Optimizing an Off-set printing press through Overall Equipment Effectiveness (OEE) calculation

A dissertation submitted by

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ABSTRACT:

Printing equipment plays a vital role in determining the packaging industry's capabilities. Although quality, innovation and efficiency are considered as the important deliverables in fulfilling the market demands but these parameters are only achievable if printing equipment is optimized properly.

This work is intended to optimize printing equipment through **Overall equipment effectiveness (OEE).** Overall equipment effectiveness is an essential and effective tool used by the top performers. This tool streamlines the **availability**, **performance** and **quality** of production equipment, operation and product.

With an aid of time and motion study initial OEE was calculated and it came out to be **27.5%** which was very low while it is stated that world class standard is 85%. The root cause observed in this case was delay in set up time and unplanned down time. This would be controlled through **Single Minute Exchange of Die** (**SMED), Group Dependent Scheduling (GDS)** and **Planned Maintenance (PM)** implementation for the respective cases.

After implementation, the OEE value was again calculated and it was found that reducing the set up time and maintaining the machine weekly not only increased the OEE value to **56%** but also **streamlined** the machine performance. But it was found that with the continuous improvement strategy this value can further be increased.

The challenges faced by this work was not limited to the practical application but **cultural hindrances** and reluctance to change were also there that were dealt with **strategy of increasing the workers interest** through trainings, taking suggestions from each individual in order to increase their involvement and finally through distribution of incentives

CHAPTER 1: SYNOPSIS

1.1 ABOUT THE ORGANIZATION:

Merit packaging Ltd. (MPL) is a well reputed organization of Pakistan when taking printing and packaging into account. MPL, which is a Lakson Group of company, is functional since last three decades. Its major customers are Philip Morris, Tapal, Continental biscuits Ltd, Nestle, Unilever, Shan foods, National foods, Abbott, GSK, KOLSON, Reckit Benckiser etc. MPL owns two state of the art printing facilities which include the Off-set technique and the Gravure Technique. Since MPL is delivering a food grade product therefore its operations are carried under clean environment following the ISO certified procedures.

1.2 BACKGROUND:

This work was conducted in collaboration with Merit packaging limited. The organization has two kinds of printing facilities one is Gravure and other one is Off-set. In this study Off-set printing facility was taken under consideration. There were 5 machines in total in off-set department.

The first task was to select the most exigent machine of all. After certain analysis one machine was selected and studied with respect to its working principle, efficiency, function and shortcomings.

Current OEE was calculated and then it was planned to implement certain managerial tools that would help the machine to gain its efficiency and become more effective. This would assist the machine to increase the OEE value. The managerial tools used were SMED (Single minute exchange of die), GDS (Group Dependent Scheduling) and PM (periodic maintenance).

1.3 AIMS AND OBJECTIVES:

The research is based on practical implication. The overall exposure is equipped with real time practices. The aim of this research is to assist in developing an understanding about the

industrial practices in a packaging industry and to contemplate the hurdles that create barriers in meeting the everyday challenges and bring improvement in daily executions.

Below are the aims and objectives of this research.

- To understand the industrial practices in a packaging industry.
- To improvise OEE before and after streamlining the activities of the printing equipment through SMED, GDS and PM.
- To develop SOP and implement same in overall organization.

CHAPTER 2: THEORY

2.1 OVERALL EQUIPMENT EFFECTIVENESS:

Overall equipment effectiveness (OEE) is a hierarchy of metrics developed by Seiichi Nakajima in the 1960s to evaluate how effectively a manufacturing operation is utilized [1].

OEE (Overall Equipment Effectiveness) is the gold standard for measuring manufacturing productivity. [2] OEE measurement helps in identifying the underlying losses and improves the productivity of equipment. The OEE calculation incorporates the three important factors, that are as under;

a) Availability: Availability takes into account Unplanned and Planned Stops. An Availability score of 100% means the process is always running during Planned Production Time. Availability= Run time/ available time [2]
b) Performance: Performance takes into account Slow Cycles and Small Stops. A Performance score of 100% means when the process is running it is running as fast as possible. Performance= Real production/ Ideal Production [2]
c) Quality: Quality takes into account Defects (including parts that need Rework). A Quality score of 100% means there are no Defects (only Good Parts are being produced). Quality= Good Parts/ Real production [2]

The formula to calculate OEE is;

OEE= Availability x Performance x Quality [3]

The nature of this calculation makes achieving a high OEE score quite challenging. For example, if all three factors are 90%, the resultant OEE will only be 73%. The maximum a company can achieve an OEE is 85% this is the world class standard for any manufacturing company but Seiichi Nakajima who led the introduction of TPM, OEE and the Six Big Losses in the early 1970s states that many winning companies in Japan have exceeded the world class standard [3].

2.2 SINGLE MINUTE EXCHANGE OF DIE:

SMED was developed by Shigeo Shingo, a Japanese industrial engineer who was extraordinarily successful in helping companies dramatically reduce their changeover times. His pioneering work led to documented reductions in changeover times averaging 94% (e.g. from 90 minutes to less than 5 minutes) across a wide range of companies. SMED (Single-Minute Exchange of Dies) is a system for dramatically reducing the time it takes to complete equipment changeovers. The name Single-Minute Exchange of Dies comes from the goal of reducing changeover times to the "single" digits (i.e. less than 10 minutes). A successful SMED program gives the following benefits:

- Lower manufacturing cost (faster changeovers mean less equipment down time)
- Smaller lot sizes (faster changeovers enable more frequent product changes)
- Improved responsiveness to customer demand (smaller lot sizes enable more flexible scheduling)
- Lower inventory levels (smaller lot sizes result in lower inventory levels)
- Smoother startups (standardized changeover processes improve consistency and quality)

In SMED, changeovers are made up of steps that are termed "elements". There are two types of elements:

- Internal Elements (elements that must be completed while the equipment is stopped)
- External Elements (elements that can be completed while the equipment is running)

The SMED process focuses on making as many elements as possible external, and simplifying and streamlining all elements [4].

2.3 PLANNED MAINTENANCE:

Planned maintenance is documented and scheduled to be completed before a breakdown occurs. This is unlike unplanned maintenance. The process of planning the maintenance

makes the tasks more efficient and eliminates the effect of maintenance on the operations of the facility. Planned scheduled maintenance activities are planned with regard to the maintenance tasks and their timing. All of the triggers for scheduled maintenance are used as triggers for this type of maintenance. These are includes time, usage, event and condition based triggers.

Being planned, the resource requirements are known and can be made available in advance. Being scheduled, a time for the maintenance is also known. When this is combined with the resource planning, the resources can be pre-arranged so that they are ready to go as soon as the job can begin.

The maintenance may be scheduled with both short and long lead times. Some scheduled maintenance may be planned years in advance, as would be the case for a yearly maintenance schedule, such as one to replace air-conditioner filters every year before summer. Other scheduled maintenances may have shorter lead times. These may be as a result of usage based schedules.

For a maintenance technician, this style of maintenance is more efficient than unplanned maintenance because the task is known in advance. As a result, the parts and supplies can be ready to go and other equipment that might make the job site unsafe can be safely shut-down. Consequently, a planned maintenance task can get done faster with the equipment returning to production faster, too [5].

2.4 GROUP DEPENDENT SCHEDULING:

Group dependent scheduling works under the same principle as that of group technology and Yuri Maurgauz defines GT as unification of parts and pieces within groups [6]. When a job shop schedule is being elaborated it is necessary to be guided by some criteria either customer service criteria or production effectiveness criteria [6]. This experiment focuses on the production effective criteria as this criterion would help in reducing the set up time and

machine would perform effectively under the same working parameters for each group of products. The way groups have been formed would be discussed in chapter 7 section 7.2.

2.5 OFF-SET PRINTING PRESS:

Offset printing is a commonly used printing technique where an inked image is transferred (or "offset") from a plate to a rubber blanket, then to paper. The offset process is a lithographic process. Lithography is a process based on the repulsion of oil and water. An image that is offset printed is separated into its fundamental colors. The brochure would be broken down into the primary printing colors; cyan, magenta, yellow and black (CMYK). Thanks to computers this process has become easier. The image is broken down into these four colors and four separate plates are made.[7]

A plate is made up of areas that are receptive to grease and areas that are receptive to water. The areas receptive to grease hold onto the ink while the other areas attract water and repel the ink.
These plates are then put on to a press. From the ink fountains, the press pulls in the ink and puts it onto the plate. The press applies great pressure to the plate and the ink imprints the image from the plate onto a rubber blanket. The image is then pressed onto the paper off the blanket to make a print [7].

All this happens really fast and many impressions can be made from one set of plates. It is a very efficient process and lends itself very well to long runs over a long period of time. **Offset Printing is great for:** business cards, letterhead, catalogs, books/booklets, business forms, flyers, brochures, calendars, invitations and so much more [7].

The sample machine is a KOMORI Lithrone S 40 model its schematic illustration can be seen in Fig 2.1. It consists of 5 inking units with a separate water base coating unit and a drying unit. The board to be printed is fed through sucker and feeder in feeder unit while the printed boards are received in Delivery unit.

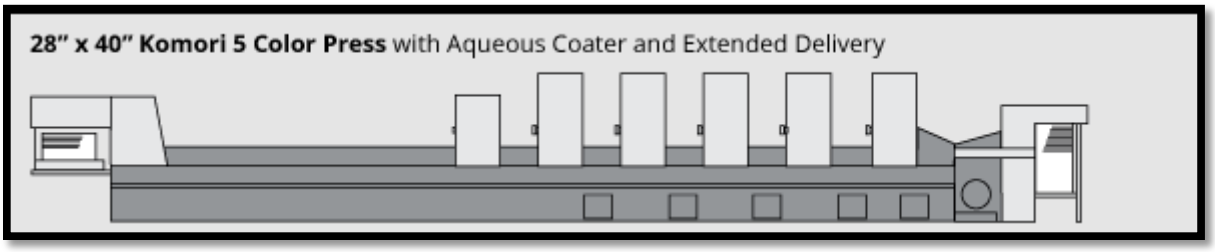


Fig 2.1: Off-set Printing unit machine layout [8]

The feeder is linked with in-feed section which slides down the board into the 1st inking unit through transfer roller. The in-feed consist of sensors that align the board and timely insert single sheet at a time any difference in time can let two sheets inside at a time that can cause damage to the rollers.

Each inking unit contains four cylinders its illustration can be seen in figure 2.2; one is plate roller over which printing plate is clamped, the second one is known as blanket roller on which rubber blanket is placed this roller carries the ink from printing plate and transfers it on the printing board, the third roller is impression roller that presses the board in between blanket to form the image on board and the fourth one is transfer roller that transfers the board from one unit to another.

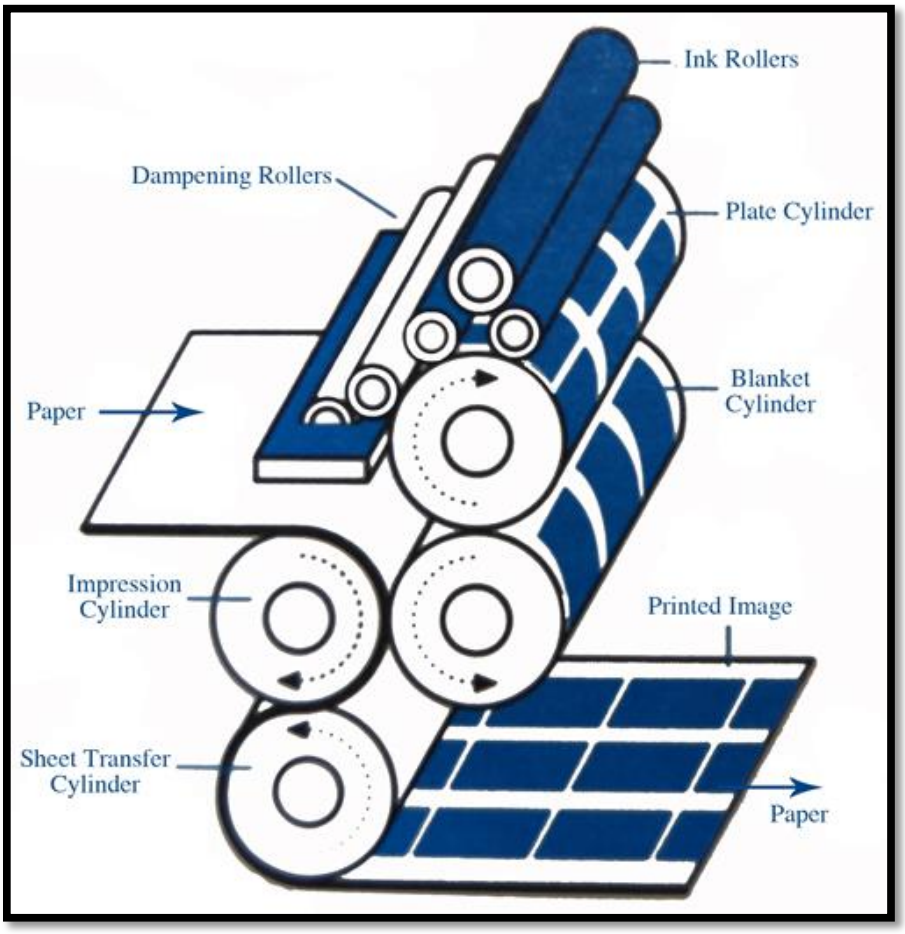


Fig 2.2: Schematic of cylinders and rollers arrangement inside the inking unit [9]

After the inking units, comes the water based coating unit which varnishes the board on customer's demand and a drying unit with UV curing lamp (shown in figure 2.3) and hot air/IR drying. Air blowers and short wave IR lamps assist in drying. The delivery unit, which is the end of the press, takes the paper from the printing unit and places it on the delivery pile.

Most modern sheet-fed presses today utilize the chain gripper system. With this type of system, the paper can be either pulled through the printing and delivery units by the same chain system or transferred from the paper grippers on the impression cylinder in the printing unit to a different set of grippers on the delivery chain. As the sheet leaves the printing unit, a set of mechanical fingers or grippers grabs the leading edge of the sheet and pulls it out of the printing system. The gripper bar is attached to a continuous chain that moves the printed sheet to paper pile, releases it, and moves the grippers back to receive another sheet. The chain

moves at the same rate and in synchronization with the feeder, registration, and printing units. [10]

Like the feed system, the delivery pile is automatically controlled for proper height. As sheets are stacked, the pile table automatically lowers itself to accommodate new sheets being added. Adjustments to the pile height can be made by the pressmen for different types of paper (board to light-weight paper). [10]

In the delivery section, most sheet-fed presses, today, have static eliminators, Infrared dryers, de-curlers and a starch powder system. Static eliminators are used to reduce any static the printed sheets may have or accumulated during the printing process. Infrared (IR) dryers Typical Press End With a Coater, IR Dryers, spray Powder system and the chain delivery are equipped on many presses today to help drive off the solvents in the ink. The IR dryers don't actually dry the ink but assist in removing the solvents in the ink allowing for the exposed varnishes to react quicker with oxygen. This results in quicker ink drying. IR dyers also are used to help quickly dry aqueous coatings that may be applied over the printed ink. Sheet-fed presses can also be equipped with Ultraviolet (UV) coaters. This type of coating usually is used to give excellent protection to the printed sheet as well develops high gloss. An example of this type of coating would be on a magazine glossy cover. The use of de-curlers is to reduce any curl the sheet may have which will hinder delivery or post press performance. The use of starch spray powder is done to help, on a microscopic level, separate the printed sheets so that air (oxygen) can reach the ink and begin setting and drying the ink. The heavier the paper weight, the larger the particle size of starch needed. Starch powders come in a variety of particle sizes [10]

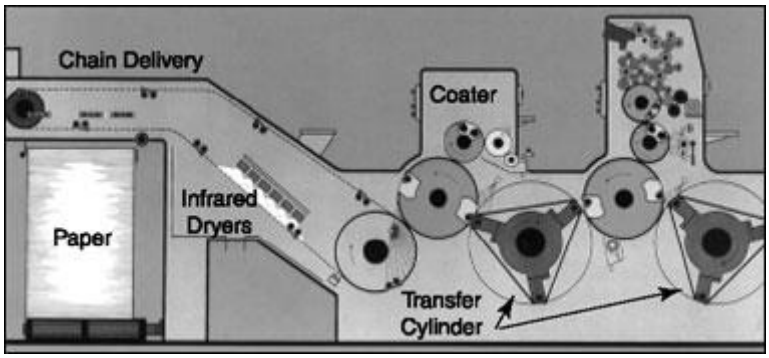


Fig 2.3: Cross-section of drying unit [10]

CHAPTER 3: LITERATURE REVIEW

When it comes to OEE implementation lots of work has already been done where OEE is taken as a metric to measure machine's/plant's effectiveness. Below is the table that summarizes few of the papers within this category. Majority of work consist of use of a Lean tool for example TPM, SMED, 5S. This work differs from the rest on the basis of industry type as there is no work conducted on an off-set printing press which itself is a complicated technology. Use of GDS distinguishes this work from others. Data compilation has taken lots of efforts as this task was completely manual and results were derived from the data after reconciliation from multidisciplinary departments (the data collected was reconciled from production planning and production data). Results have been derived from the real time data before and after implementation rather than any hypothetical approach unlike many papers that were based on some mathematical implication or some software based simulation.

Table 3.1: Summary of literature review

SR. NO.	TITLE	RESEARCH OVERVIEW	NOVELTY	IMPLICATION
1	Overall Equipment Effectiveness Improved by TPM and 5S Techniques in a CNC Machine Shop. [11]	Identification of bottlenecks, formation of TPM team, calculation of OEE before and after improvement. OEE was improved from 43% to 72%.	Incorporating the factor of cost in terms of measuring improvement.	Methodology is broken down into OEE parameters rather than focusing on TPM pillars.
2	Consideration of	Calculation of takt time in order to generate trade off	Incorporating customer	This study is applicable only on

	demand rate in Overall Equipment Effectiveness (OEE) on equipment with constant process time. [12]	b/w machine utilization and customer demand. This was achieved by bringing takt time closer to average cycle time. This study was carried out over the duration of 9 weeks and it was discovered that performance ratio can only be increased if takt time maintained exactly the same as average cycle time.	demand in calculation of OEE.	machines with constant cycle time.
3	Throughput-dependent periodic maintenance policies for general production units. [13]	The work deals with optimal maintenance policy for any production unit. For this purpose Markov decision model was generated which allows unit's throughput rate as a decision variable.	This research connects rate of deterioration of machine with its throughput.	The effect of increasing deterioration rate and increase of throughput on book value of machine should have been incorporated
4	Set up reduction in an interconnection axle manufacturing cell using	This work is about systematically reducing set up time and using OEE as an indicator of its effectiveness. The set up reduction plan helped in reducing stoppage percentage by 22% and thus availability factor was	Incorporation of versatility matrix.	There is a detailed implementation methodology of SMED but no details of OEE calculation.

	SMED. [14]	increased from 85% to 94%.		
5	Dynamic Group Job Shop Scheduling. [15]	Dynamic pareto optimal method for job shop scheduling. The design of software enabled automatic grouping of jobs along with similar work centers involved.	Trade off between customer service and production cost.	Analysis based on software rather than real time practice.
6	Evaluation of Total Productive Maintenance Implementation in a Selected Semi-Automated Manufacturing Industry. [16]	Evaluation of implementation of autonomous maintenance and planned maintenance pillars of TPM. OEE was calculated for the year before implementation and then OEE was again calculated after the implementation. OEE was improved from 22% to 24% approx. after a slight increase in availability factor.	Identification of problem areas through Pareto diagram.	Study based only on evaluation and comparison but no details of implementation. Also only one metric of OEE was improved i.e. the availability.
7	Evaluation of Overall Equipment Effectiven	Determination of OEE after removal of machine losses. It was found that OEE-MB was increased from .75 to .090.	Monitoring of production and equipment effectiveness through OEE-MB (market	OEE-MB should have been calculated over a longer period of time duration.

	ess based on market. [17]		based) in order to respond to the market.	
8	Total Productive Maintenance review and Overall Equipment Effectiveness Measurement. [18]	Implementation of TPM and measuring it through OEE calculation. It was found that OEE can be increased from 55% to 72% through TPM implementation.	Formation of multi-disciplinary team to manage the project.	No details of implementation methodology.
9	Maintenance: From Total Productive Maintenance to World Class Maintenance. [17]	After plenty of literature review the authors were able to timeline the retrospective growth of maintenance. It was a theoretical approach towards maintenance management.	The paper contains useful information about maintenance strategies that can be helpful for maintenance professionals.	Details are completely subjective.

10	Overall Equipment Effectiveness (OEE) calculation-Automation through hardware and software development. [19]	This work deals with development of hardware and software to calculate OEE instead of calculating it manually which is very hard in getting the accurate data.	Development of microcontrollers and press buttons that helped in noting down the time automatically without any assistance of stop watch. Micro controller could further be connected to system for transferring the data into report form	No test report was illustrated in the work.
11	An analysis of managerial factors affecting the Implementation and use of overall equipment effectiveness. [20]	The study includes surveys conducted on various firms through questionnaire in order to conclude the reasons of hurdles caused during OEE implementation.	Use of descriptive statistics and cross-tabulation, chi-square, analysis of variance, Tukey's pairwise comparison, Z-test and correlation tests.	Results may vary from industry to industry.

12	Evaluation of overall equipment effectiveness in the beverage industry: a case study. [21]	The study shows the analysis on failure and repair data in order to facilitate bottling production line by solving the critical points and increasing the productivity. Over the period of 8 months the actual availability, performance, quality and OEE were calculated and were compared with the ideal rates. Improvement suggestions were given w.r.t performance and quality at the end of the study.	Calculation of Performance Efficiency (PE) and Quality Rate (QR).	Only the initial OEE was calculated and no improvement plan was suggested.
13	Determination of Cost Resulting from Manufacturing Losses: An Investigation in White Durables	Determination of cost due to manufacturing losses and using OEE as a metric to calculate. Use of TPM to reduce losses and estimation of cost recovered. Total monthly cost was calculated and improvement suggestions were given but no further work was presented regarding implementation of improvement	Use of ABC (activity based costing) method.	Detailed and time consuming study to be implemented on the over-all factory.

	Industry. [22]	methodology neither any hypothetical calculation is made regarding reduction in cost due to losses.		

The papers that were studied are summarized above in tabular form. Since present work involves the improvement of OEE so the papers to be reviewed were selected on this basis. The papers that were studied involved the implementation or calculation of OEE. The tools used here in this work in order to improve the OEE included; SMED, PM and GDS therefore those papers were reviewed that involved the usage of any of the above tools to improve OEE.

CHAPTER 4: METHODS AND MATERIALS

The methods and materials have been categorized into three phases. The plan below (see figure 4.1) illustrates the transformation from AS-IS into TO-BE. The action plan has been written below for every phase.

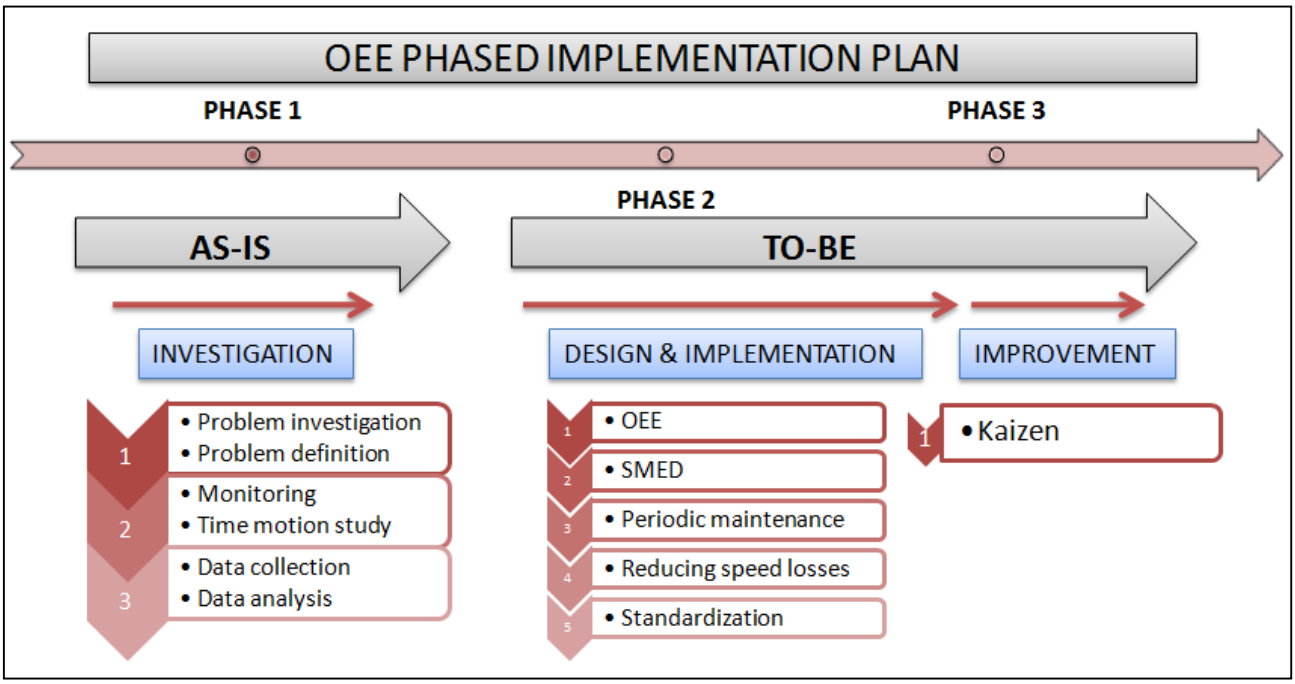


Fig 4.1: OEE Implementation Plan

4.1 PHASE 01: INVESTIGATION

The chosen industry offers Offset and Gravure printing technologies out of which Offset was examined as Gravure was under recovery stage from the fire incident that happened last year. Below is the process flow of Offset printing:

Fig 4.2: Stage wise process flow of off-set printing

Printing press is chosen for this study as 80% of product cost is incurred at printing stage and printing press itself is a vast setup to attain good learning prospective. Printing Press is a prime

operational resource of any printing and packaging firm. Therefore timely investments and improvement in process will produce a product with good quality at initial stage and thus will reduce the chances of failure in the succeeding stages.

The company has 5 printing units which serve different jobs and purpose the most critical of all is its printing press by the name of OP-18. Its selection has been done by analyzing the historical data;

a) WASTAGE QUANTITY: This analysis was carried out on seven months data. Each machine was compared on the amount of waste generated against its production quantity. It can be seen from figure 4.3 extracted from the table 4.1 that OP-18 generates most of the waste and is engaged in highest production as compared to other machines. This also gives an idea that OP-18 supports the tonnage and by reducing the amount of waste generated it can increase the tonnage with a good quality product.

Table 4.1: Production vs. wastage

	PROD (millions x sheets)	TYPES OF JOB	WASTE %
OP-16	7	1	0.42
OP-17	9	3	2.7
OP-18	12	5	8.8
OP-19	3	3	0.3
OP-20	10	5	8.4

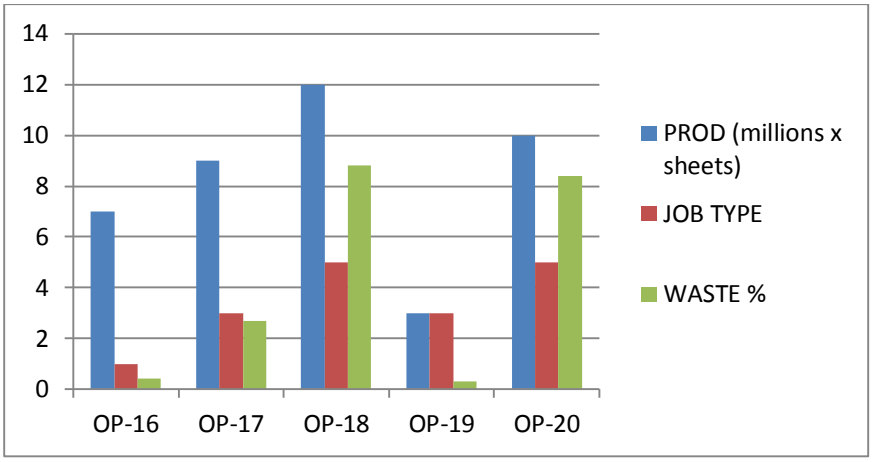


Figure 4.3: Machine vs. production, job type, waste

b) DOWNTIME ANALYSIS: Downtime analysis time frame was selected from Jan'15. As can be seen in the table 4.2 that OP-18 shows the maximum downtime. Op-19 was a new set up installed in May 2015 therefore it shows the maximum time downtime in the month of May. The same can be associated with OP-20. OP-17 could also have been selected but its most of the downtime issue were related with software errors while our main concern is to deal with the mechanical faults. It was further learned that software errors occurred due to less command of operators in software issues and as OP-17 is also a new set up so with few trainings this can be controlled.

Table 4.2: Machine downtime analysis

Machine	Jan D-T (hr)	Feb D-T (hr)	Mar D-T (hr)	Apr D-T (hr)	May D-T (hr)	June D-T (hr)	July D-T (hr)	Total
OP-16	4	0	1.5	3	4	0	0	12.5
OP-17	3	7	1.5	0	6.75	8	6.25	32.5
OP-18	7.5	3.25	12	2	13	3.5	10.25	51.5
OP-19	Un installed				51	0	0	51
OP-20	Un installed		16	6	7	3.25	1	33.25

c) PROBLEM DEFINITION: After downtime and wastage analysis it was concluded that OP-18 would be selected as sample for implementing OEE and after achieving the desired results the machine would be considered as the reference machine and same set of standards would be developed on other machines so that OEE can be implemented on the overall organization.

4.2 PHASE 02: DESIGN AND IMPLEMENTATION

a) MONITORING PHASE AND TIME MOTION STUDY:

Before implementation an initial study was carried out for calculating the initial OEE value. Machine was keenly monitored which helped in understanding its working principle and capabilities. Monitoring phase included process study and time motion study. The process study was carried out through machine manual and production team

as well as self-administered surveys. While time motion study (TMS) was conducted job wise and through the following sheet template;

Table 4.3: Time and motion study template

TIME MOTION STUDY										
MC: OP-18										
JOB:		LOT #		DATE:		Sheet (size + GSM):				
Pile No.	Start	Stop	Break down	Re-start	Sheet count	Remarks	Speed	Waste	Cycle/lot	Sheet/min

Each pile that would pass through the feeder was monitored and was given the pile number as per sequence. The time when the pile entered through the feeder and the time it completely reached the delivery were noted. If any break down occurred in between a single pile processing that time was noted down and after fixing the error the time of restart was noted as well in order to calculate the total breakdown duration. The sheet counter device on the machine displayed the number of sheets passed from a single pile. Another important parameter of speed was noted down too.

Cycle per lot can be explained as: $Number\ of\ sheets\ passed\ in\ a\ single\ pile/\ total\ duration\ a\ pile\ took\ for\ production.$ (sheet/min) (4.1)

Sheet per minute could be obtained through: $Speed/\ (cycle/lot)$ (4.2)

The purpose of calculating sheet/ minute was to evaluate which pile produced the maximum and under what circumstances. And it was found that the pile that went through zero break-down time and worked under the high speed would give the maximum sheet/minute.

The time and motion study (TMS) was conducted for 11 different jobs and through this time motion study production and speed loss was studied. Following outcome was generated from TMS;

Speed: The machine was working under an average speed of 8000 sheets/hour. The machine could go as high as 16000 sheets/ hour depending upon the condition of feeder, board grammage and board quality.

Down time: Most common down time errors were due to malfunctioning of photo cell, feeder, Board quality, environmental condition, unplanned cleaning, plate damage etc.

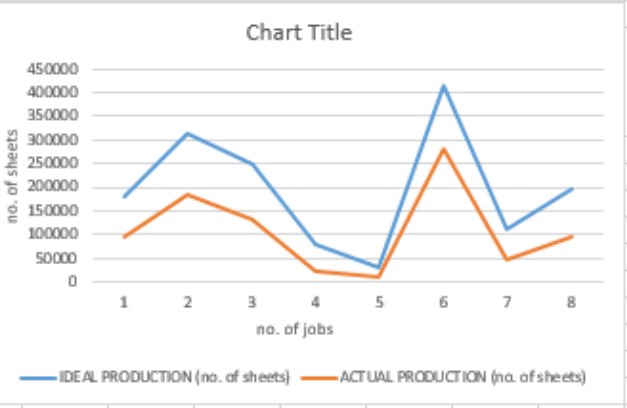
On the basis of TMS, performance loss was calculated which is demonstrated in the form of graphs as under (fig 4.4).

The machine was working under various speed limits that were dependent on printing board, colour scheme, and machine condition itself. An average speed of 13000 sh/hr is taken as ideal for normal working condition and production loss was calculated on this basis. The actual production average was 1 lakh sheet per day while it could have been 1 lakh 97 thousand sheets per day if the speed was maintained. Hence the machine was capable of producing 50% then its actual production. This amount of production can be more increased if machine run time is high by increasing the machines availability. It can be further concluded that, sudden downtime, improper machine health, low speed and delay in set up times were the causes of the loses illustrated below (fig 4.4);

PERFORMANCE LOSS

IDEAL SPEED (sh/hr)	ACTUAL SPEED (sh/hr)	IDEAL PRODUCTION (no. of sheets)	ACTUAL PRODUCTION (no. of sheets)
13000	9500	180917	95000
13000	11400	314167	185500
13000	11000	250250	131347
13000	9100	78000	21300
13000	10200	29250	10300
13000	11000	416000	280000
13000	11100	113317	47000
13000	9360	195000	94000

IDEAL CYCLE (sh/min)	ACTUAL CYCLE (sh/min)
170	114
193	128
184	114
132	59
178	76
181	146
178	90
164	104



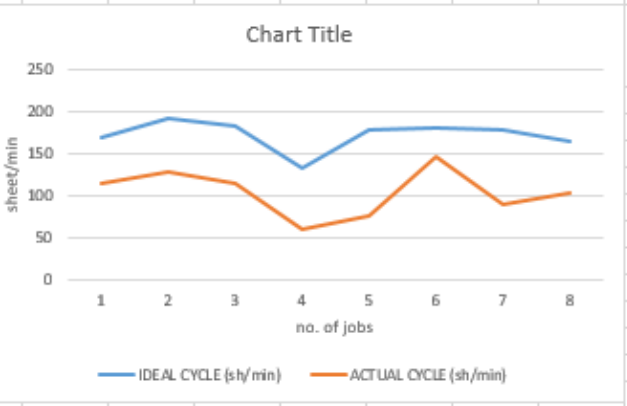


Fig 4.4 Illustration of performance lossess

b) DATA COLLECTION AND ANALYSIS

To calculate an initial OEE value 24 hour data collection was done over a period of two weeks. The format used can be seen in glossary (G.4.1). Below is the data compilation from G.4.1;

Table 4.4: Initial OEE Calculation

	Time Breakup						Production			OEE meter		
Day	Setup (hr)	MR (hr)	U/M (hr)	Waiting (hr)	Running (hr)	Total (hr)	Production (No. of sheets)	Ideal Run rate (sheets/hr)	AVAIL	PERF	QLTY	OEE %
09.11.2015	4	5.5	1	6.5	4	21	55,150	16,000	0.19	0.86	0.95	16
10.11.2015	3.5	2.25	4	0	11.25	21	88,000	16,000	0.54	0.49	0.95	25
11.11.2015	2.75	2.25	0	0	16	21	119,220	16,000	0.76	0.47	0.95	34
12.11.2015	3.25	2.75	0.75	0	14.25	21	114,500	16,000	0.68	0.50	0.95	32
13.11.2015	5.5	4.5	0	0	11	21	71,850	16,000	0.52	0.41	0.95	20
14.11.2015	2	1	0.5	0	17.5	21	145,800	16,000	0.83	0.52	0.95	33
15.11.2015	0	1	1	0	5	7	47,000	16,000	0.71	0.59	0.95	40
16.11.2015	2	2	1		16	21	131,000	16,000	0.76	0.51	0.95	37
17.11.2015	2	2	5.5	4.5	7	21	75,200	16,000	0.33	0.67	0.95	21
18.11.2015	0	0.5	7.5	0	13	21	81,100	16,000	0.62	0.39	0.95	23

Here,

SETUP TIME: It is the time taken to prepare the machine for the next job

MAKE READY (MR): It is the time required to adjust the colour and roller axis in order to produce the quality print.

UNDER MAINTENANCE (U/M): It is the time utilized in maintaining the machine due to any break down.

WAITING TIME: It is the time occurred due to absence of any resource let's say a new job was performed and test sheets were printed and required an approval from the quality department therefore the time utilized for this procedure was categorized under waiting time.

RUNNING TIME (RT): This is the time duration taken by machine to produce the printed sheets. It was calculated by the formula below [2]:

$$\text{Running Time} = Total\ Time - Setup\ time - Make\ Ready - Under\ Maintenance - Waiting \quad (4.3)$$

TOTAL TIME (TT): It is the time of the over all shift that was monitored for calculating OEE.

IDEAL RUN RATE: It is the amount of sheets the machine can produce in an hour.

AVAIL= Availability

PERF= Performance

QLTY= Quality

The formulae for AVAIL, PERF, QLTY, OEE has been mentioned in section 2.1.

The average OEE value was 28%.

c) IMPLEMENTATION PHASE:

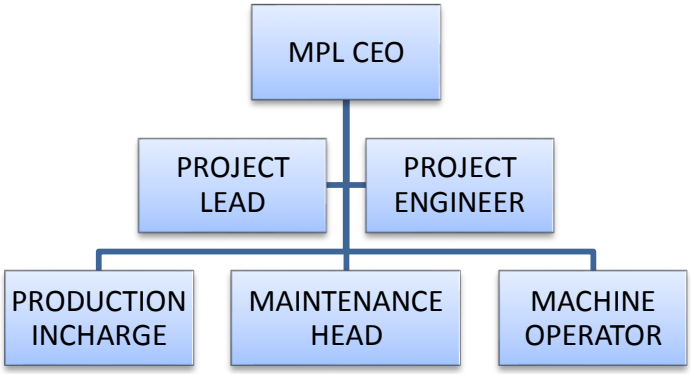
The investigation phase was concluded with an implementation plan. The main objectives of implementation plan were;

1) Development of project team.
2) SMED implementation.
3) PM implementation.
4) GDS implementation

Development of project team is explained below while rest is covered in later chapters.

c.1) DEVELOPMENT OF PROJECT TEAM:

Team build up is important in context of implementation. Below is the hierarchy of project team:



MPL CEO was found very solicitous in each and every activity starting from the investigation phase. Under his guidance a team was formed. I was leading the project while in parallel an engineer was in assistance for collecting data and monitoring of different tasks. Production in-charge, maintenance head and machine operators were included in the team in order to have a strong follow up and co-ordination regarding the whole project.

The details regarding the tools implementation is reported in the later chapters.

CHAPTER 5: SMED IMPLEMENTATION PLAN

Since the press is 10 years old and the condition of machine is no longer robust therefore it is not possible to squeeze the setup time in single digit. Therefore, the objective of this activity is to reduce the setup time as much as possible. Below is the sequence of activities for implementing SMED;

a) Data collection for calculating current set up time.
b) SMED training session for machine operator and helpers.
c) Standard set up time flow chart.
d) Data collection after SMED implementation.
e) Calculation of OEE value.

a) DATA COLLECTION OF SET UP TIME:

The setup time of OP-18 included the following activities,

b) Ink removing from tray and ink refill as per new job requirement
c) Removing of previous job printing plates and insertion of new plates
d) Cleaning of new plates, blankets, dampening roller
e) Cleaning of coating unit blanket
f) Adjustment of feeder and delivery pile
g) Arrangement of inks, boards and plates.
h) Pile making for new job.
i) Make ready of job

The make ready was not taken into account as this activity involved intensive human expertise and other parameters that are not controllable.

Below is the format used for data collection, 10 numbers of setup activities were monitored. The filled format can be viewed in glossary (REF: G.5.1: SMED DATA COLLECTION FILLED FORMAT)

Table: 5.1 Format for collecting set up time data before and after SMED implementation.

MERIT PACKAGING LIMTED							
Date:	Lot No.					GSM:	Machine:
Shift:	Man Power:					Total Qty:	Operator:
Item Description:						Color:	
Time Breakup							
Setup Time							
Activity	**End**	**Speed**	**Sheet No.**	**Down Time**	**Duration**	**Person Responsible**	**Remarks**
Make Ready							
Running							
Total							
Under Maintenance							

This format was used separately for each job. The basic data includes date, shift, item description, lot number, number of people involved in setup, number of colours in job, and name of operator.

The format was further broken into set up time, make ready (though make ready was not thoroughly analyzed). The rest sections of form were used for general monitoring of running time and maintenance event recording.

On the basis of 10 numbers of set up time data, time taken on individual activity was accumulated and an average was taken out. The average setup time came out to be 60 min. (1hr) approx. below is the table showing average set up time calculation. This average time is exclusive of waiting time and other wastages like; human resource unavailability etc. While, incorporating these factors the Set up time would exceed upto 72 min.

TABLE 5.2: Average set up time calculation (individual activities + cumulative)

SNO.	**Activity**	**Duration (min)**
1	Ink tray cleaning	10
		12
		11
		20
		15
		25
		12
		12
		27
		30
	Average time (min)	**17.4**
2	Blanket Cleaning	9
		5
		6
		15
		5
		5
		5
		8

		4
		4
	Average time (min)	**6.6**
3	Plate eject and insert	15
		17
		10
		18
		19
		11
		14
		13
		19
		16
	Average time (min)	**15.2**
4	Cleaning of new plate	3
		2
		3
		2
		6
		2
		3
		4
		3
		4
	Average time (min)	**3.2**
5	Stuffing of impression roller and dampening rollers cleaning	6
		19
		15
		12
		10
		14
		10
		20
		5
		11
	Average time (min)	**12.2**
6	Coating unit cleaning	10
		7

		5
		8
		3
		3
		6
		3
		2
		6
	Average time (min)	**5.3**
Average setup time (min)		**59.9**

Following was concluded after time motion study;

1) Time was wasted in arrangement of printing boards, plates and inks during setup time.
2) Helpers were not assigned with well-defined tasks due to which most of the helpers were found idle.
3) There was no proper sequence followed during machine set up.
4) Helpers were not giving the maximum input and efforts during set up.

b) SMED TRAINING SESSION:

The training took place separately for individual shifts. The workers were given the awareness of SMED after that the problems identified were discussed in details with the operators and helpers. Below are the examples of problems discussed during the training.

Example # 01

Setup Time					
Activity	**Start**	**End**	**Down Time**	**Duration**	**Remarks**
Cleaning	**11:37**	**11:42**		**5**	**Cleaning of blanket by 3 workers. 4 unit cleaning**
Plate change	**11:43**	**11:54**		**10**	**Plate eject and insert by 1 worker**
Blanket of coating unit	**11:54**	**12:05**		**10**	**Blanket making time is 2 min**
Water paste removing	**12:05**	**12:06**		**1**	**1 worker cleaning roller and removing water paste**
Plate cleaning	**12:06**	**12:10**		**4**	
			Total	**30**	**Less setup and make ready time due to same color sequence and similar job**

This example shows that no proper team work was exhibited during the setup time. Let's look at the cleaning activity row, the cleaning took 5 minutes and there were 3 workers cleaning the 4 units while remaining 2 workers were found idle. Same was found in plate changing activity. Another observation was that only one activity was conducted at a time this was also one of the reasons that setup time was stretched so long.

Example # 02:

Setup Time					
Activity	**Start**	**End**	**Down Time**	**Duration**	**Remarks**
Cleaning and removing paint	**8:05**	**9:02**		**57**	**From 9:20 to 9:28 only 1 worker on machine**
Blanket change(Coating unit)	**9:03**	**9:08**	**2**	**5**	**Tool break, 2 min for arranging other tool**
Removing water paste from roller	**9:09**	**9:16**		**7**	**1 worker**
Cleaning of plate	**9:25**	**9:27**		**2**	**2 workers for cleaning**
			Total	**71**	

From this report this can be seen that ink cleaning activity took 57 min. during which 8 min. were exclusively served by one worker on machine while others were engaged in arrangements of inks, plates and printing boards. And set up time on the whole took 71 min. This example suggests to convert external tasks into internal. Every new job needs new inks, printing plates and printing boards. This arrangement should be done before the preceding job ends.

Example # 03

Setup Time					
Activity	**Start**	**End**	**Down Time**	**Duration**	**Remarks**
Blanket cleaning	**1:03**	**1:09**		**6**	
Plate insert	**1:09**	**1:24**		**15**	**Same worker for plate change can save setup time**
Plate cleaning	**1:24**	**1:28**		**4**	**parallel operations, pile making, loading, cleaning**
loading of pile	**1:28**	**1:31**	**3**	**3**	**Feeder adjustment, sucker problem**

This example provokes the idea of doing multiple tasks in parallel. As one can see that loading of pile was conducted at the end and this took 3 min. while doing this activity in parallel must have eliminated this 3 min. additional time.

After discussing the observations with the machine operator and helpers, following plan was finalized for reducing the set up time.

1) Build up a team and machine operator as Team leader.
2) Convert external activities into internal activities. For example: Prepare 2 to 3 piles for the next job before current job end. Arrange inks, tools and plates before the next job starts. Timely inform maintenance for any problem that can occur in future.
3) Do things in parallel. For example: Find possibility of ejecting and inserting plates of 1^{st} and 5^{th} unit
4) Standardize the sequence

c) STANDARD SETUP TIME FLOW DIAGRAM:

The tasks involved in set up time were given a proper sequence and were standardized through placing the flow chart frame near work station. Team of five including the machine operator was formed. Operator was assigned with an overall supervision.

Below is the standardized work instruction flow diagram.

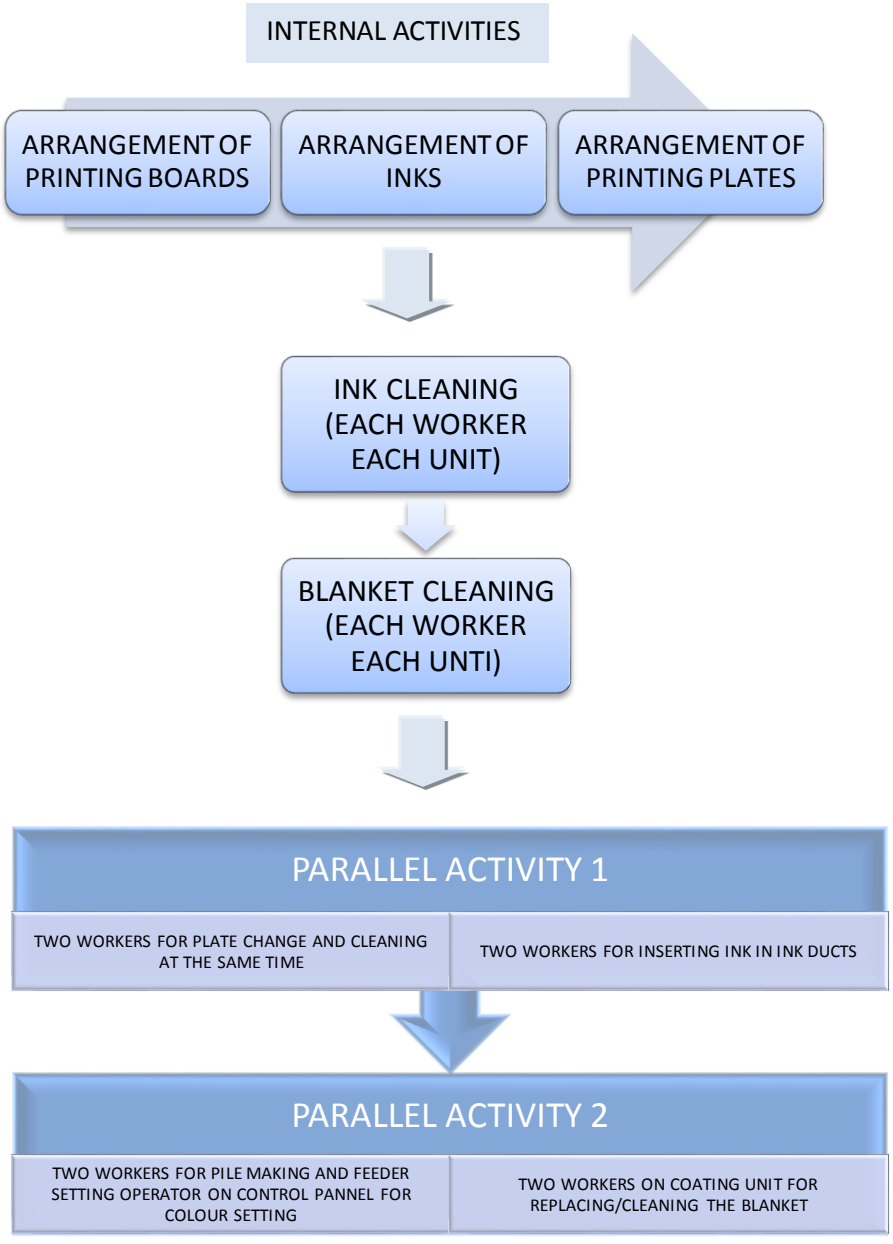


Fig. 5.1: Standard set up flow chart

The set-up flow diagram board that is placed near the work center is shown as under:

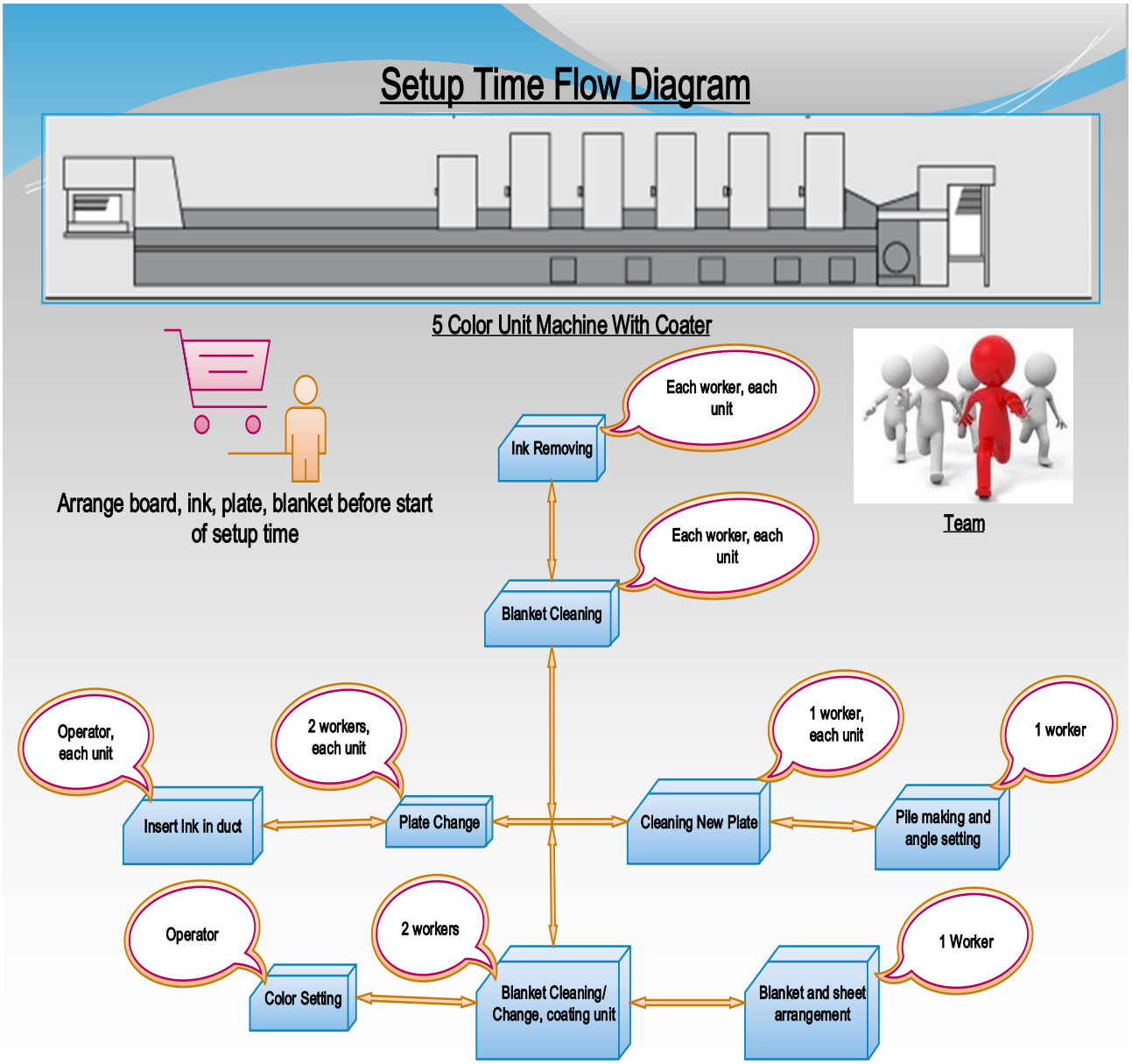


Fig. 5.2: Set-up time Flow diagram

d) DATA COLLECTION AFTER SMED IMPLEMENTATION:

The same format was used as shown in table 4.1. Six numbers of set up times were observed. After an intense supervision it was found that **set up time was reduced from 72 min to 42 min**. below is the summarized report.

Table 5.3: Average set up time summary table

SNO.	ACTIVITY	DURATION (min)
1	INK CLEANING	11
		15
		9
		11
		10
		12
	Average time (min)	11.3
2	BLANKET CLEANING	5
		5
		8
		5
		4
		5
	Average time (min)	5.3
3	PLATE CHANGE AND CLEANING + NEW INK INSERT	20
		25
		18
		25
		19
		20
	Average time (min)	21.1
4	COATING UNIT + PILE MAKING+ FEEDER SETTING	6
		3
		3
		5
		3
		8
	Average time (min)	4.6
Average Set up time (min)		42.3

e) CALCULATION OF OEE VALUE:

For calculating OEE value after implementing SMED the same format was repeated that was previously used at the time of initial OEE value calculation. The span of two weeks was taken under consideration and the following results were driven out;

The time recorder previously as waiting time was no longer there as all the raw materials/tool required before a job were arranged before time. Set up time got reduced around 53%; previous per day average of setup time was 2.69 hrs and after implementation of SMED, per day average became 1.26 hrs. Thus this reduction made the machine more available for production and the average per day production aroused from 93 thousand sheets to 1 lakh 15 thousand sheets.

SMED implementation increased the OEE value from 28% to 33% approx.

Table 5.4: OEE calculation after SMED implementation

DATE	Total time (Hr)	BREAK (Hr)	SET UP TIME (Hr)	MAKE READY (Hr)	D/T (Hr)	RUN (Hr)	TOTAL PARTS	IDEAL SPEED	AVAIL (A)	PERF (P)	QLTY (Q)	OEE = A*P*F	OEE %
7.3.2016	24	3	0.90	3	0.88	16.22	123923	16000	0.77	0.48	0.95	0.35	35
8.3.2016	24	3	1.60	2.6	0.46	16.34	99064	16000	0.78	0.38	0.95	0.28	28
9.3.2016	24	3	1.00	1.7	0.50	17.80	142561	16000	0.85	0.50	0.95	0.40	40
10.3.2016	24	3	0.77	2.58	0.28	17.37	123912	16000	0.83	0.45	0.95	0.35	35
11.3.2016	24	3.5	1.60	3.2	0.50	15.20	96502	16000	0.72	0.40	0.95	0.27	27
12.3.2016	24	3	1.50	0.8	1.12	17.58	124198	16000	0.84	0.44	0.95	0.35	35
13.3.2016	24	3	0.83	3.6	0.00	16.57	134251	16000	0.79	0.51	0.95	0.38	38
14.3.2016	24	3	1.90	4.3	0.69	14.11	97615	16000	0.67	0.43	0.95	0.28	28
15.3.2016	24	3	0.92	0.8	3.00	16.28	98539	16000	0.78	0.38	0.95	0.28	28
16.3.2016	24	3.5	0.79	1.75	2.60	15.36	120968	16000	0.73	0.49	0.95	0.34	34

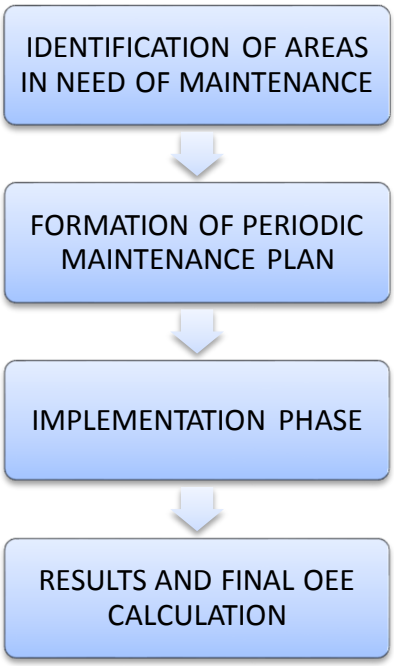
CHAPTER 6: IMPLEMENTATION OF PLANNED MAINTENANCE PLAN

6.1 OBJECTIVE:

The purpose of this activity is to increase the performance of machine by scheduling some highly critical areas of machine for maintenance. Periodic maintenance is also indented to help in utilizing the machine as much as possible. The type of maintenance strategy would include both i.e. preventive maintenance as well as repair work.

6.2 IMPLEMENTATION STRATEGY:

Below are the steps of PM implementation strategy;



a) IDENTIFICATION OF AREAS IN NEED OF MAINTENANCE:

This includes the following;

2) HISTORIC DATA REVIEW: Over a period of a year was taken into consideration for identifying machine's health. Through the report of daily

machine health it was convenient to find out the problems machine was facing during its routine process and the time taken to amend it. The sample of data has been shown in glossary (REF: G.8.1).

3) TIME MOTION STUDY: Historic data becomes more fruitful when real time study is conducted parallel to it. The combined effect of both the analysis made it easier to highlight the frequent occurring problems in the machine during its operation (Table 8.1). The format initially designed for SMED time emotion study was used for this activity too it has a section of "under maintenance" to note down the events of break downs occurring during the operation.
4) OPERATORS IDENTIFIED PROBLEMS: This approach includes operator's guidance as per his experience with the machine this was done with the help of a machine survey checklist. The checklist will be shown in the later section. This survey also helped in planning the maintenance program.

Following data was compiled from the historic data review. Below are the frequent occurring problems since January'15 till January'16. A graph was plotted for the visual understanding.

Table: 6.1 Frequency of problems occurring in OP-18

Code	DESCRIPTION	FREQUENCY
U-2	UNIT 2	1
COOL	COOLING PUMP	1
HD	HEAD LAY	6
D	DELIVERY	4
TECH	TECHNOTRANS	1
G	GRIPPER	5
U	UNIT PROBLEM	3
U-5	UNIT 5	3
U-3	UNIT 3	2
FD	FEEDER	2
CL	CLUTCH PROBLEM	1
CH	CHILLER	6
OIL	OIL PUMP	3
U-1	UNIT 1	3

CAM	CAM FOLLOWER	2
MM	MAIN MOTOR	3
FL	FRONT LAY	2
CHR	CHAMBER PROBLEM	1
U4	UNIT 4	1
COM	COMPRESSOR	2

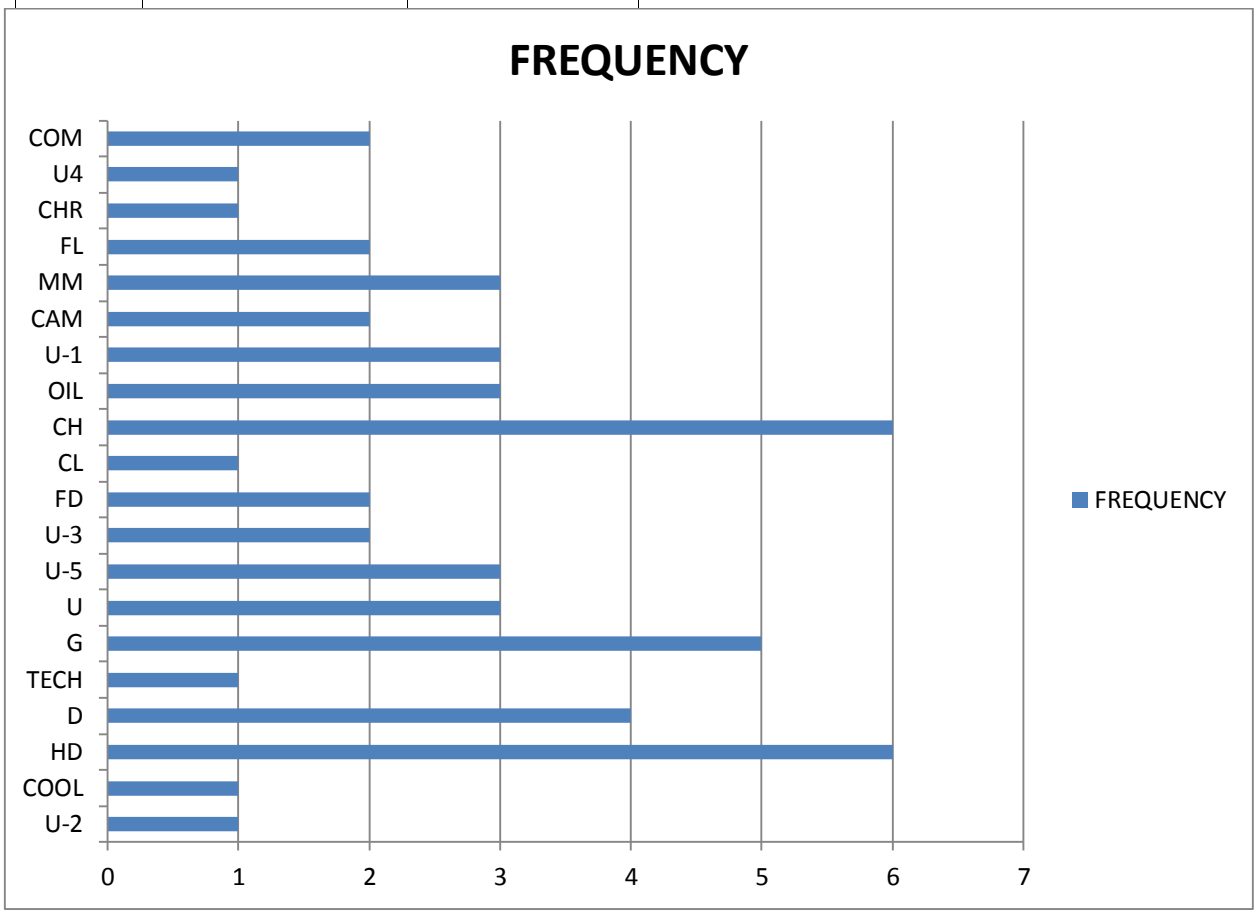


Fig 6.1: Analysis of frequently occurring problem

It can be concluded from above graph that by only fixing the chiller, head lay, grippers and delivery in first attempt of maintenance plan the machine downtime can be reduced promptly as these areas were mainly contributing towards the unplanned downtimes.

b) FORMATION OF PERIODIC MAINTENANCE PLAN:

After identification of problems occurring in OP-18 the next step was to resolve them systematically without affecting the availability of the machine at the same time

increasing its performance rate. A check list was prepared (REF: G 8.2.1-8.2.5) the purpose of this checklist was to reconcile the problems listed in the health report and to add any new problem that is being identified by the operator during the survey. The maintenance plan was further aided by the study of machine manual. The maintenance check list was prepared by dividing the machines into its essentials parts below is the top view of OP-18 press.

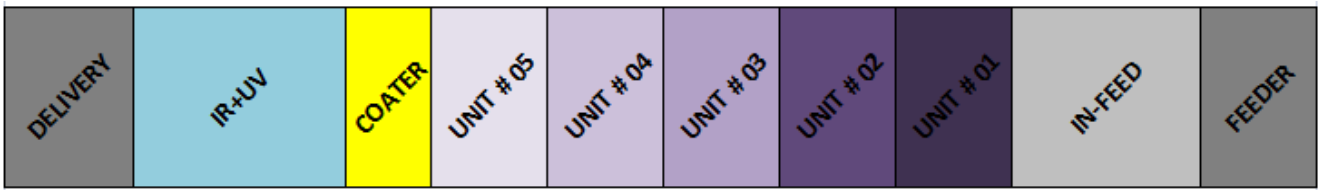


Fig 6.2: Machine lay-out of OP-18

b.1) MACHINE SURVEY CHECKLIST:

The below check list was used for the survey and operators remarks were taken for preparing the final maintenance plan. A general inspection team was also prepared from maintenance department and the purpose was to generally check the machine and highlight the problems. The summarized report can be seen in fig 8.3.

Table 6.2.1: Checklist of feeder section

MACHINE OP-18			
FEEDER			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Pile hoist chains, sprockets, bearing		
2	Pile movement left and right		
3	Pile hoist control buttonms, switches		
4	Pile safety stops, jam switches, sensors		
5	Feeder pump, side blower fan, filter		
6	Feeder blast, suck, blow, pipe work		
7	Running in wheels, brushes, holders		
8	Manual head adjustments, suckers, blowers		
9	Manual head, blowers, sheet size movement		
10	Sucker barrel wear		
11	Cams and followers wear		
12	Mechanical two sheet trip		not properly working
13	Manual Handle		broken
14	Feeder pannel, buttons, switches, lights		

Table 6.2.2: Checklist of in-feed section

IN-FEED			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Sheet guide and smoothers		
2	Guide wheels		
3	Front lay adjusters		
4	Front layhood mechanism		
5	Swing arm pad bar adjustments		
6	Swing arm trip mechanism		
7	Swing arm gripper, cam, followers		
8	Double sheet detector		Not working properly
9	Over shoot detector		
10	Front lay detectors		
11	Side lay detectors		

Table 6.2.3: Checklist of printing section

PRINTING UNITS			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Ink fountain and fountain rollers		
2	Ink Fountain Brakes (Zero-set position		
3	Ink fountain keys (clean and check)		
4	Dampening tank (clean the interior)		
5	Fountain pans and piping		
6	Fountain pan and water level detector		
7	Gripper and gripper shaft (clean paper dust)		
8	Ink cleaner (check blades for wear)		
9	Blanket cylinder surfaces, bearers, wipes		
10	Impression cylinder surfaces		
11	Transfer cylinder T.Y Clamps		
12	Sheet guides		
13	Sheet guide blowers, pumps, fitters		
14	Cylinder grippers, cam, followers		
15	Blanket cylinder bars, worm wheels		
16	Oil leaks		
17	Oil pump, filters, sight glasses		
18	Main motor, filter, belts, brushes, brake		

Table 6.2.4: Checklist of coater section and general cleaning

COATER			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Blanket cylinder surface, clamps		
2	Impression cylinder surface		
3	Impression cylinder grippers, cam, followers		
4	Anilox roller and cylinder		
5	Pump operating		
6	Wash up operation		
7	Register movements		
8	Guards, buttons, switches		
CLEANING			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Tank condition, holds pressure		
2	Leaks		
3	Wash heads complete, condition		
4	Pipe work, connectors		
5	Electric cables and connectors		
6	Pneumatics, solenoids, pistons, pipes		
7	Location wash operation		
8	Roller wash operation		
9	Blanket wash operation		
10	Impression wash operation		
11	Start buttons, interlocks		
12	Desk membrane, indicator panel		
13	Spare cores		
14	Rewind unit		

Table 6.2.5: Checklist of delivery section, general and ancillary

GENERAL AND ANCILLARY			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Plate punch		
2	Plate blender		
3	Compressor		
4	Damper unit		
5	Spray unit		
6	Dryer unit		
7	Inking chiller unit		
DELIVERY			
SNO	DESCRIPTION	Clean/ Grease/ Adjust/ replace	REMARKS
1	Pile hoist, chains, sprockets, guides		
2	Pile detection sensors (raising)		
3	Cow catcher board, bearing, runners		
4	Racking / cow catcher switches		
5	Roller . Belt valves, pipe work		
6	Extraction fan		
7	Slide jogger operation		
8	Gripper bars, castings, cam followers		
9	Gripper tips and pads		
10	Gripper bar chains, tension, wear		
11	Gripper bar chain guides		
12	Release cam wear, adjustment mechanism		

After general inspection following report was compiled that was considered as reference in preparing the final maintenance plan.

PERIODIC MAINTENANCE REPORT

M/C NO.: OP-18
ACTIVITY CONDUCTED ON: 22ND MARCH'16
TIMING: 9:15 A.M TILL 11:00 A.M

ACTIVITY CONDUCTED:

- IN-FEED: Swing arm pad bar adjustment: checked
- COATER: Impression cylinder, gripper, cams, followers: checked
- OIL LEVEL, OIL FILTER: checked
- GREASING: CAM follower, transfer and impression, and delivery gripper

PARTS IN BAD CONDITION:

- FEEDER: running in wheels, brushes, holders
- PRINTING UNIT: impression cylinder surfaces, sheet guide blowers, pumps and filters
- COATER: pump operating
- CLEANING: Pneumatic, solenoid, piston, pipes

PROLONG INSPECTIONS:

- FEEDER: feeder pump, side blower fan, filters for winding — status: not working, require 2 days
- IN-FEED: front lay adjuster require 1 day — status: drive side sensor problem,
- IN-FEED: side lays detector — status: sensor Prob, require 1 day
- PRINTING UNIT: sheet guide blower 1 day — status: blower need winding, require
- LEAKS: days — status: air leakage, require 2 to 3
- CLEANING: Pneumatic, solenoid, piston, pipes — status: require 2 days
- INK DUCTS: — status: card problem, require 1 day
- DELIVERY: Cam motor — status: require 2 days

URGENT CHECK POINTS:

- **PRINTING UNITS:** Cylinder grippers, cam, followers, 3rd unit, safety guard, switches, oil pump, filters and side glasses.
- **COATER:** clamps jammed, register movements.
- Hot air and cool air.

Fig 6.3: Periodic maintenance report

c) IMPLEMENTATION PHASE:

An Automatic entry system was developed in kamori software (machine's software). This system has already been existed in the system but was further upgraded. Another maintenance check was the physical card system. The purpose of both the systems was to ensure that maintenance takes place on time as scheduled. Software would timely update the time taken on maintenance as well as about unplanned downtime duration

while the physical card system would ensure the last maintenance activity conducted on machine to the maintenance inspector. After thorough analysis of the checklist and maintenance report following plan was derived that is segregated into repair work (table. 6.3.1) as well as preventive measures (table. 6.3.2). The Maintenance plan incorporating both the repair work as well as preventive maintenance was scheduled (table. 6.3.3) with in the span of 40 days after which TMS was conducted to check its effect on OEE value.

Table 6.3.1: List for repair work

Area	Description	Time required
Feeder	wheels, brushes, holders	few hours
Coater	procurements and replacements of parts	2-3 hours
Feeder	pump, blower, filter	2 days
In feed	adjuster + detector	1 day
Air leaks		2 days
Delivery	cam motor	2 days

Table 6.3.2: List for Preventive measures

Area	Description	Time required
Printing unit	cleaning of cylinder surfaces, sheet guide blowers, pumps and filters	1 days
Coater	Cleaning	1 day
Mechanical inspection	piston, pipes, pneumatic	few hours
Electrical inspection	Solenoid	few hours

Table 6.3.3: 1st Maintenance schedule

DATE	DAYS	AREAS	ACTIVITY
29.03.2016	Tue	Feeder	repair work
3.04.2016	Sun	Printing unit 3, hot air and cold air	
10.04.2016	Sun	Coater, infeed	repair work
21.04.2016	Thrs	General inspection	
24.04.2016	Sun	Printing unit	prev measure
7.05.2016	Sat	Delivery, air leaks, coater	repair work
8.05.2016	Sun	Delivery, coater	repair work

d) RESULTS AND FINAL OEE CALCULATION:

DATE	Total time (Hr)	BREAK (Hr)	SET UP TIME (Hr)	MAKE READY (Hr)	D/T (Hr)	RUN (Hr)	TOTAL PARTS	IDEAL SPEED	AVAIL (A)	PERF (P)	QLTY (Q)	OEE= A*P*F	OEE %
16.05.2016	24	3	1	2.6	0.50	16.90	142056	16000	0.80	0.53	0.95	0.40	40
17.05.2016	24	3	0.87	3.5	0.30	16.33	137412	16000	0.78	0.53	0.95	0.39	39
18.05.2016	24	3	0.92	0.87	1.00	18.21	160305	16000	0.87	0.55	0.95	0.45	45
19.05.2016	24	3	1.45	2.3	0.00	17.25	153161	16000	0.82	0.55	0.95	0.43	43
20.05.2016	24	3.5	0.67	1.89	0.00	17.94	157032	16000	0.85	0.55	0.95	0.44	44
22.05.2016	24	3	0.8	4	0.80	15.40	123761	16000	0.73	0.50	0.95	0.35	35
23.05.2016	24	3	0.77	1.5	0.00	18.73	167412	16000	0.89	0.56	0.95	0.47	47
24.05.2016	24	3	1.6	3.6	0.26	15.54	121094	16000	0.74	0.49	0.95	0.34	34
25.05.2016	24	3	0.62	1.2	0.00	19.18	167179	16000	0.91	0.54	0.95	0.47	47
26.05.2016	24	3	0.9	1.7	0.60	17.80	152745	16000	0.85	0.54	0.95	0.43	43

After PM implementation the average OEE value has further increased from 33% to 42 %. The reason behind this increment is reduction in downtime from 0.86 hr to 0.35 hr. The reduction in downtime has increased the availability from 78% to 83%. The performance has also increased from 44% to 53%. Due to increase in availability and performance the average per day production has also increased from 1 lakh 15 thousand sheets per day to I lakh 48 thousand sheets per day.

CHAPTER 07: GROUP DEPENDANT SCHEDULING

7.1 BACKGROUND:

There was high amount of back orders which were on pending for more than 3 months. The current machine plan was based on urgent orders due to which the orders which were due on current date were ignored and were forming a huge pile of back orders. Another reason for this pile was that Op-18 was serving as a general purpose back up press at the firm therefore if any of the machines was sent for immediate maintenance its order was transferred to OP-18.

Orders running on urgencies were of miscellaneous categories and this was causing another problem of huge setup times, as there was no sequence of colours being followed. Even if a certain pattern of colours/ sequence was followed to save the time spent on changing colour in colour unit the results were not remarkable.

7.2 METHODOLOGY:

It was assumed that if the products that were mostly/ frequently run on the machine were made to form a group and then run in the form of group will saves a lot of time. It was observed later that not only the colour unit cleaning time was saved but also the stuffing time of the impression roller was reduced because same grammage of paper was run every time for each group. The method of forming products into group is further explained below.

An analysis was conducted to distinguish the products that were running frequently and those which were non-frequent. This analysis was conducted on past one year master production planning data. (REF: G.9.1)

Now the products separated out were categorized into groups primarily on the basis of grammage and their urgency i.e. their due date and coating requirement and finally the colour sequence.

Set up time got further reduced, per day plan was on the basis of machine's capacity this also made a definite commitment with the customer, production planning became convenient, this

made material requirement planning much adequate for warehouse management. This also made easy to understand machine's behavior towards different products.

Following are the group of products on the basis of the grammage of boards used:

Table 7.1: Categorization of group of products

CATEGORY	PRODUCT DESCRIPTION	GSM
GROUP 1	TUC	250
	CANDY	250
	SURBEX Z	260
GROUP 2	SOOPER	250
	BAKERI	250
	BRAVO	250
	SUPREME	275
GROUP 3	PEANUT	275
	PARTY	275
	GLUCO	275
	PEARL DUST	275
	WHEATABLE	300
	PRINCE	300
	WELDING RODS	300
GROUP 4	JAM HEART	300
	VENTOLIN	300
	SURFICOL	300
	PADIATRIC DROP	300
	LACTOGEN	300
	TAPAL	300
	SPARKLE	300
	CLOSE UP	300
	COLGATE	300
	JELLY	300
	CUSTARD	300
	OVEN FRESH	300
GROUP 5	OREO	350
	NATIONAL	350
	SHAN	350
	NIDO	350
GROUP 6	CIGERETTE	215

7.3 CALCULATION OF OEE:

After time and motion study done over the period of 10 days it was found that OEE value was incresed from 42% to 56% . Below is the results derived from time and motion study. Due to formation of groups the set up time was further reduced froman average of 0.96 hr per day to 0.77 hr per day. As same nature of jobs were running back to back through the machine the make ready time also got reduced from an average of 2.3 hrs to 1.07 hr because of these reductions the availablity of machine got increased from 83% to 90%. As the availabilty got increased the per day average of production became 1 lakh 98 thousand from 1 lakh 48 thousand. Since activity of maintenance was carried on simultaniously with this GDS implementation the performance became further better from 53% to 66%.

Table 7.2: OEE calculation after implementing GDS

DATE		Total time (Hr)	BREAK (Hr)	SET UP TIME (Hr)	MAKE READY (Hr)	D/T (Hr)	RUN (Hr)	TOTAL PARTS	IDEAL SPEED	AVAIL (A)	PERF (P)	QLTY (Q)	OEE= A*P*F	OEE %
06.06.2016		24	3	0.48	1.8	0.00	18.72	190428	16000	0.89	0.64	0.95	0.54	54
07.06.2016		24	3	0.76	0.65	0.00	19.59	213730	16000	0.93	0.68	0.95	0.60	60
08.06.2016		24	3	0.55	1.2	0.80	18.45	193578	16000	0.88	0.66	0.95	0.55	55
09.06.2016		24	3	0.9	0.67	0.00	19.43	198369	16000	0.93	0.64	0.95	0.56	56
10.06.2016		24	3.5	0.56	1.5	1.00	17.44	185003	16000	0.83	0.66	0.95	0.52	52
11.06.2016		24	3	1	0.8	0.00	19.20	200945	16000	0.91	0.65	0.95	0.57	57
13.06.2016		24	3	0.67	0.5	0.45	19.38	203817	16000	0.92	0.66	0.95	0.58	58
14.06.2016		24	3	1.35	1	0.00	18.65	201059	16000	0.89	0.67	0.95	0.57	57
15.06.2016		24	3	0.8	1	0.50	18.70	198623	16000	0.89	0.66	0.95	0.56	56
16.06.2016		24	3	0.65	1.6	0.26	18.49	195395	16000	0.88	0.66	0.95	0.55	55

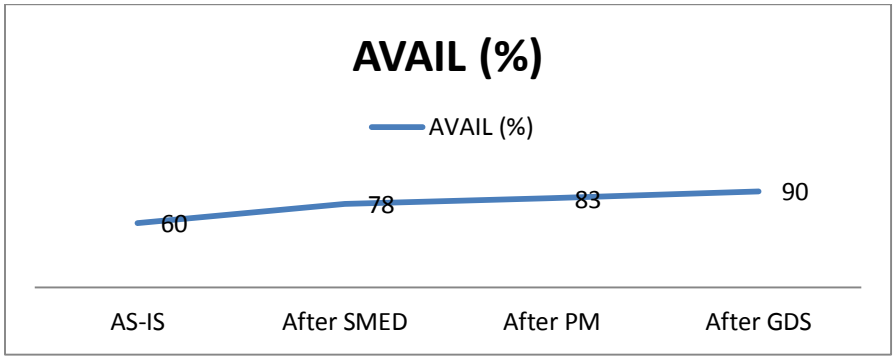
CHAPTER 08: RESULTS AND CONCLUSIONS

8.1 RESULTS:

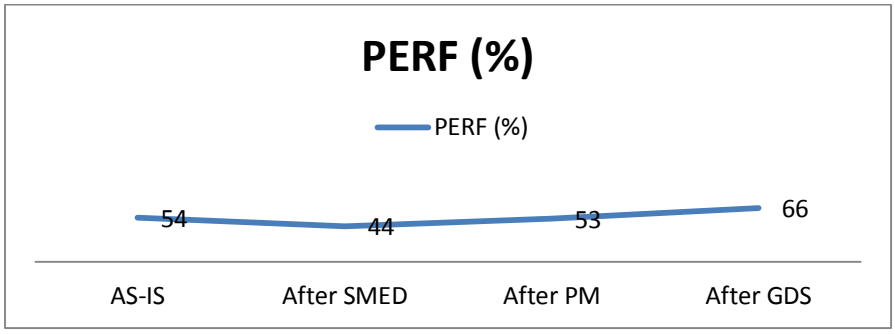
Thus after implementation of SMED, PM and GDS we were able to achieve our desired aim of increasing the OEE value along with constant monitoring and control of OEE parameters that include; availability and performance. Below are few of the graphical representations that summarize the results obtained;

	AVAIL (%)	PERF (%)	OEE (%)
AS-IS	60	54	27.6
After SMED	78	44	33
After PM	83	53	42
After GDS	90	66	56

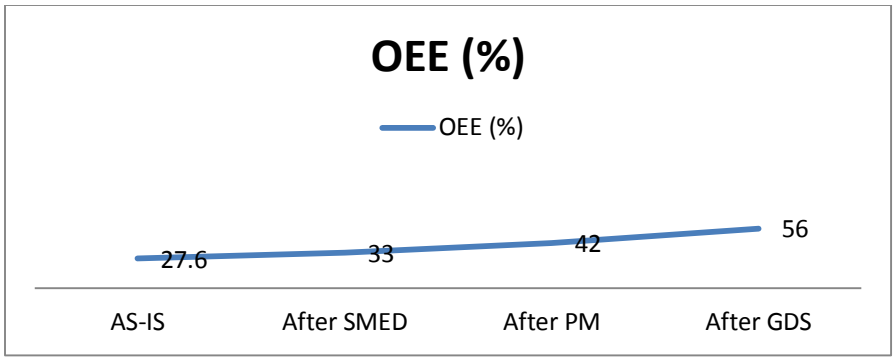
Table 8.1: summarized results



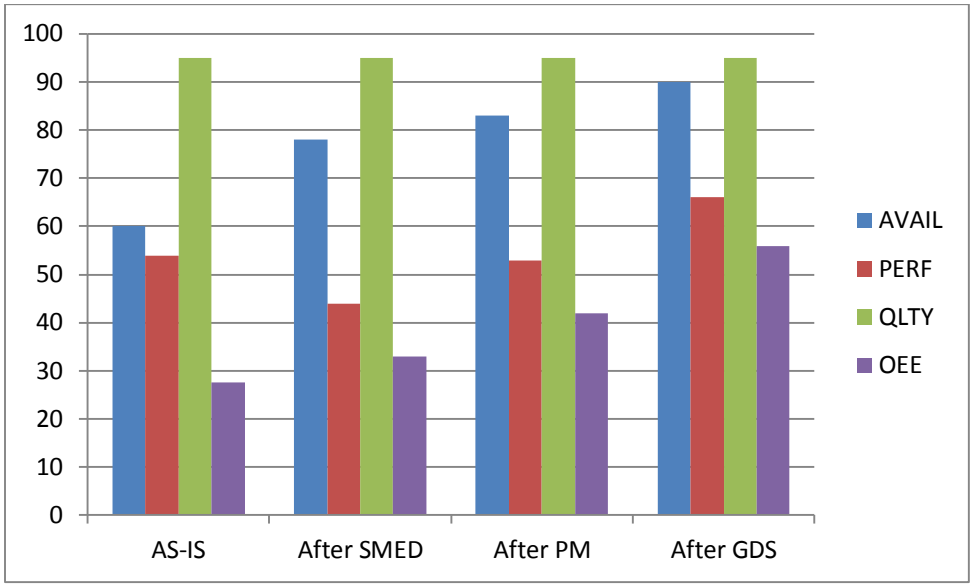
Graph 8.1: Gradual increase in availability from AS-IS phase till GDS implementation



Graph 8.2: Gradual increase in performance from AS-IS phase till GDS implementation



Graph 8.3: Gradual increase in OEE from AS-IS phase till GDS implementation



Graph 8.4: Combined Bar graph

8.2 CONCLUSIONS:

So to conclude we can say that;

The off-set printing machine OP-18 was thoroughly studied and it's role in a packaging industry was gradually perceived.

Later wards OEE was calculated and through the implementation of SMED, GDS and PM, OEE value was increased from 28% to 56%. Within in the given time period for this project an SOP was also developed for SMED implementation on other off set presses that had the same nature of work as of OP-18.

There is always a room for improvement so a continuous improvement strategy will increase the OEE value further.

8.3 FUTURE WORK:

The factor of quality was dependent on other factors like ink and board quality and printing plate development so this parameter was not experimented and kept constant as 95%. This can be conducted as future work by varying the factors of ink, printing plate and printing board to examine the effect on printing quality.

This work can be further modified by programming a software to calculate OEE.

GDS can be also be experimented by creating product mix of several products that involve almost same colour sequence. This demands thorough analysis on recipe of printing of each product. After developing the group of product mix one can feed the group list in the control panel of the machine so that printing operation can run automatically.

8.4 LIMITATION:

This work is limited for the printing industry that uses Off-set printing technology. This work involves manual data collection which demands accuracy and time therefore it is recommended to use software to calculate OEE as this will create ease, maintain data accuracy and consume less time effort.

REFERENCE:

[1]. http://www.oeefoundation.org/origin-of-oee/ **retrieved on 7 Nov, 2016**

[2]. http://www.oee.com/ **retrieved on 7 Nov, 2016**

[3]. http://www.oee.com/world-class-oee.html/ **retrieved on 24 Sept, 2017**

[4]. http://www.leanproduction.com/smed.html/ **retrieved on 24 Sept, 2017**

[5]. https://www.maintenanceassistant.com/planned-maintenance/ **retrieved on 24 Sept, 2017**

[6]. Yuri Mauergauz, (2015), "Dynamic Group Job Shop Scheduling", International journal of management science and engineering management, ISSN: 1750-9653.

[7]. http://the-printer.net/offset-printing

[8]. http://www.sun-graphics.com/equipment/

[9]. http://s-buck1114-dc.blogspot.com/2012/12/design-for-print-print-processes-offset.html

[10]. http://dynodan.com/printing-process-explained/sheetfed-printing/delivery-units.html

[11].Harsha G. Hedge, N.S Mahesh, Kishan Doss, (2009),"Overall Equipment Effectiveness Improved by TPM and 5S Techniques in a CNC Machine Shop", SASTECH, Vol.8, Issue 2.

[12].Perumal Puvanasvaran, Y.S Teoh, C.C. Tay, (2013),"Consideration of demand rate in Overall Equipment Effectiveness (OEE) on equipment with constant process time", Journal of Industrial Engineering and Management, ISSN: 2013-0953.

[13]. Eleftherios Lakovou, Chi M. Ip, Christos Koulamas, (1999), "Throughput-dependent periodic maintenance policies for general production units", Annals of operations Research, Volume 91, pp 41-44.

[14]. Jonathan David Morales Mendez, Ramon Silva Rodriguez, (2015), "Set up reduction in an interconnection axle manufacturing cell using SMED", Int J Adv Manuf Technol, DOI 10.1007/s00170-015-7845-0.

[15]. Chowdury M.L. Rahman, M.A Hoque, (2014), Evaluation of Total Productive Maintenance Implementation in a Selected Semi-Automated Manufacturing Industry", International Journal of Modern Engineering Research (IJMER), Vol. 4, Iss. 8, ISSN: 2249-6645.

[16]. Farhad Anvari, Rodger Edwards, Andrew Starr, (2010), "Evaluation of Overall Equipment Effectiveness based on market", Journal of Quality in maintenance Engineering, Vol. 16, Iss. 3, Pg. 256-270.

[17]. Osama Taisir R.Almeanazel, (2010), "Total Productive Maintenance review and Overall Equipment Effectiveness Measurement", Jordan journal of Mechanical and industrial engineering, vol. 4, Iss. 4, ISSN 1995-6665.

[18]. Goyal Ravi Kumar, Maheshwari Kapil, (2013), "Maintenance: From Total Productive Maintenance to World Class Maintenance", International Journal of Scientific Research and Reviews, Vol. 2, Iss. 1.

[19]. Ranteshwar Singh, Dhaval B. shah, Ashish M Gohil, Milesh H. Shah, (2013), "Overall Equipment Effectiveness (OEE) calculation- Automation through hardware and software development", Procedia Engineering, 51 (2013) 579 – 584.

[20]. Nur Ainunnazli Binti Aminuddin, Jose Arturo Garza-Reyes, Vikas Kumar, Jiju Antony & Luis Rocha-Lona, (2015), "An analysis of managerial factors affecting the Implementation and use of overall equipment effectiveness", International journal of production research, ISSN: 0020-7543

[21]. Panagiotis H. Tsarouhas, (2013), "Evaluation of overall equipment effectiveness in the beverage industry: a case study", International Journal of Production Research, ISSN: 0020-7543.

[22]. Izlem Tekin, Sitki Gozlu, (2012), "Determination of Cost Resulting from Manufacturing Losses: An Investigation in White Durables Industry", International Conference on Industrial Engineering and Operations Management Istanbul, Turkey.

LIST OF ACRONYMS

OEE	Overall Equipment Effectiveness
SMED	Single Minute Exchange of die
PM	Periodic Maintenance
GDS	Group Dependent Scheduling
AVAIL	Availability
PERF	Performance
QLTY	Quality
OP	Offset Printing
Sh/hr	Sheet/Hour
TMS	Time and Motion Study
MPL	Merit Packaging Limited
GT	Group technology

CERTIFICATE:

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26th May, 2016

EXPERIENCE CERTIFICATE

This is to certify that Ms. Humna Ameer has completed the project of Optimizing an Off-Set printing press through OEE (Overall Equipment Effectiveness) calculation in Merit Packaging Limited from 15th August, 2015 till 16th March, 2016 and the company was able to achieve the OEE of 56% through the aid of following management tools,

- SMED (Single Minute Exchange of Die)
- Periodic Maintenance
- Group Dependent Scheduling

Yours Sincerely,

Shahid Ahmed Khan
CEO
Merit Packaging Limited

APPENDIX - A

MERIT PACKAGING LIMTED

Down Time Report

					Sheets	Hours					
Date	M/c Nos.	Shift	Lot Nos.	Item Description	Speed	Set UP	Make Ready	U/M	Waiting	Running	Remarks

G.4.1: INITIAL DATA COLLECTION FORMAT

APPENDIX - B

MERIT PACKAGING LIMTED

Date:11/02/2016	Lot No.1094	GSM:215	Machine:OP-18	
Shift:AA	Man Power:5	Total Qty:3500	Operator:Mr Mubeen	
Item Description:Morven Gold (Health warning)		Color:3+WBC		

Time Breakup

Setup Time

Activity	Start	End	Speed	Sheet No	Down Time	Duration	Person Respon	Remarks
Ink removing	11:21	11:30				9		2 workers at unit 4 and 5. after 1 min 3 workers cleaning
Ink inserting in duct	11:30	11:45				15		By 1 workers, other 2 are free and one is arranging board, operator in plate arrangement
Blanket cleaning	11:45	11:50				5		By 3 workers in 3 units, workers misscommunication (downtime for 1 min)
Plate change	11:51	12:05				14		Plate change of 4 units, 1 in feeder adjustment, 1 in plate change (2 workers free)
Blanket change(Coating unit)	12:05	12:16				11		By two workers, 2 are free and 1 in water coater arrangement
Water fountain roller cleaning	12:17	12:21				4		By 3 workers and water level reducing
Plate cleaning	12:21	12:23				2		By 3 workers, 1 in angle setting, operator in color setting
					TOTAL	60		
Make Ready								
Board print for inspection	12:23	12:45				22		
Blanket cutting	12:45	1:05				20		
					TOTAL	42		
Running								
Total								
Under Maintenance								

Remarks:

Plates must have arranged before job.

In start of setup time, 2 workers were free for 1 min, 1 is arranging cloth piece, operator is discussing with worker for a new job. Communication gap, blaming for cloth piece, 3 workers were free from 11:32 to 11:37. Only 1 worker is cleaning and 1 in pile making while other are free (Cleaning by placing knife in unit 4). At 11:45, 2 workers cleaning unit 1, 1 is pile making and 1 is balancing alcohol level.

G.5.1: SMED DATA COLLECTION FILLED FORMAT

APPENDIX - C

MERIT PACKAGING LIMITED MT-P2-F6.1

Month:Jan/16 Daily Machine Health Report

Date	ESR Ref No.	PROBLEM DESCRIPTION	N.O.J	ACTION TAKEN	D.T(Hrs)	REMARKS
6-Nov-14	11,5	FEEDER COMPRESSOR PROBLEM	ELECT	TRIPING PROBLEM	2	WIRING ISSUE
13-Nov-14	11.1	FEEDER COMPRESSOR PROBLEM	MECH	COMPRESSOR SEVICING AND CLUTCH REP	2	REPAIR+SERVICING
14-Nov-14	11.14	DELIVERY GRIPPER PROBLEM	MECH	GRIPPER SERVICING	3	SERVICING
17-Nov-14	11.17	AIR PROBLEM	MECH	PIPE CHANGED	0.5	PIPE REPLACED
18-Nov-14	11.22	MAIN MOTOR + CAM FOLLOWER	ELECT/MEC	CONTACTOR AND CAM FOLLOWER REPLAC	3	
20-Nov-14	11.25	CHILLER PROBLEM	MECH	GAS REFILLED	1	
24-Nov-14	11.28/11.30	BLOWER PROBLEM/AIR COMPRESSOR	MECH	BLOWER SERVICING/MOTOR FAULTY	3.5	
29-Nov-14	11.33	FEEDER COMPRESSOR SERVICING + B	MECH	SERVICING	2	
2-Dec-14	12.01	Delivery chain problem	MECH	Chain greasing	1 hr 15 min	
5-Dec-14	12.07	Air Leakage From Ink Unit Grill	MECH	Pneumatic pipe changed	30 min	
15-Dec-14	12.18	Delivery Gripper Sheet Missing Problem	MECH	Servicing	2 hr 30 min	
26-Dec-14	12.22	Coating Pump not Work	MECH	Coating Pump servicing	1	
9-Jan-15	1.13	2nd Unit Ink duct problem	Elec	Contactor replaced	1.5	
23-Jan-15	1.27	Cooling pump airlock	Mech	Insufficient amount of water, tank refilled	0.5	
6-Feb-15	2.04	Headlay and gripper problem	Mech	Grippers adjusted and headlay setting	2	
10-Feb-15	2.08	Headlay out problem	Mech	Headlay adjusted	1.5	
12-Feb-15	2.1	Delivery side joker	Mech	Side joker repaired	2.75	
16-Feb-15	2.15	Check Technotrans problem	Mech	Technotrans servicing	3	
17-Feb-15	2.19	Gripper bar problem	Mech	Gripper bar Bearing changed and serviced	2.75	
11-Apr-15	4.11	5th unit ink roller not working	Mech	Ink roller serviced	1.5	
19-Apr-15	4.25	3rd unit safety lock problem	Elect	Safet lock repaired	1.5	

G.6.1: HISTORIC DATA SAMPLE OF DAILY MACHINE HEALTH REPORT

APPENDIX - D

M/C No	Description	Lot #	Customer Name	P.O	Board Name	Order Qty (Ups '000)	Size L X W	GSM	UPS	Grain (sheet)	IMP	Colours	Add Sheets	Sheets Required
OP-18														
	SUPREME -(MEDIUM)	1188	Uni Lever	0719	POLO	2,200	490 X 805	250	10	Right		4+WBC	14,500	234,500
	SHAN CHICKEN GINGER 50GM USA/CAN/**PO#1355 Online FRIDAY 10:30 AM**	1255	SHAN FOODS	0731	ELEGANT	25	595 X 760	300	9	Right		5+UV	322	3,100
	SHAN CHICKEN HANDI 50GM USA/CAN/IND **PO#1355 Online FRIDAY 12:00 PM**	1256	SHAN FOODS	0731	ELEGANT	25	595 X 760	300	9	Right		5+UV	322	3,100
	SHAN CHICKEN WHITE KARAHI 50GM USA/CAN **PO#1355 Online FRIDAY 03:00 PM**	1257	SHAN FOODS	0731	ELEGANT	25	595 X 760	300	9	Right		5+UV	322	3,100
	PEANUT PIK FAMILY PACK	1252	EBM	0752	POLO	150	790 X 680	250	9	Wrong		4	833	17,500
	PEANUT PIK HR DISPENSOR	1249	EBM	0752	POLO	400	725 X 610	275	4	Wrong		4	5,000	105,000
	PARTY FAMILY PACK	1253	EBM	0752	POLO	100	790 X 680	250	9	Wrong		5	889	12,000
	PARTY HALF ROLL DISPENSOR	1248	EBM	0752	POLO	300	725 X 610	275	4	Wrong		5	4,000	79,000
	GLUCO PLUS TICKEY PACK Rs. 5	1250	EBM	0752	POLO	250	390 X 780	300	2	Right		4+WBC(UV)	6,500	131,500
	GLUCO PLUS HALF ROLL DISPENSER Rs 15	1251	EBM	0751	POLO	200	775 X 590	275	4	Wrong		4	3,000	53,000
	RAAZ ISPAGHOL 25GM **NEW ARTWORK**	1241	RAAZ IND	-	NINGBO	50	545 X 890	250	16	Right		4+UV	275	3,400
	CRICHU DALMOOTH BOX 5	1243	PAK FOODS	-	POLO	25	805 X 570	300	2	Wrong		4+UV	700	13,200
	DAAL MASTI BOX	1244	PAK FOODS	-	POLO	10	795 X 690	300	4	Wrong		4+UV	200	2,700
	CRICHU NIMKO MIX	1245	PAK FOODS	-	POLO	50	805 X 570	300	2	Wrong		4+UV	1,500	26,500
	MEETHI MASTI NIMCO MIX RS 5	1246	PAK FOODS	-	POLO	60	795 X 690	300	4	Wrong		4+UV	900	15,900
	KROOK MIX NIMKO BOX	1247	PAK FOODS	-	POLO	25	645 X 890	300	4	Right		4+UV	350	6,600
	BOXES RS. 10 OVEN FRESH CHOCOLATE CAKE	1204	K.S.Sulemanji	0620	POLO	100	965 X 715	300	4	Wrong		5	1,500	26,500
	Layer Cake (STRAWBERRY WITH VANILLA) Rs. 10	1205	K.S.Sulemanji	0620	POLO	100	965 X 715	300	4	Wrong		4	1,500	26,500
	BOXES CUP CAKE BLUEBERRY	1203	K.S.Sulemanji	-	POLO	100	415 X 835	300	2	Right		5	3,000	53,000
	KALA KOLA LARGE 39 (NINGBO 350GSM)	1093	UNITED	0608	NINBO	25	735 X 475	350	6	Wrong		5+UV	1,033	5,200
	TOUCH 3 PACKS RIBBED RED (PK.PKGT 45) **NEW ARTWORK**	1242	GREEN STAR	0652	ELEGANT	600	545 X 800	260	30	Right		UV	1,431	21,431
	TAPAL DANEDAR 95GM HARD PACK	1098	TAPAL TEA	0496	POLO	2,000	965 X 500	250	10	Wrong		UV	15,000	215,000
	NATIONAL CHAAT MASALA 50GRAMS LOCAL	1228	National Foods	0673/0671	POLO	1,700	545 X 950	300	12	Right		UV	8,333	150,000
	OREO 12X BAR PACK - LOCAL(29.4GM) **(300GSM)**	1233	CBL	0697	POLO	400	660 X 815	300	4	Wrong		UV	5,000	105,000
	OREO 6X SNACK PACK - LOCAL (58.8gm) **(300GSM)**	1258	CBL	0717	POLO	150	630 X 795	300	4	Wrong		UV	2,000	39,500
	NATIONAL - PKT BIRYANI MASALA 45G LOCAL	1210	National Foods	0568/0745	POLO	970	585 X 760	300	9	Right		Back Print	7,222	115,000

G.7.1: MASTER PRODUCTION PLANNING DATA