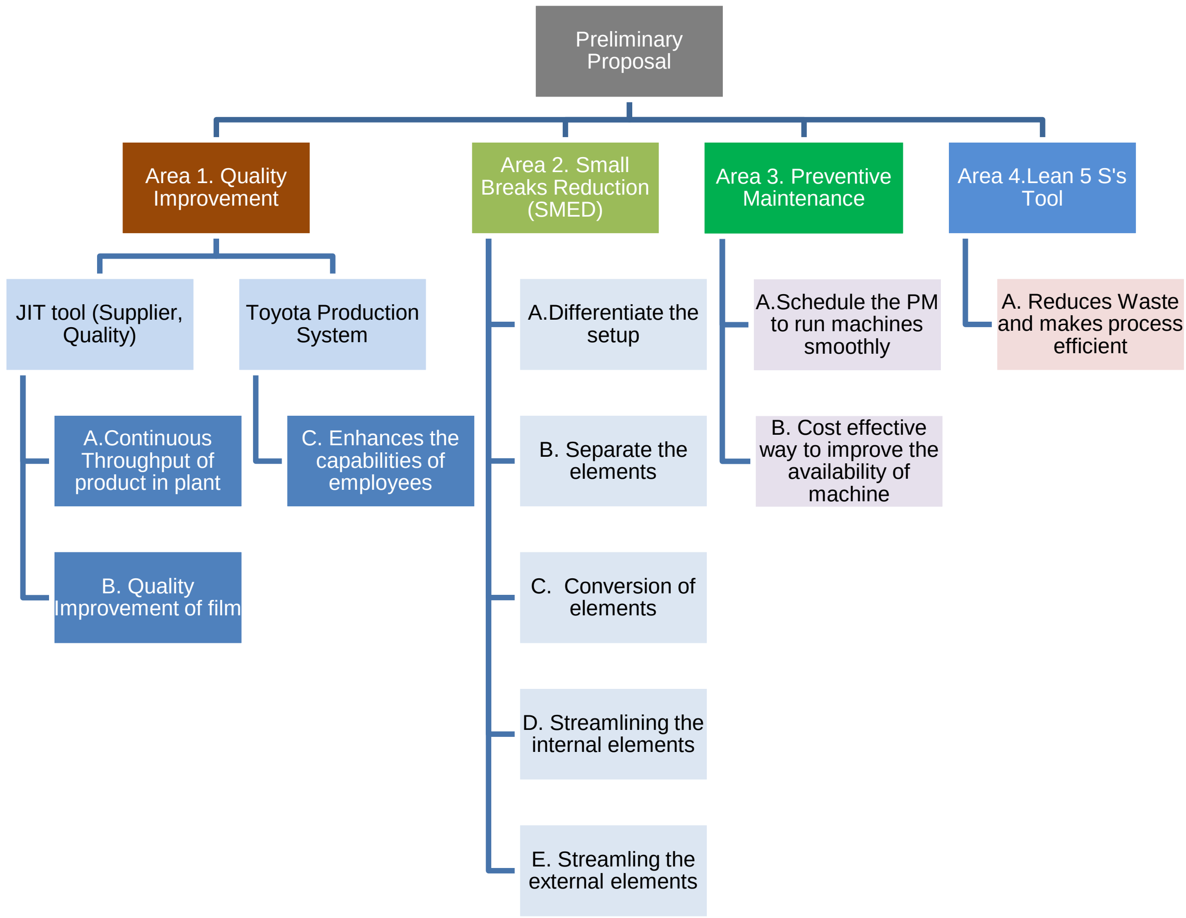


Figure 10. Waste reduction plan for composite film line (Preliminary proposal).

The preliminary proposal consists of four major improvement areas include quality improvement, a technique called single minute exchange of dies (SMED), scheduling of preventive maintenance, and the lean 5 S's tool discussed to eliminate the waste. The quality improvement tools in which JIT and TPS are described to eliminate the waste and quality improvement. In the second part of the proposal, a SMED technique is introduced to reduce the small breaks to avoid the waste of the material during the manufacturing of film. In the third part, scheduling of preventive maintenance is discussed to maintain the efficiency of the film line and scheduled the maintenance during the operations of the film line rather than the corrective maintenance at the time of failure of component or emergency time period. The details of the points shown in the hierarchy diagram as given in the Table 10 of Preliminary Proposal

Table 10: Recommendations for Waste Reduction in Composite Film Line.

	Improvement Area 1: Quality Improvement (JIT &TPS)
A	*Discard few vendors* who are not willing to develop partnerships for delivering the small lots directly on workplace and *encourage the vendors* to locate nearby and deliver frequent shipments in order to make sure the throughput of film is continuous.
B	*Develop the environment of poka-yoke* for quality inspection by the production workforce before the official inspection from the quality assurance officer. This technique helps to improve the quality of film in terms of having required mechanical and optical properties during manufacturing.
C	*Arrange the training sessions with Mitsubishi Heavy Industries (MHI)* to enhance the abilities of workforce of production to handle the trouble shootings in the film line. If the training with MHI in Japan cannot be implemented for all the production staff due to high travelling expense, then arrange online sessions would be great option in order to achieve the target.
	Improvement Area 2: Small breaks Reduction (SMED)
A	*Differentiate the external setups to the internal setups*. The internal setups are the activities needed to be performed during stoppage of production line and external setups are the activities needed to be performed during the operations of film line.
B	*Separate the internal elements into external elements* in order to reduce the downtime of small breaks during the operation of machines. The separation of elements could be done by analysing the importance of operations related to the tenter frame or in the main filter in main extrusion line to eliminate or reduce the internal setup elements.
C	*Convert as many internal elements into external elements*. The purpose of this step is to analyze whether the required activities can be done during operations which results in reduction the downtime of small breaks.

D	*Streamline the internal elements* to use alternative ways to reduce downtime such as walking, gathering tools at one place etc.
E	*Streamline the external elements* in order to reduce the time to complete the external activities which does not improve overall equipment efficiency but the free operators for other activities.
Improvement Area 3: Preventive Maintenance Scheduling	
A	*Implement preventive maintenance* in the production plant to improve the availability of machines as preventive maintenance is result oriented in terms of running the film line with continuous throughput.
B	*Schedule the preventive maintenance* (PM) on regular interval of time to avoid the interruptions of failure of important component. The main filter in the extrusion line needs to have maintenance on regular basis to operate and several components in the whole film line to operate in a perfect condition.
Improvement Area 4: Lean 5 S's tools	
A	*Introduce the concept of lean 5S's* in the production department to eliminate the waste and raise the standard of work in the production premises. These 5S's are included sorting the unnecessary items from the production area, then generate the tools in setting to make sure to get access the tools when needed. The sweep clean is also the key factor to keep everything in top condition, then standardize the normal condition and sustain the root causes of the production issues.

Table 10 illustrates the preliminary proposal built for the case the company to eliminate the waste of polymeric materials during the manufacturing of composite film line of BOPP. The preliminary proposal is divided into four improvement areas to implement in each of the section of the production line, so that most of the problems could be resolved in a structured manner in the film production line.

In the first improvement area, JIT and TPS techniques are described to increase the quality of produced film and increase the throughput of the film. In JIT technique, quality improvement and throughput is the major part to discuss and this can be achieved by sorting some suppliers who are not willing to develop the mutual relationship with buyers and encourage the interested vendors who are willing to develop better relationship in terms of locating nearby the workplace, delivering small lots as per requirement. The arrangement of training session with the Principal (MHI) to enhance the capabilities of the employees.

The second improvement area is included a technique called single minute exchange of dies by which, small breaks in the manufacturing film line can be reduced by differentiating the internal and external elements. The external setup elements are the activities which are to be performed during operations of the production line and internal setup elements are those which are performed only when plant is in shutdown condition. In this way, external setup elements are the essential elements to be focused, so that downtime could be reduced when any required operation can be performed without disturbing the production.

The third improvement are in the preliminary proposal is the preventive maintenance. The preventive maintenance is the major element in the production line as the proper scheduling of maintenance avoid severe damages of the production line. Preventive maintenance is preferable rather than corrective maintenance as it prevents the several components of film line and enhances the overall operating efficiency of the plant to run and produce continuous throughput and quality assured product which as a result waste eliminates.

The fourth improvement area included in the preliminary proposal is the implementation of lean 5S practice in the production premises. This practice is used to eliminate the scrap the waste by setting in order the required tools used in the production line. In this practice, unnecessary tools should be removed and tagging each tool to make it accessible at the time of use. In this way, scrap waste is eliminated from the production unit by implementing this technique.

5.5 Implementation of Recommendations on Production Line

Figure 11 describes the improvement areas of BOPP film line with the practical implications of improvements area as shown in Table 8 of preliminary proposal and the description of the changes will take place in the production film line with respect to the recommendations in the preliminary proposal and Figure 11 shows the relevant units in the BOPP film line with each of the improvement areas as discussed in the preliminary proposal that will act as a roadmap for the management of the company in order to reduce or eliminate the waste of polymeric material and raise the profitability with production.

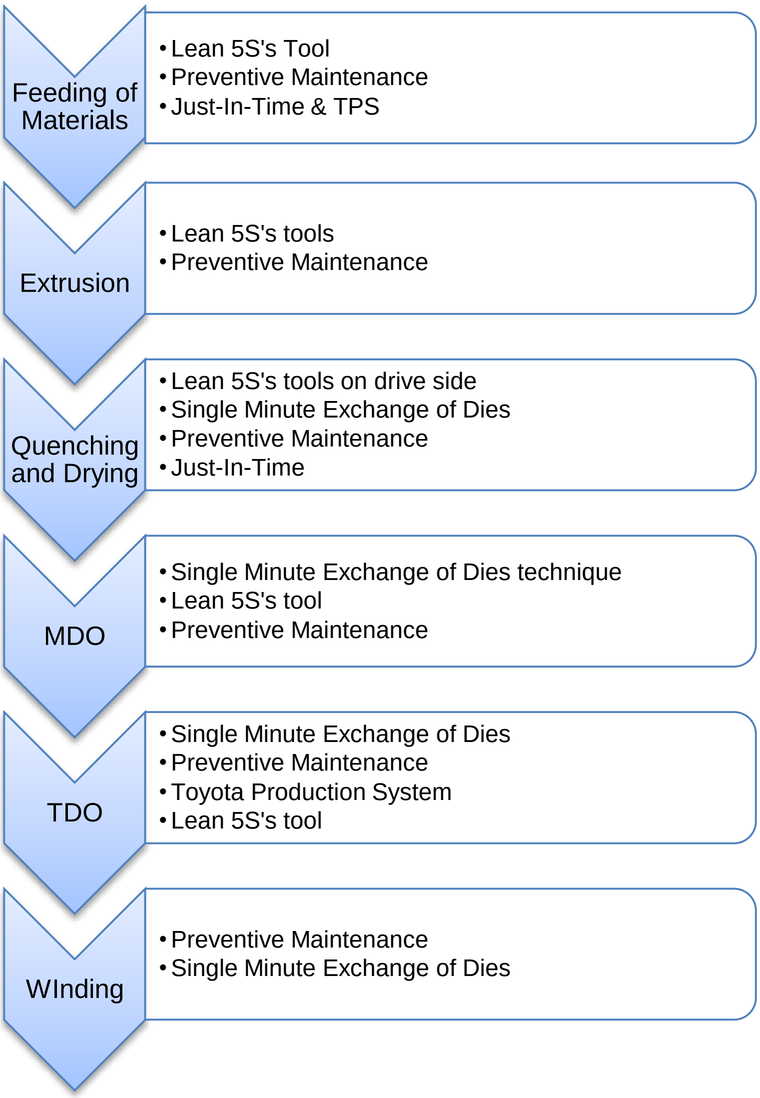


Figure 11. Implementation of recommendations on film line.

In the BOPP film line, several units combine to produce the quality assured product starting from the feeding of material and ends to the winding of the film in the winding up section in the line. In order to increase the throughput of the product and quality improvement, Just-In-Time technique applies in the feeding section of the production line to ensure the supply the required raw material from the vendor on the right place from where feeding starts for the line. The customer-suppliers partnership shows the delivery of lot sizes, delivery of the material on time and passed several quality standards. The workforce requires continuous training, respect for the workforce and trust the, and attain the standard work practices for the feeding and calculation for all other kinds of materials like copolymer and other anti-static agent depends on the thickness and other mechanical and optical properties that are required to have.

The technique called single minute exchange of dies (SMED) are applicable on the units of production line where quick changeover is required. The quenching process, machine and transverse direction orientation units are the most core units for this technique to be applied. Since in the orientation units, breaking of film takes place and quick changeover required in order to get back the production line into continuous production. Therefore, the orientations sections of the line are most important clients for this technique.

Preventive maintenance is required on almost all parts of the production line and it starts from the main filter on the extrusion line in which molten extruded material allows to pass and generates the inlet and outlet pressure. In order to make sure the pressure difference in the filter, preventive maintenance is required. The PM is necessary on other sections like MDO, TDO particularly, in the tenter frame where clips to clamp the film and act as a carrier up to the exit of transverse direction orientation.

The lean 5S's technique is applicable in every section of the plant as it is required to use tools for the maintenance or other purposes in the line. The company has allocated a specific place for the placement of tools and arrangement on the drive side of the film line. The 5S practice applicable on the drive side of the line where proper tagging, arrangement of tools required for the plant operation, sweeping the area and sustain, so that every employee who is relevant to the production may use the tools in a proper way. Next section describes the validation of the provisional proposal from the main stakeholder and the discussion with the main stakeholder lead to the final proposal for case the company particularly for the waste elimination of the polymer material during the manufacturing of composite film line.

6 Validation of the Preliminary Proposal

This section describes the validation of the proposal for waste elimination in the composite film line manufacturing process for the case the company. This section of the thesis illustrates how feedback round was organized, contents of the feedback and additional plan suggested by the management. This discussion lead the preliminary proposal to the final proposal contains the practical recommendations for the case the company.

6.1 Description of How Feedback Round was Organized

In order to get the feedback from the management of the case the company in regards with the preliminary proposal for waste elimination, a telephonic session was organized with the Manager Operations (MO) after a rent less effort. The discussion started with the brief introduction of preliminary proposal and its contents. The sections of the proposal was discussed separately and obtained feedback and comments on each section of validation view point. The discussion on each section of the provisional proposal with the respondent discussed below.

6.2 Feedback by the Management

The provisional proposal was presented to the respondent 'G' and shared the contents. As the whole study had already sent via electronically to the respondent G for detailed analysis. The Manager Operations appreciated my work for the case the company in terms of elimination of waste of polymeric materials and commented on the first section of proposal, related to Quality improvement of film.

The recommendation '1A' seems to be possible to implement immediately to develop suppliers-buyers relationship to improve throughput of the material in the film line. It must be make sure by the vendors to deliver the goods with zero defect and delivery on sit e to reduce the transportation problems. The recommendation '2A' appreciated by the respondent 'G' but this principle of JIT does not seem to be possible immediately as reduction in inventory space, having flexible machineries, small lot sizes by the vendors as most of vendors belong to Middle east and thus this recommendation is not able to implement immediately but the respondent G noted for near future

In the second section of the proposal in which reducing small breaks, which is critical issue of film production line by several issues. The SMED technique proposed to respondent G and he commented that differentiation and separation of internal and external setup elements are critical point in the film line as using this concept, the company save the shutdown cost during the internal elements and thus, this idea lead to the conversion of internal setup elements into external setup elements.

In the third section of the preliminary proposal in which implementation of preventive maintenance (PM) is proposed rather than Corrective maintenance. According to the Respondent G, it is better to take care of each component in film line instead of failure of that component which results increase the downtime, loss of material and part repairing etc. The scheduling of the preventive maintenance for the plant is possible and necessary to implement on immediate basis on the film line. Even though the case the company schedules the routine maintenance and the maintenance on immediate basis at the time of failure or any other trouble shooting in the production line but the preventive maintenance is far better than the corrective maintenance in terms of costing, delaying or applying different theories.

According to Respondent G, the lean 5S's practice, this practice is ready to implement on immediate basis and it would help to find the necessary tool required to complete the task of production regarding maintenance or some other purpose. The drive side of the plant is designed for this purpose only and it would be applicable at once by passing through information in the production department by using the electronic mail system.

Furthermore, the respondent G suggested to show some methods or technique to utilize the wasted product which would be beneficial and of course, profitable for the case the company. The technique to convert the wasted polymeric materials into transport fuel is presented to the Manager Operations which would also be appreciated and promised to keep in mind for near future. This technique is being discussed in Section 7.2 where next plans to be implemented is being discussed.

Therefore, the preliminary proposal needs to be modified by keeping in mind the suggestions and recommendations by the internal stakeholders of the case the company in the next part of this section.

6.3 Waste Reduction Plan for Film Line

Table 10 illustrates the details of the final proposal based on the theme discussions with the internal stakeholders in the company and Manager Operations of the whole plant and responsible for each recipe and core decisions regarding production of film line.

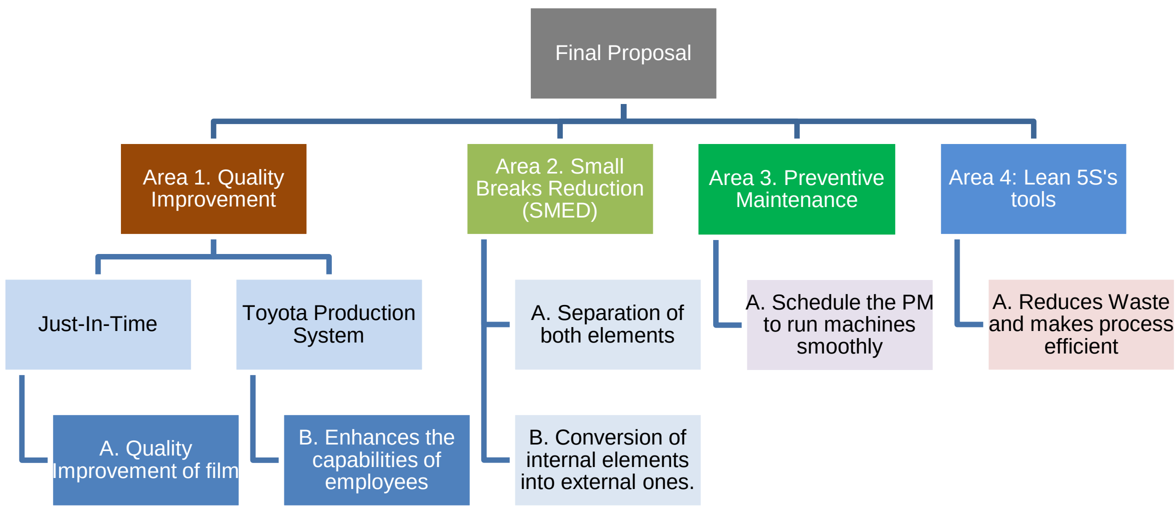


Figure 12. Waste reduction plan for composite film line (Final proposal).

In Figure 13, a plan for waste elimination for the composite film line is built after having deep analysis with the internal feedback of the stakeholder of the case the company and then the preliminary Proposal is refined. By going through the Preliminary Proposal, some changes have to be made in order to be a Practical Proposal which consists of recommendations to achieve the target. The details of the elements included in the Final Proposal are given in Table 11 below:

Table 11. Recommendations for waste reduction in composite film line

	Improvement Area 1: Quality Improvement (JIT &TPS)
A	*Develop the environment of poka-yoke* for quality control by the production personnel to avoid the rejection from quality assurance officer at the time of inspection. This technique helps to improve the quality of film in regards with the required properties of the film.
B	*Arrange the training sessions with Mitsubishi Heavy Industries (MHI)* to enhance the capabilities of workforce of production to handle the trouble shootings in the film line. To avoid the cost of travelling in Japan, it is obvious to arrange the online training sessions via online. In this way, continuous throughput of the film enhances by employees abilities.
	Improvement Area 2: Small breaks Reduction (SMED)
A	*Separate the internal elements into external elements* in order to eliminate the downtime of small breaks during the operation of machines. The separation of elements is done by making the focus on the importance of operations such as tenter frame in TDO or the filter in main extrusion line to reduce the internal setup elements.
B	*Convert as many internal elements into external elements*. The purpose of this step is to convert the internal activities into external activities to avoid the reduce downtime of small breaks.
	Improvement Area 3: Preventive Maintenance Scheduling
A	*Schedule the preventive maintenance* (PM) on regular span of time to avoid the interruptions of failure of major components. The main filter in the extrusion line needs to have maintenance on regular basis to operate and several components in the whole film line to operate in a perfect condition. This step is essential to make sure to run the machines of the production line in a continuous manner without stoppage which as a result waste elimination occurs.
	Improvement Area 4: Lean 5 S's tools
A	*Introduce the concept of lean 5S's* in the production department to eliminate the waste and raise the standard of work in the production premises. These 5S's

	are included sorting the unnecessary items from the production area, then generate the tools in setting to make sure to get access the tools when needed. The sweep clean is also the key factor to keep everything in top condition, then standardize the normal condition and sustain the root causes of the production issues.

Table 11 illustrates the preliminary proposal built for the case the company to eliminate the waste of polymeric materials during the manufacturing of composite film line of BOPP. In the first improvement area in the Final proposal, develop the environment of poka-yoke in the production to avoid any issue of quality, which could lead to the rejection of product and increase waste. Since case company has a joint venture with a Japanese trading company called Mitsubishi Heavy Industries and thus, capabilities of employees may enhance by arranging the training sessions with MHI.

The second improvement area in which single minute exchange of dies introduced to reduce the small breaks in the manufacturing line. This SMED technique is appropriate for quick changeover at the time of breaking of film in BOPP plant. This could be done by focusing on the external setup elements rather than internal setup elements as the external elements are those activities that could performed during operations of production which in turn the reduction of downtime and ultimately, the reduction of waste takes place.

The third improvement area is the preventive maintenance which is also an essential task in the production industry to operate the plant smoothly. The proper scheduling of preventive maintenance is the key factor to prevent the component from failure. By implementing this scheduling technique in production line, a continuous throughput of the product and quality assured product obtained which as a result, waste eliminates in the production line.

The fourth improvement area in the Final proposal is the implementation of lean 5S practice in the production film line in order to eliminate the scrap waste. This could be done by setting the tools in a proper order on the specific place in the drive side of the BOPP film line. The proper tagging on each tool helps to make it easy access at the required time and make them in a shining condition to long run. The expertise of employees to use those tools are also essential to make the process smooth. This practice is particularly used to eliminate the waste in the production premises.

Next section discusses the discussions and conclusions about this thesis that includes summary of the thesis as a whole and the evaluation of the paper, investigates the comparison between outcome and objective. Lastly, the validity and reliability measures the thesis in practical view point.

7 Discussion and Conclusions

This section overviews the results of the study. In this section, implementation of immediate next steps of the plan discussed. It presents the evaluation of the thesis in terms of outcome and validity and reliability as well.

7.1 Summary

The purpose of the study was to make reduction of the manufacturing waste of composite film line in Bi-axially oriented polypropylene (BOPP). The need of this study arose after analysing the huge proportion of waste which was on an unacceptable level by the company. There were several reasons of the waste generation found during the research of the thesis.

The waste reduction in the manufacturing without the changes in the production line often challenging tasks due to not possible several major amendments in the line. This study tells the ways how to reduce the scrap waste during the manufacturing process by using the different techniques and tools of lean philosophy. In lean manufacturing technique, different tools had been used in order to reduce the small stops in the production line, improvement in throughput by Toyota Production System (TPS) and Just-In-Time (JIT) technique and lean 5S's, and implementing the preventive maintenance rather than the corrective maintenance.

The study completed in several rounds of data collection. The first round of data collection was the current state analysis of the company in regards with the production process and found the different reasons and sources. As the case the company is a manufacturing company, the quality of the produced goods and improvement of throughput and reduce the small breaks during the manufacturing of film plays an important role to reduce the waste. The small breaks of the production line mainly depends on the non-regular maintenance of the plant. If the scheduling of the maintenance is not a proper planned, failure of the components may occur which leads to the small breaks of the plant, and thus generation of waste (scrap) happens.

Based on the literature review, a conceptual framework was developed by analysing the ideas related to scheduling of maintenance, different tools of

Just-In-Time, Toyota Production System to make the throughput continuous of the processed material in the former part of the plant. It specially described the lean 5 S's tool to eliminate the waste of the manufactured or processed material of polypropylene (PP). A technique was introduced during the literature study to reduce the small breaks during the production line which is called single minute exchange of dies (SMED). This technique contains the five principles to implement and reduce the small stoppages during the manufacturing film line. The scheduling of maintenance found a major reason for failures the core components of film line. The case the company focuses the corrective maintenance which is costly, not much effective and less result oriented. The implementation of preventive maintenance introduced during the research which is cost effective in a way that machines are available at any time, efficient and result oriented.

Based on the conceptual framework, the feedback of the stakeholders of the company and the researcher's experiences, a preliminary proposal was built for the case the company to make the waste reduction. Then the preliminary proposal was presented to the higher management in order to build the final proposal and some changes had to make in the preliminary proposal to implement on immediate basis in the company to get the desired results.

Thus, the proposed scheduling and maintenance proposal contains the necessary additions. It helps to understand the needs of the manufacturing process in the case the company and stakeholders of the department. The presented proposal helps to locate the challenges in terms of producing the scrap waste of material and align those in certain tasks.

7.2 Managerial Implications

It is necessary to assign the respected activities and tasks to the dedicated and responsible persons from the managerial team in order to implement in an effective manner. Therefore, the managerial implications towards the improved process of film line of the case the company are given in Table 10 below:

In order to apply the tasks mentioned in the Final Proposal, the top management have to set the roles and responsibilities for the application of the recommendations to achieve the goal in terms of quality improvement, reducing the small breaks, and scheduling the preventive maintenance. The following roles and responsibilities for the responsible workforce are given in Table 12.

Table 12. Roles and responsibilities.

Improvement Area 1: Quality Improvement (JIT and TPS)	
Action Points of Final Proposal: **A, B**	Responsible: **Plant Manager and Managing Director**
Improvement Area 2: Small breaks Reduction (SMED)	
Action Points of Final Proposal: **A, B**	Responsible: **Line Manager**
Improvement Area 3: Preventive Maintenance Scheduling	
Action Points of Final Proposal: **A**	Responsible: **Line and Plant Manager**
Improvement Area 4: Lean 5S's tools	
Action Points of Final Proposal: **A**	Responsible: **Line Manager**

Table 12 summarizes the roles and responsibilities of the relevant managers to implement the actions points showed in the final proposal by the managerial team. Since the suggested recommendations are not only one time solution rather it is continuous effort and this is the main point that managerial team has to take into account to obtain the excellent results in terms of waste reduction, quality improvement and throughput of the process.

7.3 Evaluation

This part of the section analyses the evaluation of the thesis in term of outcome vs objective and validity and reliability point of view that how much is the study reliable and valid.

7.3.1 Outcome vs Objective

The objective of the thesis was to reduce the manufacturing waste (scrap) improved process in terms of the quality and reduction of small breaks during manufacturing of composite film line. The outcome of the thesis was set to develop the set of recommendations for reduction the scrap waste, reduce the small breaks and scheduling the preventive maintenance. Based on the interviews from the stakeholders of the company, the proposed roadmap for the improved process for the reduction of waste and small breaks of the process could achieve very well.

7.3.2 Validity and Reliability

To secure the validity, the outcome of this study met the objective, which was a plan to reduce waste. One of the challenges identified in the current state analysis was approached in the systematic manner and a solution was built in a grounded manner. The theme interviews were built on the basis of best practice from the literature, researcher's experience for several years and discussions with stakeholders of the company. The proposal was then presented to the management to re-assure the relevance to the case the company.

The reliability was ensured by using the different databases to gather the reliable articles and journals during the study. The existence material of the company was examined in order to better understand the sources of the waste in the manufacturing plant of film line. Only well-grounded and well-established references were used to make the study more reliable. The outcome of the study then presented to stakeholders of the company to obtain the feedback and validation.

There were certain limitation of the study during this research. Firstly, all the stakeholders were from the same the company and from the same department. Secondly, the researcher could not get the views of the customers of the film from the case the company in terms of quality improvement and well graded film due to insufficient period of time and this is because of the location of case the company in another region of world. This task may provide an opportunity to another researcher to develop the research in terms of the customers' feedback of the product. Since the case the company is located in another region of the world, so the appointment for conducting the interviews with the stakeholders was a challenging job and hence contacting the higher management to present my work was also challenging as well. Hence, these issues had to be faced to complete the research but it at the end, it generated the required outcome.

7.4 Further Development

During the theme interviews and getting the feedback from the stakeholders of the company and the researcher's experience during his working in the case company, a need arose to utilise the wasted material into some useful product for the company rather than the mechanical recycling of the material into the pallets. There is a method to utilise the wasted material into transport fuel by applying a small setup.

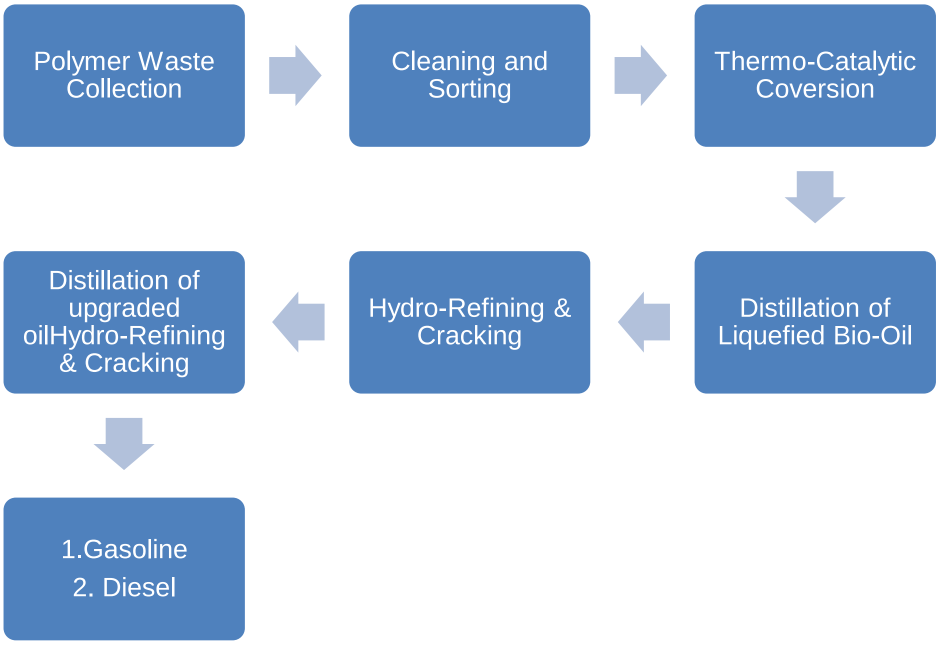


Figure 13. Thermo-catalytic process of waste plastic into fuel (Hazrat, et al., 2014).

The single stage high temperature pyrolysis method is used to convert transport fuel from the wasted polymer. The process used for this technique is thermos-catalytic cracking in which high density polyethylene (PE) and polypropylene (PP) wastes could be transformed into gasoline and light oil by thermos-catalytic cracking process. Moreover, Mani and Nagarajan converted the plastic waste into hydrocarbon fuel and piloted in diesel engines. Furthermore, many steps are required to reduce emissions and to increase the thermal efficiency of the diesel engines. The quality of oil produced by wasted plastic is found as better than the wasted tyre pyrolysis.

References

Aswathappa, K. and Shridharabhat, K., 2010. *Production and Operations Management.* Delhi: Himalaya Publishing House.

Abdullah, F., 2003. *Lean Manufacturing Tools and Techniques in Process Industries with a Focus on steel,* Pittsburgh: s.n.

Antero , O., 1999. Maintenance has Role is Quality. *The TQM Magazine,* 11(1).

Anwar, H., 2015. *Shift Engineer,* Dammam: Personal Communication on Skype.

Avinash, P. and Rakesh, J., 2015. Lean Implementation in Indian Process Industries. *Jouranal of Manufacturing Technology Management,* Volume 26, pp. 131-160.

Benjamin, s. and Murugaiah, U., 2012. The use of SMED to Eliminate the Small Stops in a Manufacturing Firm. *Emarald,* p. 17.

Bicheno, J., 2008. The Lean Toolbox for Service Systems. *Production and Inventory Control,Systems and Industrial Engineering Books.*

Boonchai, N., Supawan, T. and Kritapas, L., 2014. Practical Approach in Surface Modification of BOPP Films for Gravure Printability. In: *Applied surface science.* s.l.:ScienceDirect.

Cassady, C. R. and Erhan, K., 2005. Integrating Preventive Maintenance Planning and Production Scheduling for a single Machine. *IEEE transactions on reliability,* Volume 54.

Conner, G., 2001. Lean Manufacturing for Small Shop. *Society of Manufacturing Engineer.*

Cox, A. and Chicksand , D., 2003. The Limits of Lean Management Thinking: Multiple Retailers and Food and Farming Supply Chains. *European Management Journal,* 23(6), pp. 648-662.

Evgeny , M. and Tomohiro , M., 2012. Simulation Based Plant Maintenance Planning with Multiple Maintenance Policy and Evaluation of Production Process Dependability. *Proceedings of the International Multiconference of Engineers and Computer Scientists,* Volume II.

F.Fricke, C., 2010. *Lean Management: Awareness, Implementation Status, and need for Implementation Support in Virginia's Wood Industry,* Blacksburg: s.n.

Fumagalli, M. M., 2013. A Maintenance Maturity Assesment Method for the Manufacturing Industry. *Journal of Quality in Maintenance Engineerin,* 19(3).

Gabriella , B., Rommert , D. and Robin , P. N., 2006. A Review of Planning Models for Maintenance and Production. *Econometric Institute Report.*

Hani, S., 2014. Continuous Improvement of Maintenance Process for the Cement Industry. *Journal of Quality in Maintenance Engineering,* 20(4).

Hazrat, A. et al., 2014. Utilization of Polymer Wastes as Transport Fuel Resources- a Recent Development. *Energy Procedia,* Volume 61, pp. 1681-1685.

Heizer, J. and Render, B., 2011. *Operations Management.* New Jersey: Patience Hall.

Hodge, G., Goforth, K., Joines, J. and Thoney, K., 2011. Adapting Lean Manufacturing Principles to the Textile Industry. *Production Planning and Control,* 22(3), pp. 237-247.

Hokama, R., Khan , M. and Hussain, K., 2008. Investigation into the Implementation Stages of Manufacturing and Quality Techniques and Philosophies within the Libyan Cement Industry. *Journal of Manufacturing Technology Management,* 19(7), pp. 893-907.

Ho, S., 1996. Japanese 5-S practice. *The TQM Magazine,* 8(1).

Hossein, F., Mustapha, N. and Michel, G., 2014. Profit Maximization by Integrating Production Planning,Maintenance Schedule, Quality aspects and Sales decisions.

Hunter, S. L., 2003. The 10 steps to Lean Production. *FDM Management.*

Kamakura, Y., 2006. Corporate Structural Change and Social Dialogue in the Chemical Industry. *International Labour Organization Publication.*

Liker, J., 2004. The Toyota Way. *McGraw Hill.*

Lyons , A., Vidamour, K., Jain, R. and Sutherland, M., 2013. Developing an Understanding of Lean Thinking in Process Industries. *Production Planning and Control,* 24(6).

Mann, D., 2005. Creating A Lean Culture. *CRC Press.*

Melton, T., 2005. The Benefits of Lean Manufacturing: What Lean Thinking has to offer the Process Industries. *Chemical Engineering Research & Design,* 83(A6).

Michels, B., 2007. Application of Shingo's Single Minute Exchange of Dies (SMED) methodology to punch press changeover. *American Psychological Association.*

Moxham, C. and Greatbanks, R., 2001. Prerequisites for the Implementation of SMED Methodolgy. *The Internaltional Journal of Quality and reliability Managament,* 18(4), pp. 404-414.

O'Eocha, M., 2000. Use of 5Ss for Environmental Management at Cookie Brothers. *The TQM Maagazine,* 12(5), pp. 321-330.

Phillip , M., Joshua , B. and Jeff , C., 2011. Problem Solving for Managers: a Mathematical Investigation of Toyota's 8-step Process. *Journal of Manufacturing Technology Management,* 22(7), pp. 837-852.

Richa , C., Kumar Gaur, D. M. and Rohit , T., 2013. Implementing a Preventive Maintenance Planning Model on an Ageing Deteriorating Production System. *HCTL Open Int. J. of Technology Innovations and Research.*

Shah, R. and Ward, P., 2003. “Lean Manufacturing: Context, Practices Bundles, and Performance. *Journal of Operations Management,* 21(2), pp. 129-149.

Shingo, S., 1985. A Revolution in Manufacturing: The SMED System. *Cambridge,Massachusetts: Productivity Press.*

Stephen , J. W. and Graeme, K., 2004. An Investigation into Japanese 5-S practice in UK Industry. *The TQM Magazine,* 16(5), pp. 347-353.

Trovinger, S. and Bohn, R., 2005. Setup Time Reduction for Electronics Assembly: Combining Simple (SMED) and IT based methods. *Productions and Operations Management,* 14(2), pp. 205-217.

Wang, H., 2002. A Survey of Maintenance Policies of Deteriorating Systems,. *European Journal of Operational Research.*

Waseem, I., 2015. *Production Line Manager,* Karachi: Tri-Pack Films Limited.

Zanoni, S. and Zavanella, L., 2005. Model and Analysis of Integrated Production-Inventory System: the Case of Steel Production. *International Journal od Production Economics,* Volume 93/94, pp. 197-205.

Appendix 1

Description of Current BOPP Process

This appendix introduces full description of BOPP process comprises the following steps to obtain the bi-axially oriented Polypropylene film. i.e., feeding, extrusion, quenching, MDO, TDO, trimming, corona treatment, winding up.

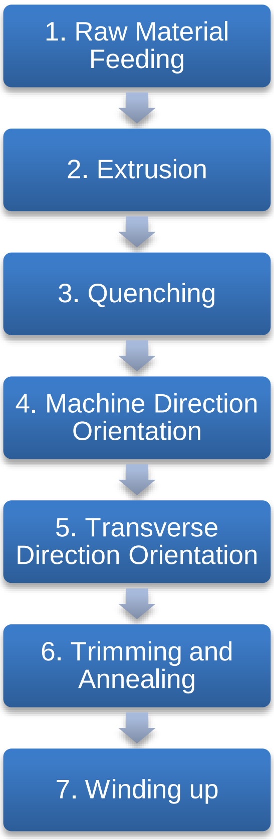


Figure 2. Current BOPP process

Step 1: Feed Materials

Poly propylene homopolymer (PP) is used in BOPP film line to manufacture any type of film as a core material. This material is used in the form of pallets / grains which is filled in silos and later it moves to the main hoppers of the extruders. The film manufactured by BOPP film line is a three layered film in which PP material is used as a core component while the upper and bottom layer is made up by a copolymer of poly propylene.

Copolymers of propylene in the film provide increased toughness at the cost of tensile strength. Random copolymers represent the major changes like increased elasticity and decreased melting point. Copolymers having different structures like a block, in which ethylene is distributed in some of molecules, gives the good compromising properties between strength and toughness. Antistatic agent is used to avoid the static charges in the final product which in turns to the shrinkage of film.

Step 2: Extrusion Process

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed or pulled through a die of the desired cross-section. The apparatus used for this process is called extruders. The polypropylene feed material is extruded through conventional extrusion process at a temperature of softening point. There are three extruders used for this process in order to manufacture three layered PP sheet. The main extruder which is used to process homopolymer PP contains the huge capacity and the remaining two extruders which are being used to process the copolymer of polypropylene are caller satellite extruders 1 and 2. The extrusion process is carried out at 230 to 250^{o}C in the extruders and the same temperature in the die lips under the pressure of 1000 to 1500 pounds per square inch.

There is a main filter between extruders and die whose inlet and outlet pressure is quite necessary parameter in regards with the wastage of plastic sheet at the next section of plant call MDO or TDO. The major difference between inlet and outlet pressure of filter is the main reason for wastage of polymeric manufactured sheet. The difference increases between inlet and outlet pressure of the main filter is due to not having the proper maintenance and improper additives of homopolymer and copolymer of polypropylene.

Usually, the difference between the inlet and outlet pressure of molten material is 25 to 30 bar which is the ideal ratio to run the plant smooth. As the pressure difference increases, the flow of material from the main filter is not continuous due to which operations of the film line plant is unable to run smooth and the breaking of sheet takes place at the exit point of TDO section, where transverse direction stretching is to be happened which in turns the wastage of plastic sheet, which must be controlled and this is the core issue of the thesis. The extrusion process with all the heating zones and main filter is shown in Figure:

Figure deleted

Bi-axially oriented polypropylene describes for the ease of operations as operation side and drive side. The side where all the operating panels and the devices required for the complete operation of the plant is called operation side (OS) and this side usually used by the personnel to operate. The side where water control system, valves, pumps and the heaters installed for the driving process of BOPP, called drive side (DS).

Step 3: Quenching and Drying

In materials science, quenching is the process where rapid cooling of material takes place to obtain certain properties and phase transformations. The extruded polypropylene is then quenched by passing through water and the distance between die lips and water is being maintained to about 2.0 inches. If the gap is less than the required distance, haziness in the product of polypropylene sheet is appeared as a result while the greater gap of 2.0 inches fails to melt properly in the extrusion process line and ultimately, the chances of breaking the film during the machine direction section or transverse direction orientation increased and thus wastage of polypropylene film happens. If the melting of PP material is not sufficient, it is impossible to achieve a commercially accepted PP sheet at the end of whole process.

There are two air knives to stick the film on the chill roll to further process in the next section called Machine direction orientation and if there would be trouble shooting during the process in the next stages, then the chilled sheet does not allow to send to MDO section but in auxiliary winder as shown in figure 4. This sheet is still in the auxiliary winder until and unless the necessary parameters for the next sections will be fine. BOPP film line is synchronized with the speed of chilled roll in quenching process. Once there is changing in speed in the chilled roll, there is automatically changing speed in MDO and TDO and as a matter of fact, the speed depends on the production rate of the film at the winding. The purpose of this step is to draw the melt down over a sharp distance and cool quickly before thermal disorientation can take place.

Step 4: Machine Direction Orientation

The machine direction orientation or stretching is the section of the BOPP plant where extruded quenched PP sheet is stretched about 60% in the longitudinal direction by preheating up to the softening point. The extruded film is subjected to a first stretching operation where longitudinal direction orientation is achieved. The machine direction orientation process is carried out at the temperature range 92 to 150^{0}C and the stretching ratio 1.2:1 to 1.6:1 in the machine direction orientation.

In the MDO section, there are arrangement of slow and fast horizontally disposed, closely spaced, parallel driven. The rolls are maintained in the case company by circulating oil at the optimum temperature of about 92 to 150^{o}C. Other methods of heating these rolls and internal system may be employed like steam boiler and hot water. The film is being stretched in MDO in such a manner that there is combination of slow and fast rolls to control the film during the longitudinal stretching and to obtain the required degree of orientation without distorting the film and if the distortion of film happened inside the MDO, there is huge wastage of film as the whole plant from extrusion cannot stop and thus the manufacturing is taking place continuously form the previous sections.

Figure deleted

The temperature of polypropylene sheet varies at the stretching point in the range of 100 to 150^{o}C and the film rate is equal to the speed of the whole film line ranges from 150 to 350 rpm. The rate of the film production depends on the several major mechanical and optical properties at the desired level. The MDO section is as shown in the Figure from the case company.

Machine Direction Orientation.

In order to prepare the PP sheet in MDO section for the transverse orientation, the stretched film is usually preheated to about 105 to 150^oC. This preheating comprises by providing the conventional method like generating the preheating zone directly by the hot oil circulated rolls.

Step 5: Transverse Direction Orientation

This is the section of BOPP film line in which the lateral stretching of PP sheet takes place to obtain the desired width of the sheet. In this section of the BOPP film line, tenter frame apparatus is employed for transverse direction stretching. The entire length of tenter frame consists of the parallel chains with clamps for gripping and moving forward of polypropylene film through the transverse direction of the frame. The longitudinally stretched polypropylene sheet is clamped by the clips from both sides of the frame and moves in the transverse direction through the frame of TDO. The film is released at the end of the frame and the chains of the clamps return back to get the longitudinally extruded film. The transverse direction stretching section is divided into four zones include preheating zone, first stretching zone, second stretching zone and annealing zone.In the pre-heating zone, the film is heated by circulating the hot air ranging from 160 to 180^oC but no stretching takes place in this zone. The PP sheet attains its softening point for orientation in the coming first and second stretching zones.

Figure deleted

The clamped film is maintained at the temperatures of about 140 to 160^oC and high speed fans are employed for heating and the stretching of film takes place by clips of tenter frame about 8:1 ratio. The stretched film is then entered in the annealing zone where temperature is dropped to cool down the oriented film to further process.

Step 6: Annealing and Trimming

In the annealing step, the film is cooled down around 50ºC for stability and allows shrinkage of film but no stretching in this section. The longitudinal and transverse oriented film is the moved to the next process while the clamps at both OS and DS returns back at the starting point of tenter frame to engage with the longitudinal stretched film for transverse orientation.

During the process of transverse orientation, two types of breakage of film may happen. One is hot break which is happened from the middle section of the PP sheet at the outlet of TD. Second one is cold break which is responsible from the edges that are gripped by clamps of the tenter frame. The reason of hot break is increment of temperature parameters and this raising in temperature may occur due to several reasons and ultimately, the breakage of film during the process is happened and huge wastage of film / sheet is occurred as the film from longitudinal stretching section is producing.

Secondly, the film is collected in the edges of tenter frame in the cold breakage and this reason is vice versa as hot break. Wastage of PP sheet is generated in both cases and in order to control the waste, labour must have the expertise to adjust the critical temperatures in TDO to avoid the breakage of film.

Step 7: Corona Treatment and Winding

The capillary action is the process in which a liquid flows in the narrow spaces in the film without external gravity force. The longitudinal and laterally oriented film is then provided corona treatment to enhance the capillary properties either in one side or both sides, depends on the customers' requirement. In the corona section of the BOPP line, the high energy beta rays bombarded to the surface of PP sheet. The treatment is provided by electrodes with high energy of 2.4 KJ /m^2 to the film. The corona treatment is necessary for the manufacturing and to generate the adhesiveness for printability. After treating in this manner, the commercially accepted ink is applied to PP sheet.

Appendix 2: Questionnaires for data collection

Questionnaires for data collection (Data 1)

1) Please explain the current schedule for the changeover the components in BOPP film manufacturing line.
2) Could you please state the shear actions and efficiency of barrels of main extruders and satellite extruders as well in terms of heating viewpoints?
3) What is the current condition of main filter in the extrusion line and what is the time period to change the filter with the new one (Scheduling issues)?
4) What is the rate of failure components in each of the orientation units (Machine direction orientation and transverse direction orientation)?
5) What is the scheduling of maintenance in the BOPP composite film line manufacturing line?
6) What is the current rate of breaking films at the exit point of transverse direction of orientation and how much time does it take to get back to the quality controlled production?
7) Will you please explain the slackness in the film and other properties like shear strength, tensile strength, air bubble and other mechanical properties?

Questionnaires for data collection (Data 2)

1) Could you please give your opinions about the different lean tools used in the theoretical section in order to develop the preliminary plan for waste reduction in film line?
2) Which of the tools and techniques are most appropriate in the manufacturing process from the selected tools and techniques from the literature.
3) How to implement these changes in the production premises according to your point of views which would be suitable for the personnel as well.

Questionnaires for data collection (Data 3)

1) Will you please give me brief explanation about the preliminary proposal for the BOPP film line?