OEE (Overall Equipment Efficiency) Analysis and Recommendations based on uptime data at a Crane Manufacturing Unit

Capstone Project – Business Data Management

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Final Project Report on OEE Analysis and Recommendations based on uptime data at a Crane Manufacturing Unit

Executive Summary:

Sanjyot Engineering Works is a prominent B2B manufacturing firm specializing in heavy-equipment production, serving major industry players such as Ceat Tyres, Godrej & Boyce, and Mukand Limited. With an estimated annual turnover of ₹4 Crores, the company holds a vital position within the industrial manufacturing landscape. Despite its strong market presence, the firm faces notable operational challenges—specifically frequent machine breakdowns, prolonged maintenance downtimes, and a persistent shortage of skilled labor. These issues contribute to production delays and missed business opportunities. High attrition rates and inconsistent worker attendance further exacerbate disruptions in production efficiency.

To better understand and address these inefficiencies, Sanjyot Engineering Works provided access to key operational datasets, including sales records, machine downtime logs, and worker attendance data. The raw data was systematically cleaned and transformed to enable accurate statistical analysis.

An Overall Equipment Effectiveness (OEE) analysis—focused on availability, performance, and quality—revealed that the firm was underperforming particularly in the areas of availability and performance. These were identified as critical bottlenecks in operational efficiency. A deeper analysis of downtime data highlighted two specific machines as significant contributors to production delays, showing the lowest uptime. It was recommended that these machines undergo more frequent and proactive servicing.

Multiple regression analyses were conducted from five distinct perspectives to examine the interrelationships among key operational variables. The results revealed strong correlations between:

- Machine downtime and sales
- Worker availability and sales
- Worker availability and machine downtime
- Machine downtime and monthly production
- Worker availability and monthly production

These findings indicate that worker availability is a central driver influencing both machine efficiency and overall output. Based on the regression models, it was concluded that improving worker availability could simultaneously address several of Sanjyot Engineering Works' core challenges.

Based on these analytical insights, a series of data-driven recommendations were presented to Sanjyot Engineering Works. The company has since begun planning to implement several of these strategies in an effort to improve operational performance and drive sustainable growth.

Detailed Analysis Process/Method

OEE (Overall Equipment Effectiveness) Analysis

Overall Equipment Effectiveness (OEE) was utilized as a key performance metric to evaluate the manufacturing efficiency at Sanjyot Engineering Works. OEE is a comprehensive measure based on three critical components: **Availability, Performance, and Quality.**

Sanjyot Engineering Works operates within the heavy-equipment manufacturing sector, where consistent machine uptime, optimal performance, and high-quality output are essential to maintaining productivity. The company currently faces several operational challenges, including frequent equipment breakdowns, unexpected downtime, and labor shortages. In this context, OEE offers a structured and data-driven approach to gauge how effectively production assets are being used.

The company's inefficiencies can be better understood through the lens of OEE's three core dimensions:

- **Availability:** Captures the impact of machine failures and maintenance-related downtime—key issues currently affecting operations.
- **Performance:** Assesses whether machinery is operating at ideal cycle times or whether slowdowns are hindering throughput.
- **Quality:** Measures the rate of defective output, ensuring that efficiency is not achieved at the expense of product standards.

Widely adopted across industries such as automotive, aerospace, and heavy manufacturing, OEE serves as a benchmarking tool for identifying gaps and improving productivity. For Sanjyot Engineering Works, applying OEE not only provides insights into internal operations but also enables comparison against industry best practices, paving the way for targeted improvement initiatives.

Availability, performance and quality are calculated as follows:

$$\boldsymbol{Availability} = \frac{\text{Actual Uptime}}{\text{Expected Uptime}}$$

$$\boldsymbol{Performance} = \frac{(\text{Total good units produced x Ideal Cycle Time})}{\text{Actual Uptime}}$$

$$\boldsymbol{Quality} = 1 - Defect\ Rate$$

Study of Correlation using Linear Regression Analysis

To gain deeper insights into how operational variables influence business outcomes, a **linear regression analysis** was conducted at Sanjyot Engineering Works. This analysis explored the relationships between **monthly sales, machine downtime, and employee attendance**.

By quantifying how fluctuations in machine availability and workforce presence affect revenue, the regression model revealed how closely these factors are intertwined. Since absenteeism and workforce attrition can lead to unplanned machine stoppages, improving one often contributes to resolving the other. Thus, regression serves as a powerful tool not just for identifying operational issues, but for prioritizing them based on impact.

Unlike basic correlation, regression analysis offers a **predictive framework**—highlighting not only the existence of relationships but also their **strength and direction**. This enables the development of more precise, data-informed strategies.

Key outcomes from the analysis included:

- The measurable impact of increased employee attendance on monthly sales.
- The revenue loss associated with each additional hour of machine downtime.
- The sales uplift linked to a 1% improvement in attendance.
- The decrease in revenue corresponding to each extra hour of downtime.

These insights provide a robust, data-driven foundation for addressing inefficiencies and improving profitability at Sanjyot Engineering Works.

Performance Benchmarking of All Eight Machines

A detailed performance comparison was also carried out across all eight machines to identify patterns of **downtime and efficiency**. This analysis pinpointed which machines consistently underperform and which deliver optimal output.

Machines were ranked based on performance indicators, allowing for a clear distinction between the most and least efficient assets. This ranking guided the development of a **targeted service and maintenance plan**, which has been shared with Sanjyot Engineering Works for operational implementation.

By aligning maintenance priorities with actual performance data, this approach ensures that resources are directed toward machines requiring the most attention, thereby maximizing uptime and operational efficiency.

Please Click Here to download the data analysis file. (Please Note that the drive link opens the file in Google Sheets, which does not display the analyses correctly. Please download the excel version to see the correct analyses with charts.)

Results and Findings:

Analysis part 1: Calculation of OEE (Overall Equipment Efficiency)

Availability, performance and quality were calculated for Sanjyot Engineering Works as follows:

1. Availability:

Availability measures how much of the scheduled production time the equipment was actually running. It takes into account any unplanned downtime or stoppages (like breakdowns or setup delays). If the machine isn't operating when it should be, availability drops.

$$Availability = \frac{\text{Actual Uptime}}{\text{Expected Uptime}} = \frac{9817\ Hours}{11776\ Hours} = 83.3\%$$

Availability at 83.3% indicates that downtime is affecting productivity. The machines are not running as much as expected, possibly due to maintenance, breakdowns, or unplanned stoppages.

2. Performance:

Performance looks at how fast the machine is working compared to its ideal speed. Even if a machine is running, it might be moving slower than expected due to minor issues or inefficiencies. Performance shows whether production is happening as quickly as it should.

$$Performance = \frac{(\text{Total good units produced x Ideal Cycle Time})}{\text{Actual Uptime}}$$

$$= \frac{53 \text{ units x } 144 \text{ hours}}{9817 \text{ Hours}} = 85.58\%$$

Performance at 85.58% indicates that the machines are not running at their optimal speeds. The reason could involve minor inefficiencies.

3. Quality:

Quality reflects how many of the products made are good versus defective. It focuses on the output: if parts are flawed or require rework, they lower the quality score. High quality means most products meet the required standards the first time.

$$Quality = (1 - Defect\ Rate) * 100 = (1 - 0.05) * 100 = 0.95 * 100 = 95\%$$

A **high quality score of 95%** means that most products meet standards and are not defective.

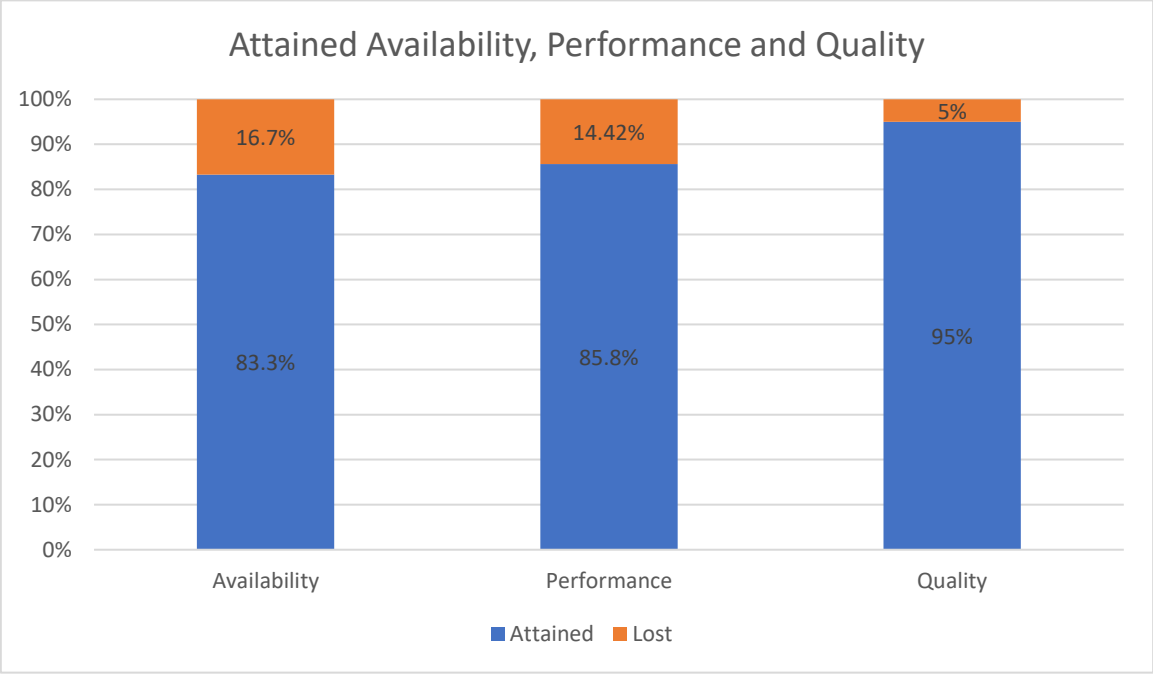

Image 1: Availability, Performance and Quality Percentage Values

OEE (Overall Equipment Effectiveness) is a way to measure how well a manufacturing process is performing. It combines three important aspects — availability, performance, and quality — into a single percentage that shows how efficiently equipment is being used. A perfect OEE score means the machine is running whenever it should, operating at its maximum speed, and producing only good-quality parts. In short, OEE helps identify where productivity is being lost and shows how close a process is to its full potential.

$$\boldsymbol{OEE} = \text{Availability x Performance x Quality}$$

$$= (0.833 * 0.855 * 0.95) * 100$$

$$= 0.6772 * 100 = 67.72\%$$

OEE score of 67.72% suggests that there is room for major improvement in the areas of availability and performance. Availability needs to be increased by reducing downtime and arranging quicker changeovers. Performance needs to be boosted by identifying and eliminating bottlenecks slowing down production.

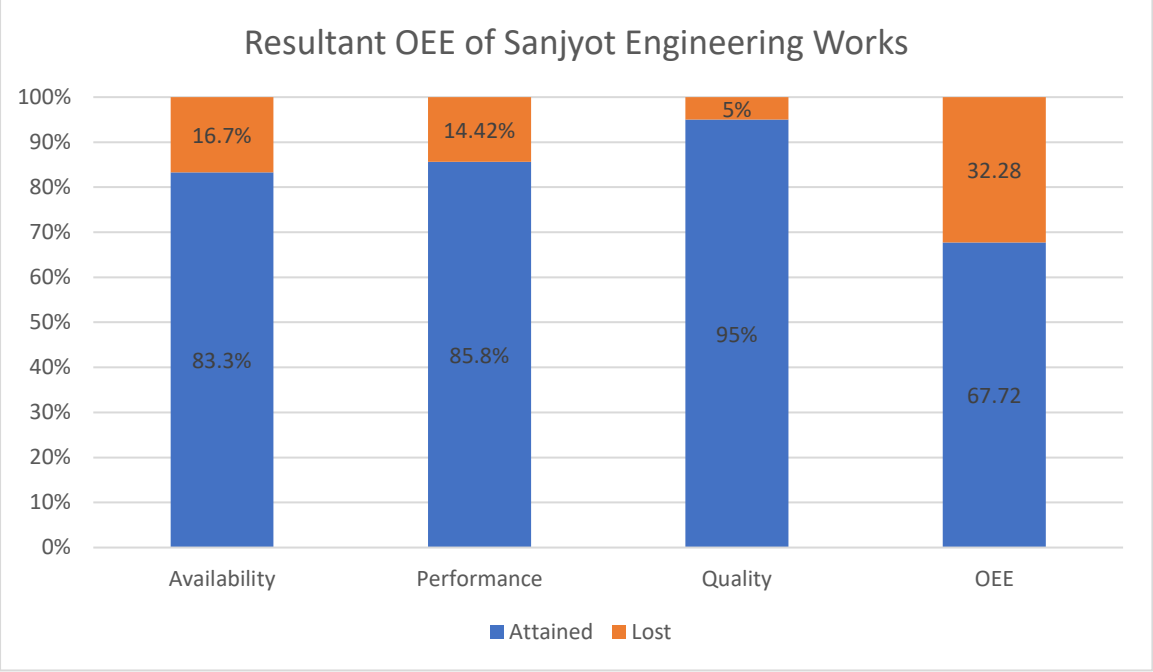

Image 2: Resultant OEE of Sanjyot Engineering Works

Analysis Part 2: Study of correlation using Linear Regression

Running a Linear Regression model to check how the Machine Downtime affects sales:

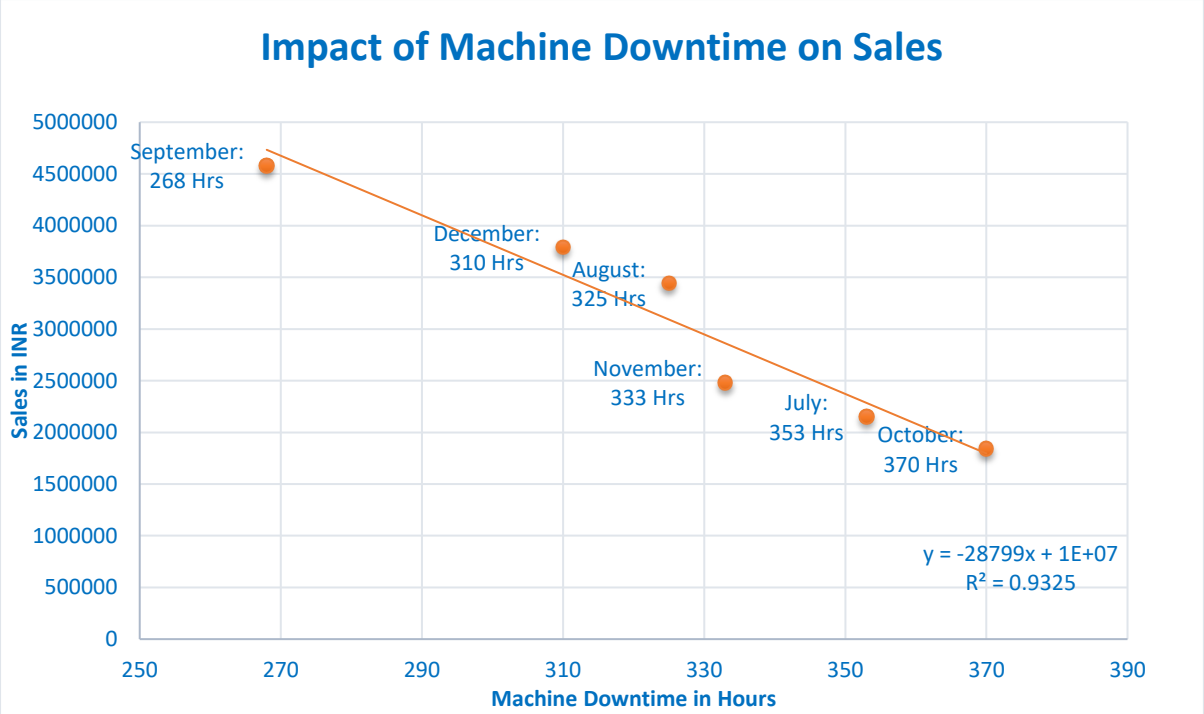

Image 3: Impact of machine downtime on monthly sales.

As we can see from the plotted graph, Machine Downtime has a very strong negative correlation with sales.

Key Findings on Machine Downtime Impact on Sales:

- Regression Plot – The graph shows a negative trend, meaning higher downtime leads to lower sales.
- **Coefficient:** –28,798.79
  → For each additional hour of downtime, monthly sales **decrease** by approximately INR 28,799.
- R^2 (0.93) – This means 93% of sales variation is explained by machine downtime, showing a strong impact.
- p-value (0.0017) – This is very low (< 0.05), proving a statistically significant negative relationship.

Running a linear regression model to check how the worker availability affects monthly sales of Sanjyot Engineering Works:

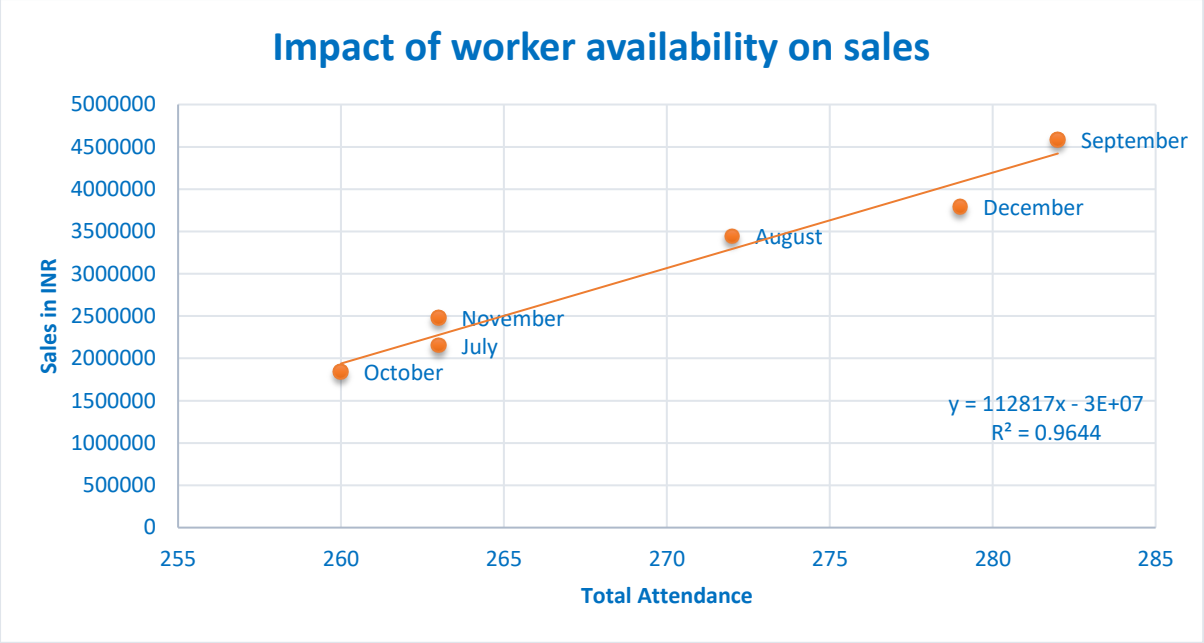

Image 5: Impact of worker availability on monthly sales.

The graph suggests a strong positive correlation between total attendance and sales.

Here are the key insights from the analysis:

- Regression Plot – The graph shows a strong positive trend between attendance and sales, with a regression line indicating the predicted relationship.
- **Coefficient:** 112,816.80
  → For each additional person attending, sales **increase** by about INR 112,817.
- R^2 (0.96) – This means 96% of sales variation is explained by attendance, showing a very strong relationship.
- p-value (0.00048) – Since this is very low (< 0.05), the relationship is statistically significant. Attendance strongly affects sales.

The two preceding graphs clearly demonstrate that:

1. **Monthly sales decline notably** as machine downtime increases.
2. **Monthly sales rise significantly** with higher labor attendance.

Building on these findings, an additional linear regression analysis was conducted to examine the relationship between labor availability and machine downtime. This step aimed to evaluate whether increasing workforce availability could potentially reduce machine downtime, thereby enhancing overall sales and profitability. The results would help assess the viability and business impact of hiring additional staff.

Running a linear regression model to check how worker availability affects machine downtime:

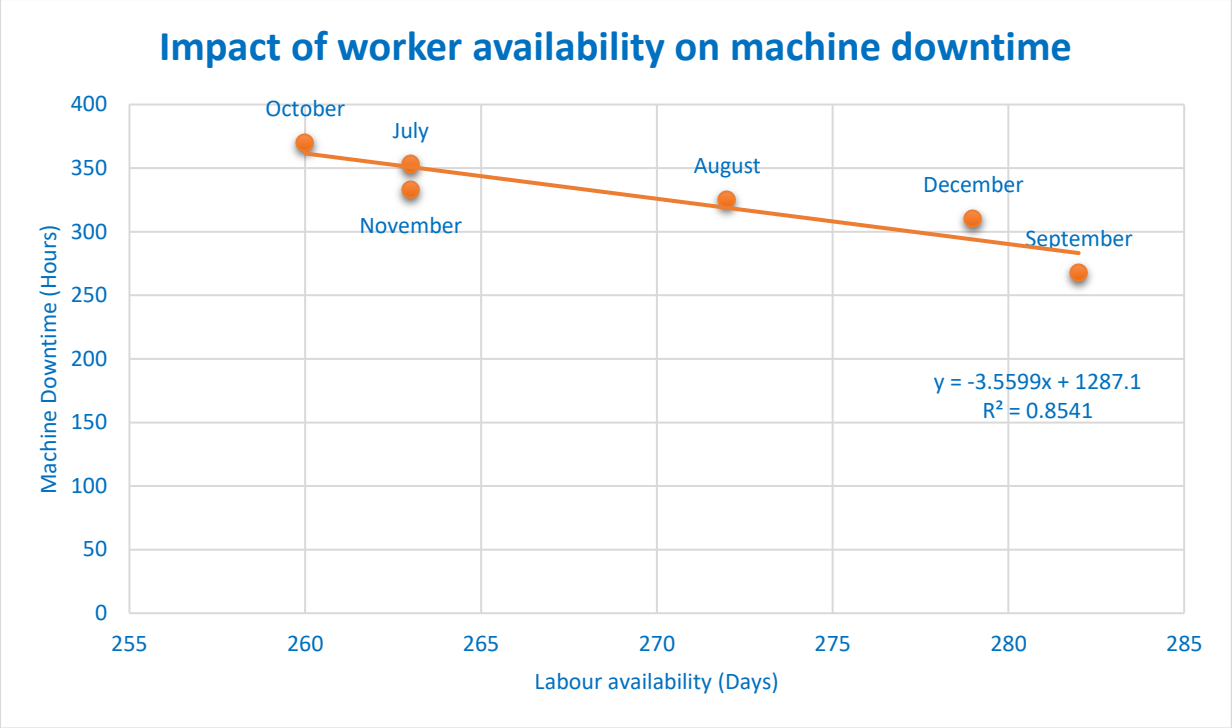

Image 6: Impact of worker availablity on machine downtime

- **Coefficient:** –3.56
  → Each additional attendee is associated with a **reduction** in downtime by about 3.56 hours.
- **R²:** 0.85
  → A **strong inverse relationship** is present between attendance and downtime.
- **p-value for Attendance:** 0.0084
  → Statistically significant ($p < 0.05$), supporting the conclusion that higher attendance tends to reduce machine downtime.

After observing the influence of machine downtime and worker availability on monthly sales, a subsequent linear regression analysis was conducted to evaluate how these two factors impact the monthly production output of the firm.

Running a linear regression model to check the impact of machine downtime on production:

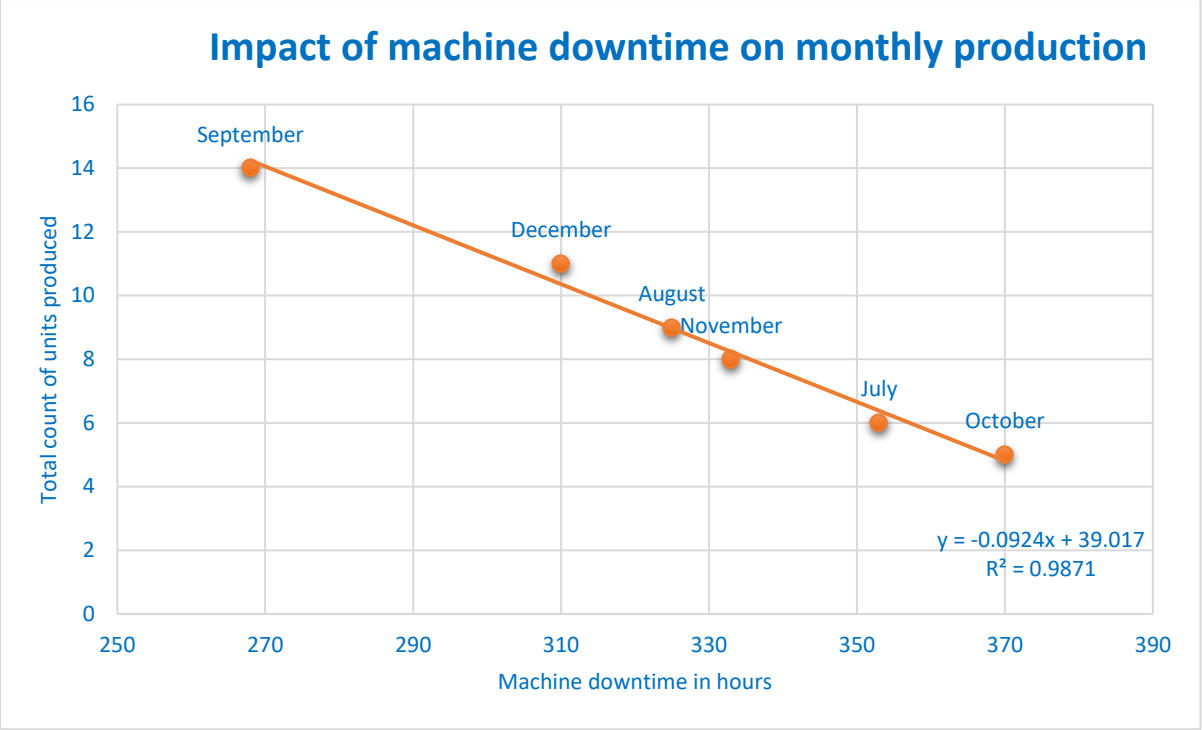

Image 7: Impact of machine downtime on monthly production

How machine downtime affects units produced:

- **Coefficient:** –0.092
  → For every additional hour of downtime, units produced **decrease** by about 0.092 units.
- **p-value:** 0.000063
  → **Highly statistically significant** ($p < 0.001$), meaning downtime strongly impacts production.
- **R^2:** 0.99
  → The model explains **98.7%** of the variation in units produced — an **excellent fit**.

Running a linear regression model to check the impact of worker availability on production:

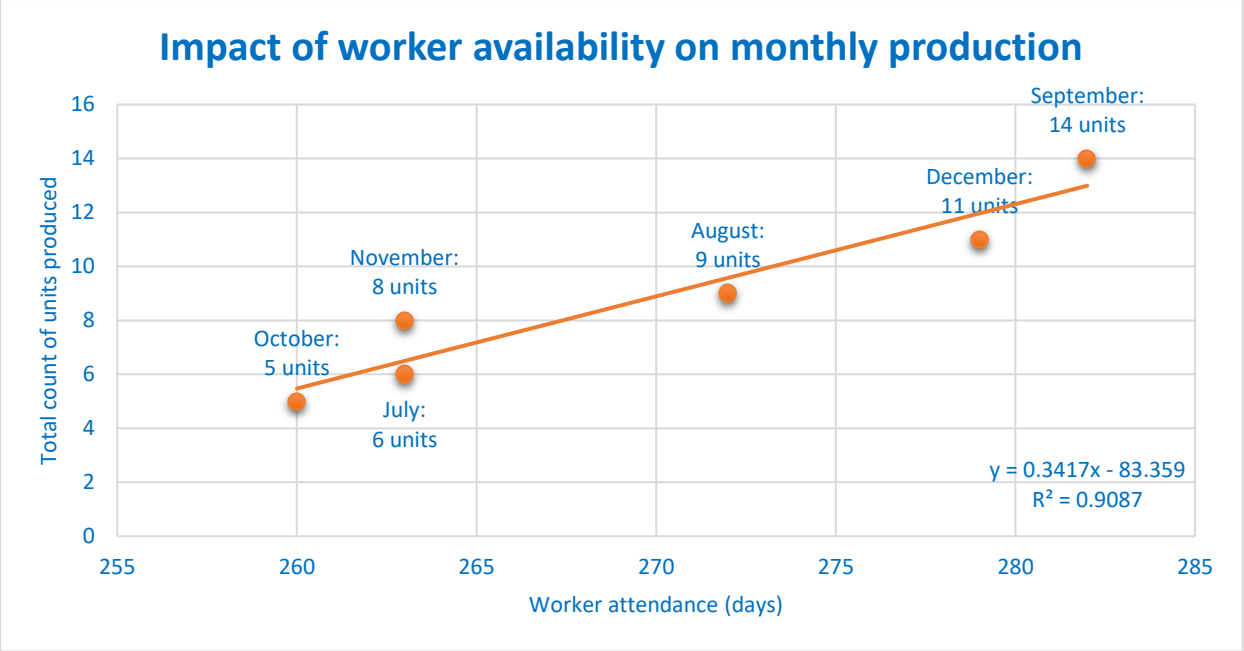

Image 8: Impact of worker availability on monthly production

How monthly attendance affects units produced

- **Coefficient:** 0.342
  → Each additional person in attendance increases units produced by about 0.34 units.
- **p-value:** 0.0032
  → **Statistically significant** ($p < 0.01$), so attendance clearly influences output.
- **R^2:** 0.91
  → The model explains **90.9%** of the variation — also a **very strong fit**.

1. Key Insights from Regression and Chart Analysis
2. The five charts presented above reveal several important findings:
3. Monthly sales are significantly influenced by both machine downtime and labor attendance.
4. Improved labor availability has a measurable impact in reducing machine downtime.
5. On average, each additional unit of attendance reduces machine downtime by approximately 3.5 hours.
6. Given that each hour of downtime leads to a sales loss of ₹28,798.79, reducing downtime by 3.5 hours results in an estimated sales increase of ₹1,00,796 (₹28,798.79 × 3.5).
7. Hiring one additional worker (contributing ~25 extra labor days/month) could therefore yield additional sales of around ₹25,19,900 (₹1,00,796 × 25).
8. Hiring two workers (~50 labor days/month) could potentially generate ₹50,39,800 in added sales.

9. Furthermore, each additional labor day increases production by approximately 0.34 units. Thus, 50 added labor days per month could more than double production, substantially improving the firm's profitability.
10. Since machine downtime negatively affects production, and higher labor availability reduces downtime, increasing labor input would help prevent unplanned stoppages, especially during frequent changeovers.
11. Reduced downtime and increased production capacity would directly address current gaps in Overall Equipment Effectiveness (OEE), specifically in the areas of availability and performance.
12. In summary, both major operational challenges—machine downtime and labor shortages—can be effectively mitigated by increasing labor hours.
13. Importantly, the investment in additional labor can be offset by the resulting increase in production and sales, as the analysis suggests a strong potential for significantly higher returns.

Analysis Part 3: Performance Benchmarking of All Eight Machines

A comparative analysis was conducted to identify which machines were experiencing the highest levels of downtime. Based on this evaluation, a ranked list of the most and least efficient machines was compiled to highlight performance disparities across the equipment.

Using the machine downtime data provided by the company, the following table was generated:

Machine	Total Downtime (Hours)	Average Daily Downtime (Hours)
Hoz. Boring Machine	242	1.31
Lathe Machine 1	267	1.45
Lathe Machine 2	224	1.21
Lathe Machine 3	226	1.22
Lathe Machine 4	231	1.25
V.T.L Machine	269	1.46
VTL 3.5 meter (CNC)	241	1.30
Lathe Machine 5	259	1.40

Table 1: Machine downtimes of all eight machines

As evident from the table, the **VTL Machine** and **Lathe Machine 1** are recording the **highest downtimes**, indicating lower operational efficiency. In contrast, **Lathe Machine 2** and **Lathe Machine 3** stand out as the **most efficient machines**, with minimal downtime.

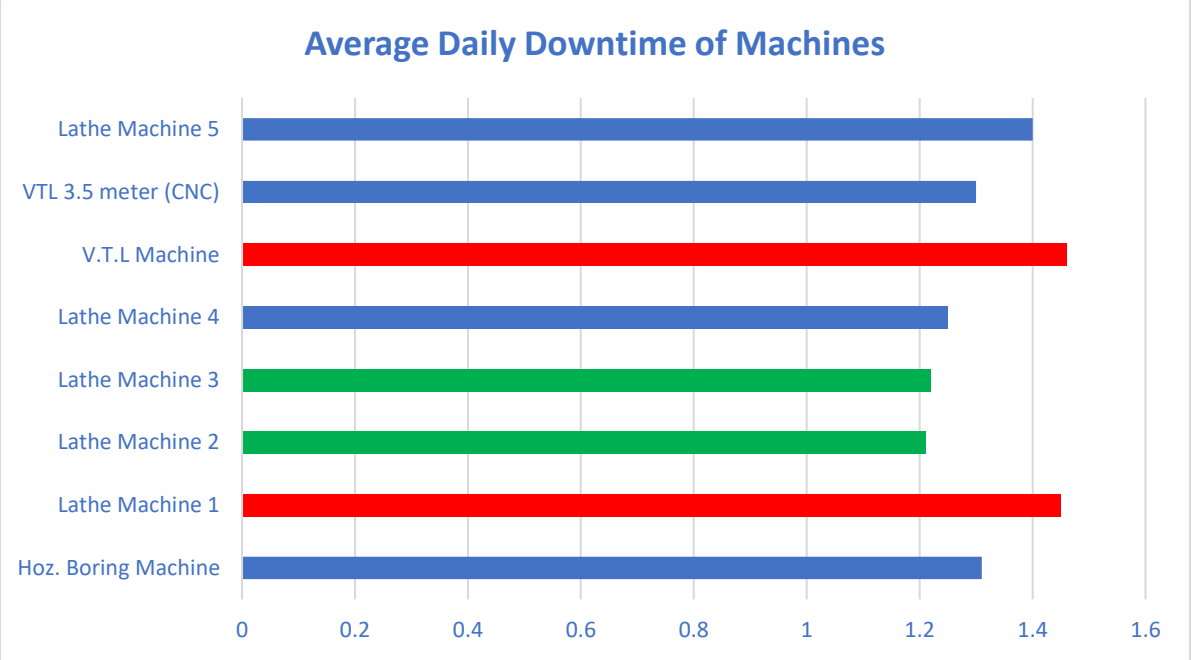

Image 9: Average daily downtime of machines

In this graph, machines with **downtimes highlighted in red** represent those with **higher levels of downtime**, contributing significantly to the decline in sales. Conversely, machines with **downtimes shown in green** indicate **the highest efficiency** among the eight, reflecting minimal disruptions and optimal performance.

Machines ranked as per their respective efficiencies:

1. Lathe Machine 2
2. Lathe Machine 3
3. Lathe Machine 4
4. VTL 3.5 meter (CNC)
5. Hoz. Boring Machine
6. Lathe Machine 5
7. Lathe Machine 1
8. V.T.L Machine

As observed from the list above, two machines are significantly impacting the firm's overall efficiency due to their high downtime levels. To improve performance, these machines require more frequent servicing and shorter maintenance intervals.

Interpretation of Results and Recommendations:

Before we move into the interpretation of our findings, let's begin with a brief recap of the key challenges identified at Sanjyot Engineering Works.

🔁 Recap of Problem Statements from Sanjyot Engineering Works

Sanjyot Engineering Works is currently facing two major operational challenges:

- Frequent machine breakdowns and unscheduled maintenance, resulting in significant drops in productivity and efficiency.
- Shortage of skilled labor and high attrition, causing unplanned downtimes and missed business opportunities.

🔗 Interconnection of Issues

Our analysis reveals that these two problems are closely linked. A lack of skilled workers directly contributes to increased machine downtime, which in turn reduces overall production output and disrupts operational flow. Addressing one issue in isolation is unlikely to deliver sustained improvement.

Projections Based on Linear Regression Modeling

To resolve these issues in a meaningful and measurable way, we simulated the impact of increasing monthly labor availability by approximately **50 additional man-days**. This can be realistically achieved by hiring **two additional skilled workers** and **retaining the existing workforce**.

Our regression models clearly demonstrate the benefits of this change across multiple performance metrics.

The table below summarizes the projected improvements:

Month	Monthly Attendance (Labour Days)	Down Time (Hours)	Monthly Sales (INR)	Units Produced (Count)
July'24	263	353	21,52,001.4	6

August'24	272	325	34,41,871.2	9
September'24	282	268	45,81,066.8	14
October'24	260	370	18,42,145.2	5
November'24	263	333	24,82,625.6	8
December'24	279	310	37,90,325.2	11
Total	**1619**	**1959**	**1,82,90,035.4**	**53**

Table 2: Summary of data received from Sanjyot Engineering Works

If monthly attendance is increased by 50 labour days and the remaining metrics are projected using our linear regression models, the resulting figures show a significant and positive shift:

Month	New Attendance (Labour Days)	New Down Time (Hours)	New Sales (INR)	New Units Produced (Count)
July'24	313	163	86,08,006	24
August'24	322	130	10,32,5614	27
September'24	332	98	98,16,572	30
October'24	310	173	84,73,868	23
November'24	313	163	74,47,877	24
December'24	329	108	99,92,676	29
Total	**1919**	**835**	**5,46,64,611**	**157**

Table 3: Projections after adding 50 labour days to existing attendance

A comparison of the tables clearly demonstrates that increasing monthly attendance by 50 labour days could lead to a **reduction in machine downtime by over 50%**, a **surge in sales of more than 250%**, and an **increase in production by nearly 300%**.

These projections also indicate that the additional cost incurred from hiring or retaining the workforce can be recovered many times over through the resulting increase in profits. Moreover, the firm would be well-positioned to offer **performance-based incentives or bonuses ranging from 2% to 10%** per month to achieve the 50-day labour target. This strategy would not only improve operational efficiency but also help **retain skilled workers**, effectively addressing both key challenges currently faced by the company.

Impact of Projected Figures on OEE at Sanjyot Engineering Works

Using the projected data from Table 3, we can calculate an updated Overall Equipment Effectiveness (OEE) to assess how the firm's operational efficiency would improve with the addition of 50 labour days per month.

This revised OEE analysis offers a clear view of the potential gains in performance, availability, and output quality — helping us understand the tangible impact of increased labour availability on the firm's overall productivity and profitability.

Projected Availability:

$$Projected\ Availability = \frac{Projected\ Uptime}{Expected\ Uptime} * 100 = \frac{10941\ Hours}{11776\ Hours} * 100$$

$$= 0.9290 * 100 = 92.9\%$$

Projected Performance:

Since the production has nearly tripled with the projected figures, let's assume that the ideal cycle time comes down to 58 hours (144/2.5 = 57.6) from the existing 144 hours.

$$Projected\ Performance = \frac{(\text{Total good units produced x Ideal Cycle Time})}{\text{Actual Uptime}} * 100$$

$$= \frac{157 \text{ units x } 58 \text{ hours}}{10941 \text{ Hours}} * 100 = 0.8322 * 100 = 83.22\%$$

Projected Quality:

Since these factors do not affect the quality, it will remain unchanged at 95%.

Projected OEE:

$$\boldsymbol{OEE} = \text{Availability x Performance x Quality}$$

$$= (0.929 * 0.832 * 0.95) * 100$$

$$= 0.7342 * 100 = 73.42\%$$

As evident from the updated OEE calculation, Sanjyot Engineering Works could experience an increase of nearly 6 percentage points in its OEE based on the projected figures — assuming the ideal cycle time extends to 58 hours.

When compared with the current OEE, this marks a significant improvement, particularly in the area of availability, driven by reduced machine downtime and improved workforce stability. This reinforces the effectiveness of increasing labour availability as a strategic lever to enhance operational efficiency.

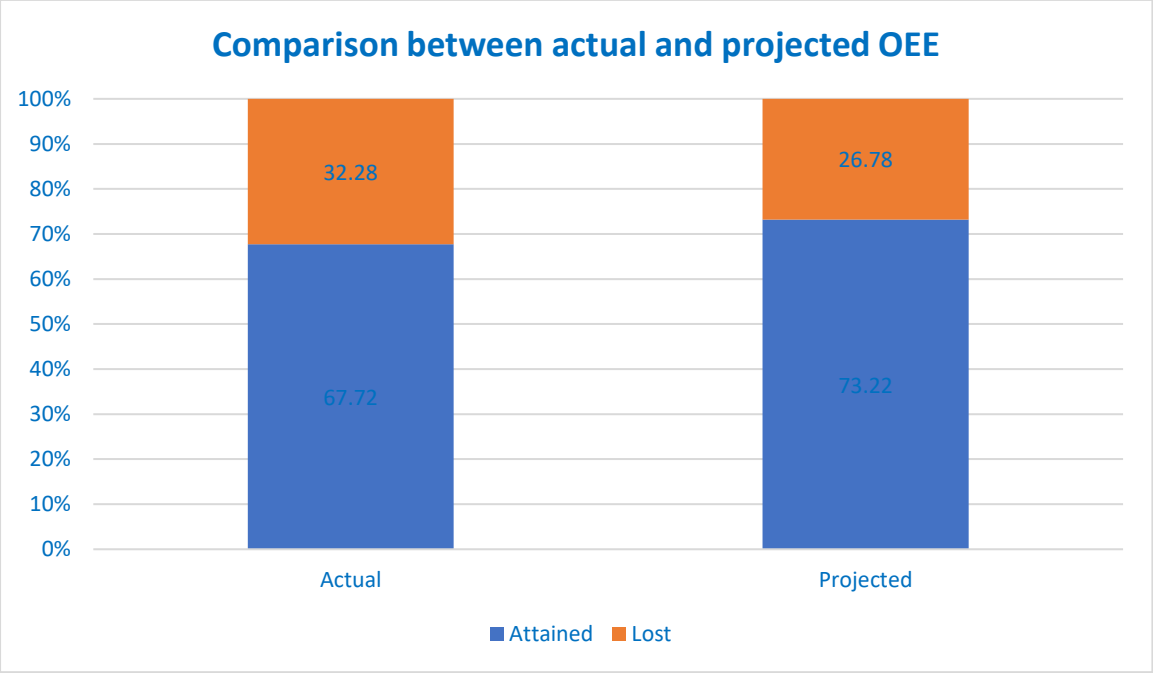

Image 10: Comparison between actual and projected OEE

How efficiency can be improved further

🔍 Insights from Analysis — Part 3

The data clearly indicates that **Lathe Machine 1** and the **VTL Machine** are experiencing the **highest levels of downtime**, significantly impacting the overall efficiency of the firm. These two machines appear to be critical bottlenecks in the production process, and their performance directly affects output and delivery timelines.

To enhance operational efficiency and reduce unplanned machine outages, it is essential to implement **more frequent servicing and scheduled maintenance** for these machines.

☑ Recommendations for Sanjyot Engineering Works

Based on the analysis and findings presented, the following strategic actions are recommended:

1. **Increase Skilled Workforce Capacity**
   Hire 2 to 3 additional skilled workers to target an increase of 50 additional labour days per month. This initiative could potentially triple production and boost sales by over 250%, while also reducing machine downtime and resolving labour availability challenges. The investment in additional manpower would be minimal compared to the projected increase in profitability.
2. **Introduce Performance-Based Incentives**
   Offer monthly bonuses or salary hikes of 2–10% to high-performing employees. This approach not only helps retain the existing workforce but also encourages greater motivation, productivity, and job satisfaction.
3. **Enhance Maintenance Scheduling**
   Reduce the service intervals for Lathe Machine 1 and the VTL Machine by adding more planned maintenance hours per week. Proactive maintenance will help prevent breakdowns, increase machine availability, and ultimately lead to more consistent and reliable production.

Thank You
