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# Reliability Assessment of Production Machines at a Local Industry

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***Abstract*—**OEE offers an effective framework to monitor and enhance equipment performance. This metric integrates three key components: availability, performance, and quality, which together provide a detailed insight into the operational effectiveness of machinery. The method used in this study is arithmetic calculation of overall equipment efficiency (Availability, Performance and Quality).The results of a thorough data-driven approach offer paper sack makers practical suggestions to boost output, cut waste, and improve long-term equipment dependability, all of which contribute to more sustainable. The current OEE of Thal Packaging calculated was 58%.The downtime for the January 2023 was 6108 minutes. The vital few causes of Thal Packaging downtime was equipment failure, Tube shortage, Paper shortage, Power shutdown and Machine Idleness.

***Keywords*—**ReliabilityAssessment, Availability, Performance, Quality, Manufacturing and Production System.

## I. Introduction to Reliability

Reliability in the manufacturing industry is a critical factor that directly impacts production efficiency, product quality, and overall operational performance.[1] Conducting a comprehensive reliability assessment helps organizations identify potential issues, reduce downtime, and optimize the lifespan of machinery, equipment, and processes. This assessment involves systematically evaluating the ability of manufacturing systems to perform their intended functions consistently, with at least failure, over specified time. Due to rising demand for paper bags**,** companies are under increasing pressure to meet production targets and fulfill customer orders on time. To stay competitive in this growing market, it's crucial for manufacturers to minimize downtime and maintain high efficiency in their operations. This makes reliable equipment essential especially when it comes to paper bag machines. Reliability is not only about avoiding breakdown **s**it encompasses several dimensions that together determine how dependable a machine truly is. To understand the types of reliability such as mean time to failure, mean time to repair, reliability centered maintenance and design reliability can help paper bag industries make informed decisions when selecting or upgrading their paper bag machines.

MTBF is a fundamental reliability metric used to measure the average time between consecutive failures of a system or component. A higher MTBF signifies greater reliability, while a lower MTBF indicates that equipment is more prone to frequent failures, necessitating a more detailed inspection or redesign.[2].MTTR measures the average time required to repair and restore equipment to its normal operational state after a failure occurs. The faster the repair time, the less downtime a manufacturer experiences, which is crucial in maintaining production schedules and minimizing costs associated with stoppages.[3].RCM is a proactive approach that integrates maintenance activities into the design, operation, and maintenance stages of machinery and systems. This method focuses on ensuring reliability by performing maintenance based on the importance of equipment, operational risks, and failure consequences. Recently, manufacturing firms facing capacity challenges opt to increase hours and invest in new machinery or lengthen shifts. As a different strategy, businesses ought to select improving the efficiency of their current machines to enhance equipment reliability, boost operator performance, and reduce downtime time.[4]

## II. Introduction to Industry

Thal Limited is the parent company of the Pakistan Papersack Division. Pakistan Papersack, the first multi-ply maker, began operations in the 1970s and has dominated the industry ever since. We are ideally situated to quickly meet the growing demand for our products thanks to our two strategically placed production facilities in Gadoon, Khyber-Pakhtunkhwa, and Hub, Baluchistan. Both of these plants can currently produce 150 million bags, and we intend to increase their capacity in the future to maintain our position as leaders. Cement, chemicals and dyes, bonding adhesives, industrial salt, calcium, gypsum, carbon black, milk powder, and guar gum are just a few of the industries that the company serves with high-quality packaging solutions. Pakistan Papersack Division recently added Self-opening bags (single or multi-ply square bottom) to its portfolio. These bags have an annual capacity of 25 million.

Burger wraps, tray liners, and SOS bags for food service and delivery are among our offerings in the fast food sector.

## III. Problem Statement

Thal Packaging is facing significant production downtime and inefficiencies, leading to increased costs and reduced profitability. Despite ongoing maintenance efforts, equipment performance remains suboptimal. This research aims to assess the company's Overall Equipment Efficiency (OEE) to identify root causes of downtime, improve equipment reliability, and enhance overall productivity, ultimately reducing operational costs and improving competitiveness.

## IV. Aims and Objectives

The aims and the objectives of the research work are as under:

- It is to measure and assess the efficiency of manufacturing equipment through the OEE framework, ensuring that machinery performs at its optimal capacity in the Papersack industry.
- To identify areas where equipment reliability can be improved, contributing to longer operational life, reduced downtime and foster a culture of continuous improvement by utilizing real-time data for decision-making that drives reliability and performance.
- To use OEE results to plan and schedule maintenance activities, ensuring fewer breakdowns and minimized disruptions in the production flow and systematically collect and analyze data on Availability, Performance, and Quality metrics that contribute to OEE.

## V. Significance of this Research

- Machine performance monitoring: OEE tracks the performance of individual machines,such as paper machines, cutting machines, and sewing machines.
- Downtime analysis: OEE identifies and categorizes downtime, enabling manufacturers to address root causes and implement corrective actions.
- Production capacity optimization: By analyzing OEE data, manufacturers can optimize production capacity, reduce bottlenecks, and improve overall efficiency.
- Quality control: OEE can be used to monitor quality parameters, such as defect rates, and enable data-driven decision-making.

## VI. Literature Review

Automating data collection procedure is a critical objective, as it will bring about a great deal all the more convenient and exact data that gives managers and operators the capacity to respond rapidly to any issues that emerge. It is likewise vital to give operators the objectives that provide real time feedback on the current standards.[5]

Overall Equipment Efficiency including lean manufacturing, maintenance management, Total Productive maintenance and Lean tools. The smooth continuity of production systems have been highly impact on maintenance management due to its financial impact on the final product. Secondary data used from past empirical studies in this work. The conclusion of this paper is due to lack of awareness about the overall equipment efficiency approach the industrialists are reluctant to adopt this approach in the industry.[6]

The research of improvement productivity through the combination of statistical process control, autonomous maintenance. The research was carried out on the tiles manufacturing company in which two lines working. The tile size considered was 30×30 cm because the same tile company producing 60% of the total production. There are total seven processes in the tile manufacturing including dryer exit, blower, double disk cabin 1, brushing machine, double disc cabin 2, spray cabin and alumina track. The conclusion of this research is due to use of above three strategies the defect rate reduction is 6.12% from 14.61% and the decrease in breakdown of the machine is from 2502 minutes to 1161 minutes which resulted in upgradation of overall equipment efficiency from 22.12% to 28.61%.[7]

In high salaried countries overall equipment efficiency is counted. The main function of using OEE is to count the waste time which are unplanned downtime and planned downtime. The research is focusing on high mix low volume manufacturing environments.Planned downtime considers lunch break while unplanned downtime considers speed losses, minor stops, sudden breakdowns. Total equipment effectiveness production (TEEP) is a technique which focusing how to reduce planned downtime mainly used by the production managers.[8]

OEE has significant impacts in the chemical industries. This work was carried out on the maintenance systems. The company manufacturers methanol, nitric acid, sulphuric acid, ammonium sulphate, liquid carbon dioxide and porous ammonium nitrate. The data collected through questionnaires, company logbook. The overall equipment efficiency of the chemical manufacturing company calculated was 37% which are far below than the international standards. The result concluded that maintenance practices involved only 14% of the machine operators. The cause of downtime in this chemical industry was primarily from shortage of labours mostly, shortage of materials and power shutdown problems. The TPM strategy can be used in the chemical company to reduces losses and rework.[9]

The production optimization in a handbag packaging industry to gain best possible balance of workloads through. The workload on the assembly line have been divided by the foreman that how much time each work takes. The problem raised in assigning the position to each operator is after sometime redistribution was needed due to job variation and shifts change. The data utilized by four different models traditional routines, optimization algorithm of Kottas and Lau, Bucket Brigades and bucket brigades line performance. The

research work shown a great increase in production performance, operators are self-aware about assemble any bag without assembly redesigning. [10]
The reliability in which there is no data available of failure is difficult. In this research work they used the possibility approach rather than probability approach. The new quantitative method used new approach Dempster-Shafer Theory in which an index is needed for decision making due to unavailability or insufficient data. The decision can be made by adopting this new concept of risk-based reliability.[11]
Reducing non-value-added operations that take place during machine failure can improve the overall efficiency of the equipment. The production of surface mounting technology was the subject of the case study. The key component in determining the production systems' efficiency is availability. The equipment's overall efficiency increased from 83.4 to 84% as a result of the shorter changeover time. The production of units enhanced per month were 2180 which increased 545000 Malaysian Ringgits monthly. [12]

To produce high production to get maximum efficiency on small and medium size enterprises (SMEs) as high production enterprises calculated its efficiency on real time. The six big losses proposed in the availability, performance and quality of the production systems. The data collected through a sensor with some inputs at the PCB. Analysis software was used to analyze the data and calculates OEE (number of parts produced, length of downtime, reuse work). Downtime at any instant can be find at one click. The research work objective was to find cost effective production approach with the use of no complicated and expensive software. [13]

A case study to determine overall equipment efficiency of flexographic printing press. Total Predicative maintenance approach has been applied for reduction in downtime. 5 whys analysis has been utilized in this research work. The time saved in different sections from the current state was 7985 minutes in the matching with liquor section, 4177 minutes in shade card presentation, 6051 minutes in doctor blade problem and 16716 minutes in ink mottling. OEE act as a major calculator to shown the areas where improvement was needed. [14]

The sigma metric utilization to find the performance of the instruments through external quality assessment. The data obtained from five different external quality assessment programs. The five different programs of five different countries including American EQA program, Canadian EQA program, Domestic EQA program, United Kingdom EQA program and Australian EQA program. This approach can be used as preliminary for purchasing new instruments to get better insight of the instrument performance.[15]

The overall equipment efficiency utilized time study in the aerospace industry. The main cause of lowering OEE in the industry is the autoclave process which took long time. The world class standard of OEE is availability (90%), performance (95%) and Quality (90%) given by the Frost and Sullivan. The main time study techniques are stopwatch, work sampling, predetermine motion time. The availability increased from 84.62% to 89,26%, performance and quality remained the same, overall equipment efficiency increased from 84.32% to 88.94%. [16]
The lean approach used to enhance overall equipment efficiency of a small medium enterprise (SME). The OEE is increased by minimization of process setup time, changeover time and elimination of unnecessary activities. The tool used for improvements are project charter, Kano questionnaire, 5S, market analysis and value stream maps. [17]

The case study a new scoring approach to find Overall equipment efficiency, Total effective equipment performance (TEEP) and Total productive maintenance (TPM). The barcode system was installed with the ERP system. The calculated value will be unreliable if the data provided is inaccurate. The lean manufacturing focusing on the reducing of waste, reduction of downtime and utilization of natural resources. Under lean production the TPM and OEE metrics are efficiently contributing in the balancing of nature. [18]

The equipment efficiency which plays a vital role in the financial stability of the manufacturing company. It impacts various factors like throughput, downtime, costs and return on investments. The case study was carried out on the semiconductor backend facility. The research integrated OEE measurement system with personal trainings and lean six sigma.The methodology of the research was comprised on Bottleneck management systems, OEE improvement teams, adjustment of the operations management procedures which increased the overall facility by 18% in less than eight weeks.[19]

The six sigma brings the organization's increased efficiency into sharp relief. It focusses on making small, ongoing adjustments to advance the industry's current technologies. It helps find solutions for enhancing the process that must be handled throughout time by identifying the root causes of problems. [20]

Production management relies heavily on efficiency, since many methods have been developed with the ultimate objective of improving industrial performance. Any organization's management routines that need to be monitored on a regular basis include worker responsibility, administration obligations, organization, and employee contributions.[21]

Downtime is one of the main factors lowering a facility's OEE since it may require a significant investment of scheduled production time. The period of time that any planned overhauls or repairs are completed as part of predictive or preventative maintenance tasks. To ensure that their plans work as intended, businesses should set goals and test them frequently. Schedule maintenance techniques supported by OEE were essential to the efforts to reduce downtime incidents and, as a result, costs.

Reducing downtime is a maintenance function that is not well understood.[22]

Productivity of any industrial production line is exceptionally vital in light of the fact that it results in an enhanced generation and use of assets accessible. Management usually ought to have the capacity to search for relevant production data and precisely interpret data. Notwithstanding, an exact on line data management system can guarantee that these issues are overcome.[23]

## VII. METHODOLOGY

The research process consists of several steps. First, a detailed study was conducted about the manufacturing processes of the proposed industry to know about the existing problems. It has been observed that the industry is a traditional manufacturing based industry with no consideration of improving the production processes. The problems identified were in the production of paperbags. After a detailed review, the data was collected about the major downtimes for possible improvement and analyzed using the OEE and cost analysis was carried out for comparison. Based on these observations several suggestions and recommendations were given to the said industry for making necessary improvements. The research data collection is majorly based upon the secondary data collected from the log books, production sheets in the Papersack industry.

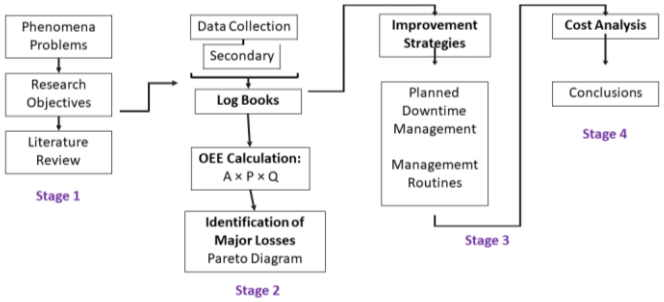



Figure 1. Methodology

### A. Overall Equipment Efficiency

OEE measures the total equipment performance which is the degree to which the equipment is doing, what it is supposed to do. OEE is an important tool which identifies areas that may have bottleneck in the production line, covering three major aspects such as the availability, performance, and quality rate of the output of equipment. OEE is considered as one of the important content for total productive maintenance (TPM) and lean manufacturing philosophy. Additionally, it is an important metric for measuring the success of manufacturing improvement approach known as Total Productive Maintenance (TPM).Overall equipment effectiveness consists of three components which are availability (1), performance (2) andquality(3). [24]

### B. Data Collection

The research data collection is majorly based upon the secondary data collected from the log books, production sheets in the Papersack industry. There are total six machines in the industry Tuber 1(Industrial Sack Line), Tuber2(Old Cement Line), Tuber3(New Cement Line), Bottomer 1(Old Cement Line), Bottomer 2(Industrial Sack Line) and Bottomer 3(New Cement Line). Operation of machines depends on the type of Paperbag production and production quantity. Two types of paperbags has been manufacturing in the industry. Cement bags and Industrial Sacks. The demand for the data collected month was 2.8 million. Average Capacity of Thal Packaging is 6.8 million per month.

TABLE I. Overall Equipment Efficiency data Thal Packaging

| Serial. No | Date | Machine No. | Cycle time in second | OK Qty | Total Qty | Planned Down Time (Minutes) | Available Time (Minutes) | Actual Operating Time Minutes | Down Time |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | T-3 | 0.36 | 30000 | 30183 | 60 | 419 | 181.1 | 120 |
| 2 | 2 | B-1 | 0.4 | 22500 | 23625 | 60 | 419 | 158 | 165 |
| 3 | 3 | T-3 | 0.36 | 45000 | 45353 | 60 | 419 | 272 | 0 |
| 4 | 3 | B-1 | 0.4 | 51975 | 51975 | 60 | 419 | 347 | 0 |
| 5 | 4 | T-1 | 0.6 | 3200 | 3200 | 60 | 419 | 32 | 180 |
| 6 | 4 | T-3 | 0.36 | 50000 | 50201 | 60 | 419 | 301 | 0 |
| 7 | 4 | B-1 | 0.4 | 52775 | 53079 | 60 | 419 | 354 | 0 |
| 8 | 5 | T-1 | 0.6 | 4000 | 4000 | 60 | 419 | 40 | 120 |
| 9 | 5 | T-3 | 0.36 | 39600 | 39887 | 60 | 419 | 239 | 90 |
| 10 | 5 | B-1 | 0.4 | 39900 | 39937 | 60 | 419 | 266 | 90 |
| 11 | 6 | T-1 | 0.6 | 1800 | 1800 | 60 | 419 | 18 | 390 |
| 12 | 7 | T-1 | 0.6 | 3000 | 3000 | 60 | 419 | 30 | 0 |
| 13 | 12 | T-3 | 0.36 | 7000 | 8029 | 60 | 419 | 48 | 330 |
| 14 | 12 | B-1 | 0.4 | 10150 | 10153 | 60 | 419 | 68 | 330 |
| 15 | 13 | T-3 | 0.36 | 30000 | 30345 | 60 | 419 | 182 | 168 |
| 16 | 13 | B-1 | 0.4 | 29800 | 29979 | 60 | 419 | 200 | 180 |
| 17 | 14 | T-3 | 0.36 | 49000 | 49512 | 60 | 419 | 297 | 0 |
| 18 | 14 | B-1 | 0.4 | 50000 | 50125 | 60 | 419 | 334 | 0 |
| 19 | 16 | T-2 | 0.6 | 13000 | 13148 | 60 | 419 | 131 | 0 |
| 20 | 16 | T-3 | 0.36 | 59600 | 59900 | 90 | 869 | 359 | 360 |
| 21 | 16 | B-1 | 0.4 | 69900 | 70097 | 90 | 869 | 467 | 300 |
| 22 | 17 | T-1 | 0.6 | 15000 | 15055 | 60 | 419 | 151 | 0 |
| 23 | 17 | T-2 | 0.6 | 27000 | 27135 | 60 | 419 | 271 | 60 |
| 24 | 17 | T-3 | 0.36 | 92400 | 93039 | 90 | 869 | 558 | 90 |

### C. Overall Equipment Effectiveness Calculations

$$\text{Availability}(A) = \frac{\text{Operating Time}}{\text{Planned Prodction Time}} \quad (1)$$

Whereas
Planned Production time = Total available time – Schedule downtime
Operating time = Total available time – (Schedule downtime + Unschedule downtime)

$$\text{Performance} = \frac{(\text{Standard Cycle Time} \times \text{Quantity}}{\text{Running or Operating Time}} \quad (2)$$

**Whereas**

$$Running\ Time = Available\ Time - (\text{Planned Down Time} + \text{Unplanned Downtime})$$

$$\text{Running Time} = \text{Available Time} - (\text{Planned Down Time} + \text{Unplanned Downtime})$$

$$\text{Quality}(Q) = \frac{\text{Total Production} - \text{Rejected}}{\text{Total Production}} \quad (3)$$

**Overall Equipment Effectiveness (OEE)**

$$\text{OEE}(\%) = A \times P \times Q \times 100\% \quad (4)$$

Whereas A is availability, P is performance and Q is quality

The total available time for the month January 2023 is 46468 minutes while the down time is 6108 minutes.

(1) => $\text{Availability} = \frac{46468-6108}{46468}$

$$\text{Availability} = \frac{40360}{46468}$$

$$\text{Availability} = .868$$

The total time is 870 hours which are 52200 minutes. Planned downtime is 5520 minutes and downtime is 6108 minutes which makes 11628 minutes. The Running operating time can be obtained by subtracting 11628 minutes from 52200 minutes which gives 40572.

(2) =>

$$Performance = \frac{27175}{40572}$$

$$Performance = 0.669$$

Startup rejects at the beginning of the manufacturing process and production rejects which are produced after manufacturing process are two types of quality losses. The quality of Thal Packaging is extremely good. The total Papersacks produced are 3989280 while the accepted Papersacks are 3966900.

(3) =>

$$Quality = \frac{3989280 - 22380}{3989280}$$

$$Quality = \frac{3966900}{3989280}$$

$$Quality = 0.994$$

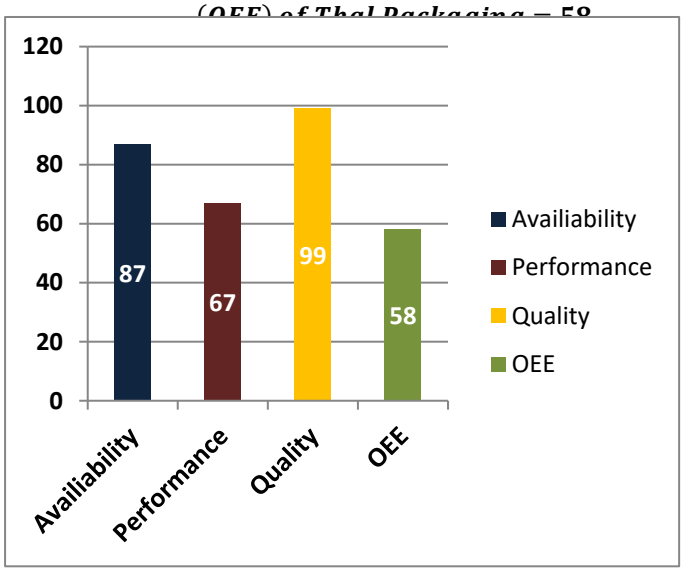
The Overall equipment efficiency of Thal Packaging can be calculated by multiplying equations (1), (2) and (3).

$$(OEE) = Availability \times Performance \times Quality$$

$$(OEE) = 0.87 \times 0.67 \times 0.994$$

$$Overall\ Equipment\ Efficiency\ (OEE) = 0.579$$

$(OEE)$ of Thal Packaging = 58




Graph 1

The benchmark about the good score of OEE was presented in 2005 by Frost and Sullivan. The idea was to define world class standards for calculated OEE is 85% which was derived from the three factors of OEE which are availability, performance and quality. The availability is 90%, performance is 95% and quality is 99% [25].

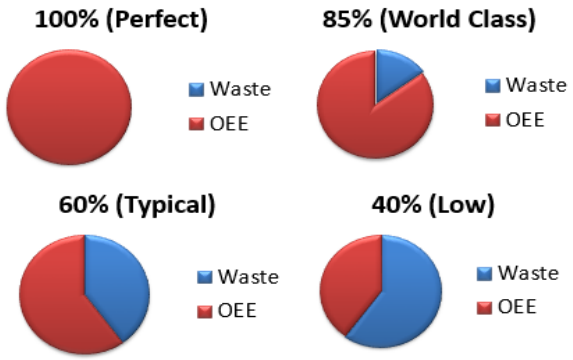



Figure 2 (OEE Classification)

*D. Downtime Analysis*

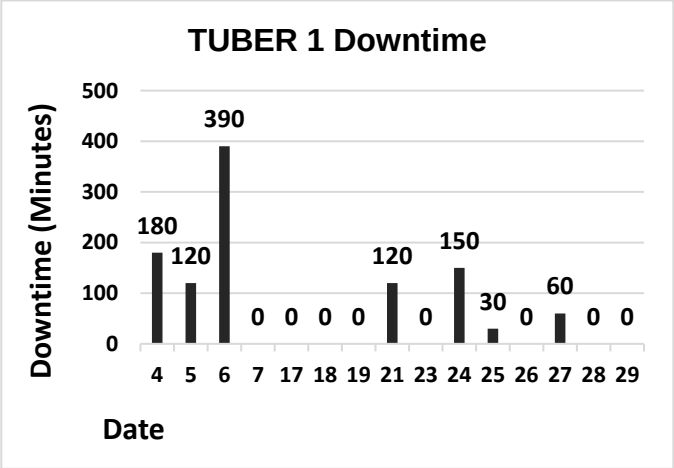
Losses from availability (such as breakdowns, changeovers), performance (like stoppages, decreased speed), and quality (startup rejects and process rejects) are responsible for major breakdown in quality. Local industries are not employing lean methods to recognize these losses that affect their production and result in substantial expenses. Breakdown loss is a significant problem in manufacturing sectors.The downtime (in hours) in the Thal Packaging is due to various factors shown in the table.

Table II. Downtime Factors affecting

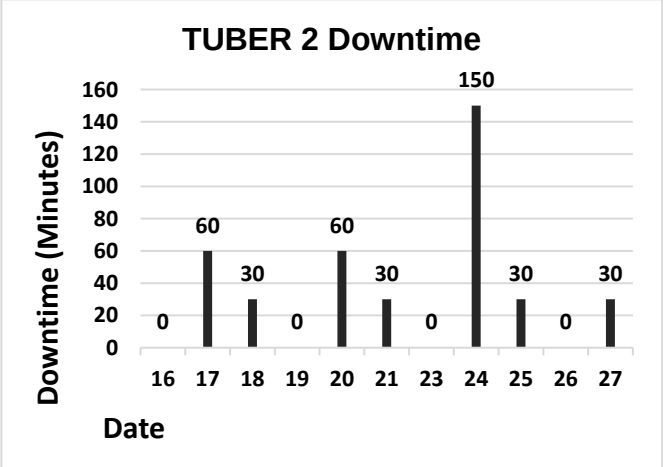
| 12.5 | 1.5 | 10.5 | 5.5 | 1 | 12.5 | 11.3 | 19 | 6.5 | 21.5 |
|---|---|---|---|---|---|---|---|---|---|
| Paper shortage | Stereo not available | Setup and adjustment | Change over | Speed Loss | Tube Shortage | Power downtime | Equipment Failure | Spares Not Available | Machine Idle |
| | | 1.5 | | | | | 0.5 | | |
| | | | | | 2 | | 0.75 | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | 3 | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | 1.5 | | | | 0.5 | | |
| | | | | | | | 1.5 | | |
| | | | | | 1.5 | | | | |
| | | | | | | | | 6.5 | |
| | | | | | | | | | |
| | | 3.5 | | | | | 2 | | |
| | | | | | 5.5 | | | | |
| | | | | | | 0.8 | 1 | | 1 |
| | | | | | 2 | | | | 1 |

*E. Downtime of Thal Packaging Production Machines*

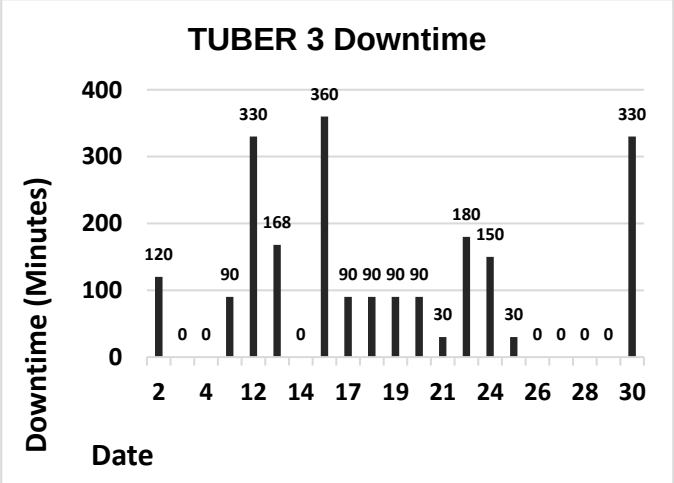
The downtime of six production machines (three Tuber and Three Bottomer). The downtime (minutes) of machines on various dates explained in the graphs.



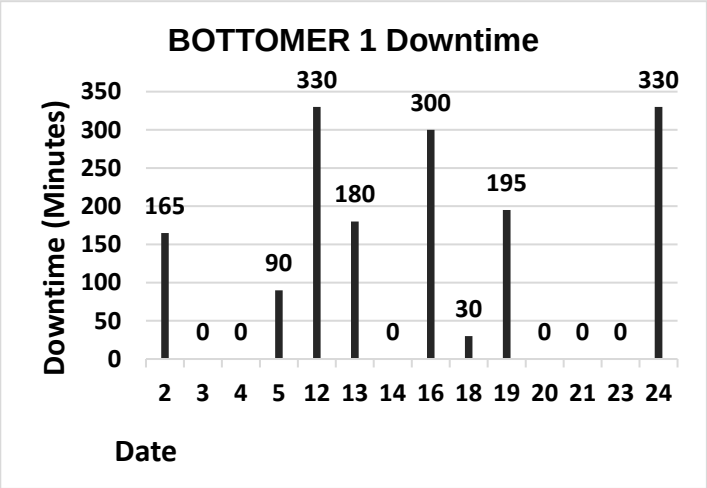

Graph 2



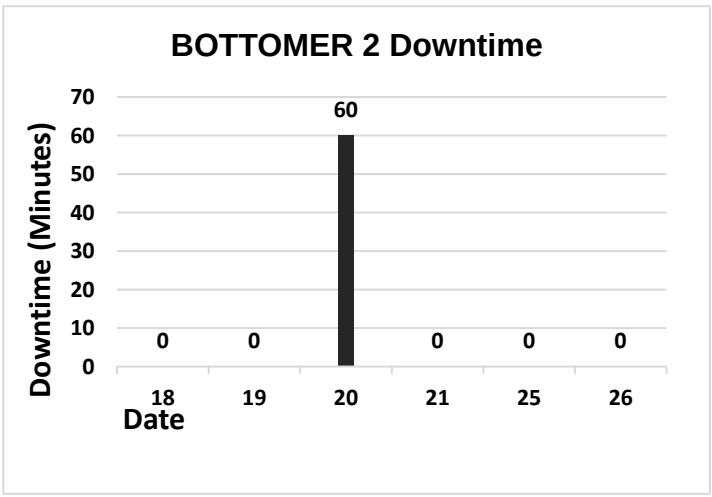

Graph 3



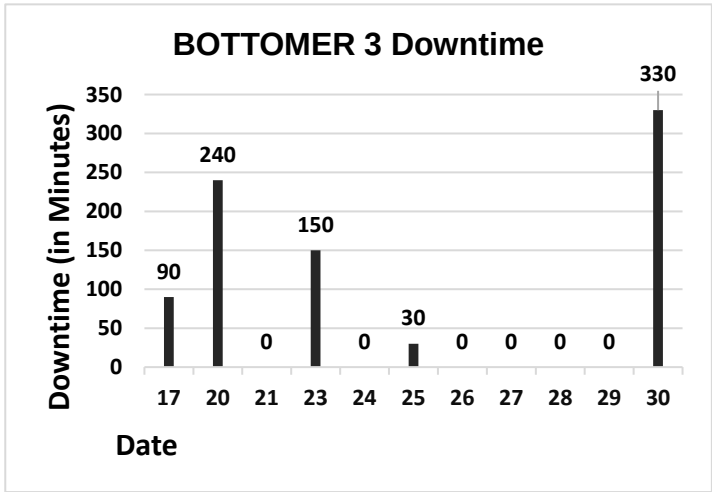

Graph 4




Graph 5



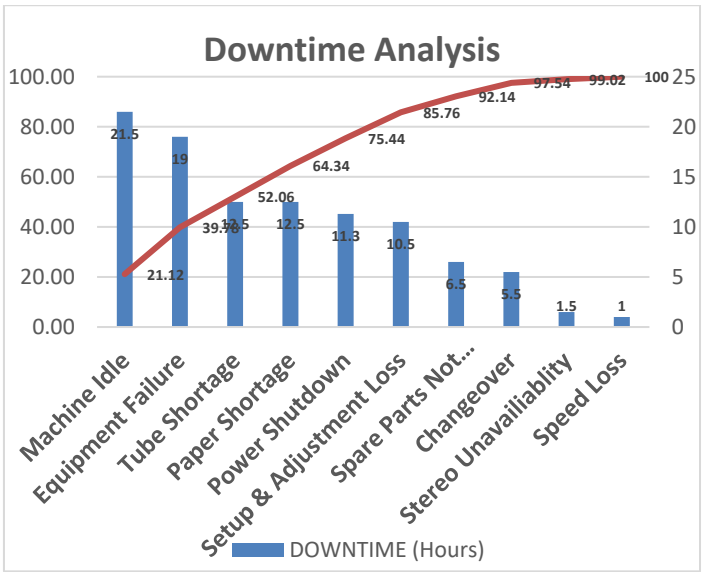

Graph 6




Graph 7

*F. Pareto Analysis of Downtime*

The factors affecting due to which Thal Packaging faces severe downtime are explained in the graph 8. The downtime factors explained are based on the monthly data.



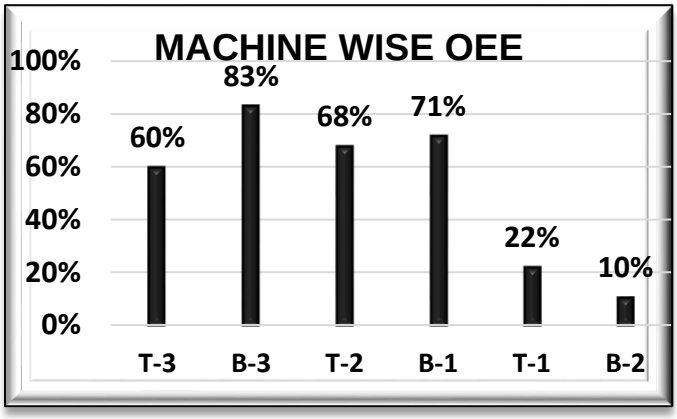

Graph 8

The Vital few downtime in Thal Packaging are as follows:

- Machine Idlness
- Equipment Failure
- Tube Shortage
- Paper Shortage
- Power Shutdown

*G. Machinewise Effiiciency of Thal Packaging*

The efficiency of all six machines calculated based on the Overall Equipment Efficiency calculations:




Graph 9

## VIII. IMPROVEMENT STRATAGIES

The stratagies to improve downtime in the Thal Packaging, the following recommendations are made for necessary actions.

### *A. Planned Downtime Management*

- Machine Idleness:

Optimize production scheduling: Plan production runs efficiently to minimize idle time. [26]
Implement predictive maintenance: Regularly inspect and maintain equipment to prevent unexpected failures.
Train operators: Ensure operators are skilled in machine operation and basic troubleshooting.

- Equipment Failure:

Regular maintenance: Schedule routine maintenance to prevent equipment failures.
Condition-based maintenance: Monitor equipment condition and perform maintenance when necessary.[27]
Spare parts management: Keep essential spare parts in stock to minimize repair time.

- Paper Shortage:

Inventory management: Monitor paper stock levels and reorder when necessary.
Supplier management: Develop relationships with reliable suppliers and negotiate favorable terms.
Just-in-time delivery: Arrange for timely paper deliveries to minimize stockouts.

- Plan maintenance during scheduled downtime.

Utilize downtime for operator training or other non-production activities.[28]
Track downtime reasons and duration to identify areas for improvement.

### *B. Management Routines*

- Ensure effective communication between production, maintenance, and management teams.
- Track key performance indicators (KPIs) like downtime duration, production efficiency, and equipment reliability.[28]
- Regularly review production data and downtime reasons to identify areas for improvement.

## IX. RESULTS AND DISCUSSION

Reliability is a characteristic of a system or a component which can perform its intended functions under given conditions and a specified time period. Achieving high productivity and reducing downtime in any manufacturing system requires that machinery, equipment, and processes operate consistently and effectively. The idea of dependability evaluation is one of the core components of guaranteeing such performance. A systematic method for assessing and enhancing these systems' dependability, reliability assessment finds possible flaws before they cause expensive malfunctions or interruptions. Finding the weak points that have an impact on Thal Packaging's total equipment efficiency is the ultimate purpose of the OEE metrics application. The Overall Equipment Efficiency of Thal Packaging calculated was 58% . The main loopholes involved in the downtime of the industry was Machine Idleness, Equipment Failure, Tuber Shortage, Paper Shortage and Power shutdown. The Overall equipemt efficiency of six machines has been calculated in the research.

## CONCLUSION

The research concluded equipment performance is greatly impacted by downtime, which has a major effect on overall equipment efficiency (OEE). One important indicator of how well a manufacturing operation is being used in relation to its full capacity is OEE. Three primary aspects are taken into account when calculating it: quality, performance, and availability. The Availability component of OEE is directly impacted by downtime, and enhancing manufacturing process efficiency requires an understanding of its function.**The research found** Identification of Major losses, choosing an appropriate method plays a crucial role in identifying the key factors affecting downtime.The research has pointed out several loopholes in production system.This research is also valuable for evaluating the current management techniques.

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