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A Case Study on the Application of TPM Techniques in the Manufacturing Industry

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Abstract

The steel sector has developed dramatically during recent years, driven by technical breakthroughs, competitive challenges, and changing client requirements. Consumers now place increasing focus on cost effectiveness, shorter delivery lead times, and consistently excellent product quality, driving industrial organizations to continually strengthen their operational performance. Adopting structured quality and maintenance systems has become crucial for maintaining competitiveness and attaining operational excellence in response to these difficulties. With a focus on enhancing work quality, equipment dependability, and overall productivity via the methodical implementation of TPM pillars, this research assesses the effects of Total Productive Maintenance (TPM) efforts on Power & Steel Ltd.'s manufacturing performance. By incorporating workers at all organizational levels, TPM aims to maximize equipment effectiveness and promote a culture of proactive maintenance and continuous development. The goal of the study is to investigate how TPM techniques affect important performance metrics including production efficiency, defect minimization, and downtime reduction. An extensive case study was carried out at a Power & Steel Ltd. production site in order to verify the efficacy of the suggested strategy. Production records, maintenance logs, and quality reports were used to gather data both before and after TPM installation in order to evaluate changes in operational performance. The implementation of TPM pillars showed promising results, such as decreased equipment failures, higher overall productivity, better process stability, and improved product quality. The findings suggest that rather than being seen as an extra operational expense, maintenance should be seen as a strategic expenditure meant to increase productivity. Effective maintenance procedures help businesses to maximize asset utilisation, decrease waste, and increase process dependability, consequently increasing their competitive position in the market. Additionally, TPM helps create a workplace that is safer, cleaner, and more organized, all of which have a favorable impact on employee engagement and morale. The report also cites a number of crucial success criteria for TPM adoption, such as the active participation of top management, strong leadership commitment, and the integration of traditional maintenance procedures with complete TPM programs. The success of TPM programs was shown to be further enhanced by employee training, cross-functional coordination, and ongoing performance monitoring. All things considered, the results validate TPM as a workable and successful approach to attaining sustainable manufacturing competitiveness in the Indian steel sector, providing insightful information for researchers and practitioners looking to enhance operational performance via structured maintenance excellence.

Keywords: Total productive maintenance (TPM), manufacturing systems, industrial performance, productive maintenance, and overall equipment effectiveness (OEE)

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INTRODUCTION ABOUT MAINTENANCE

An organization that works in tandem with production must prioritize maintenance. The final

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product is production's principal output, but it also creates a secondary output: the need for maintenance. Maintenance involves both preventing equipment failure from regular wear and tear and fixing equipment after it has failed. According to the definition, maintenance is "the work of keeping something in proper condition, upkeep," which suggests that it includes both repairs and preventive steps to keep equipment working. Every piece of equipment has a limited operational life and needs to be maintained in order to continue operating as intended.

At first, maintenance took a "breakdown" or remedial approach. The primary goal of mass manufacturing was to keep machinery operating, and maintenance was only carried out in response to malfunctions. Because the operations staff prioritized fulfilling daily output objectives, this frequently resulted in lengthier idle times on the shop floor. Preventive maintenance was developed as a solution to this problem, enabling maintenance crews to foresee malfunctions and make adjustments to increase equipment dependability. The idea of productive maintenance ultimately resulted from the combination of preventive maintenance, maintenance prevention, and maintainability enhancement. Optimizing the life cycle cost of manufacturing equipment while maximizing equipment effectiveness was the aim of productive maintenance. Nippon Denso created quality circles concurrently to engage staff in maintenance tasks. Total Productive Maintenance (TPM) emerged as a result of encouraging full employee engagement in productive maintenance implementation. The Toyota group's Nippon Denso was the first business to be certified by the Japanese Institute of Plant Engineers (JIPE) for the development and application of TPM.

Objectives of the Work

With a focus on the application of Total Productive Maintenance (TPM), this study examines the variables impacting maintenance practices in manufacturing businesses. The study focuses on how TPM helps businesses stay competitive in a market that is changing quickly while supporting effective maintenance systems.

This study's goals are to:

(a) Evaluate the degree to which manufacturing firms have adopted Total Productive Maintenance (TPM).
(b) Determine and describe the main TPM techniques used by manufacturing companies.
(c) Analyze the connection between maintenance performance and TPM procedures.
(d) Examine the connection between the adoption of TPM procedures and corporate culture.
(e) Examine how TPM helps reduce waste and improve operational effectiveness in a changing economic climate.
(f) Examine how TPM may save production costs without sacrificing product quality.
(g) Evaluate how well TPM supports low-batch manufacturing with the minimum lead time.
(h) Examine how TPM guarantees that customers receive items free of defects.

LITERATURE REVIEW

The definition of maintenance in industry is given by S. Borris [1]. He classifies maintenance into four groups. The goals of maintenance are explained by S.A. Kumar and N. Suresh [2]. They claim that equipment is a crucial resource for enhancing the value of goods. It needs to be maintained in a functional state. Inadequate maintenance causes quality problems, production disruptions, and downtime. In mass production lines, this is particularly true. Upkeep must to be cost-effective. To reduce expenses, an integrated strategy is required.

Three forms of maintenance are identified by Kumar and Suresh [2]: predictive, preventive, and breakdown. They describe each type's benefits and drawbacks. Total Productive Maintenance (TPM) and Reliability-Centered Maintenance (RCM) are two popular approaches, according to S. Borris [1]. They both began in the United States. Later, TPM moved to Japan, where it continued to grow. It was referred to as preventive maintenance (PM) in the United States. PM concentrated on enhancing

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equipment dependability. TPM is similar to Total Quality Management (TQM) and is more comprehensive [2]. It makes use of instruments like documentation, benchmarking, and employee empowerment. TPM increases competitiveness, according to studies. TPM initiatives improved an Indian organization's production performance in [3]. Additionally, TPM enhances product quality [4]. Using TPM, a small manufacturing facility found equipment issues and decreased defects. Together with TPM, the Kanban method decreased inventory, improved flexibility, and cut operating expenses [4]. Agriculture has also used TPM [5]. Its objectives are to increase output, avoid errors, and efficiently handle equipment.

Apart from the above listed studies, a number of researchers have investigated how maintenance techniques might enhance manufacturing efficacy. One of the forerunners of TPM, Nakajima [6], describes it as an all-encompassing strategy that aims to maximize Overall Equipment Effectiveness (OEE) by including every employee, from shop floor workers to top management. He emphasizes that the eight core pillars of TPM—autonomous maintenance, planned maintenance, targeted improvement, quality maintenance, and training and education—all help to achieve zero malfunctions, zero faults, and zero accidents. Nakajima's work provided the groundwork for the broad adoption of TPM across numerous industrial sectors.

Muchiri et al. [7] stress that good maintenance management greatly effects productivity, cost savings, and equipment availability. Their analysis reveals that businesses employing organized maintenance frameworks have increased asset performance and decreased life-cycle costs. According to Eti, Ogaji, and Probert [8], inadequate maintenance procedures are a significant contributor to low productivity in the industries of developing nations, underscoring the need of preventive and predictive maintenance strategies for long-term industrial development. The link between TPM implementation and manufacturing performance has been examined in a number of empirical investigations. After conducting a thorough analysis of TPM techniques in Indian manufacturing organizations, Ahuja and Khamba [9] came to the conclusion that TPM adoption significantly boosts employee morale, productivity, quality, and safety.

Additionally, their results show that ongoing training, employee participation, and management commitment are essential for a successful TPM adoption. In a different research, Cooke [10] highlights the behavioral and cultural shifts necessary for TPM effectiveness, pointing out that TPM should be seen as an organizational transformation project rather than just a maintenance strategy. Additionally, a favorable correlation between TPM techniques and manufacturing performance characteristics including cost, quality, delivery, and flexibility was empirically demonstrated by McKone, Schroeder, and Cua [11].

According to their study, TPM improves process stability and equipment dependability, which enhances lean manufacturing and Just-In-Time (JIT) systems. This perspective is also supported by Swanson [12], who contends that combining TPM with lean methods produces better operational results. TPM research has been expanded outside typical manufacturing in recent studies. In his discussion of the strategic significance of maintenance management in gaining a competitive edge, Tsang [13] makes the case that proactive maintenance practices strongly correspond with long-term corporate goals. Al-Najjar and Alsyouf [14] show that TPM implementation lowers operational risks and increases equipment efficacy in service and process sectors.

These results show that TPM is a flexible and adaptive strategy that may be used in a variety of industrial settings. The usefulness of TPM as a strategic maintenance philosophy that improves productivity, quality, safety, and organizational competitiveness is generally well-supported by the research now in publication. Nevertheless, additional industry-specific case studies in the Indian steel business are still needed despite a great deal of international study. By analyzing the effects of TPM implementation at Power & Steel Ltd., this study aims to close this gap and offer actual data to the expanding corpus of TPM literature.

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TPM FOLLOWED AT STEEL INDUSTRY

The TPM team, management, and union representatives determine the program's scope, choose equipment, establish objectives, and gather baseline performance data in a master plan that serves as the foundation for TPM implementation. While maintenance personnel offer training and assist in creating safety protocols, operators in autonomous maintenance are in charge of cleaning, inspecting, and carrying out routine maintenance. In order to prevent conflicts, planned maintenance entails tracking performance, assessing equipment data, and integrating maintenance plans with production. In order to improve future equipment design, arrange spare parts, schedule periodic analyses, and carry out proactive replacements, maintenance reduction makes use of data and lessons learned. In order to simplify activities and maintain the program, holding the gains guarantees that new TPM practices are integrated with production systems, integrated into standard operations, and constantly enhanced. The various pillar of TPM shown in Figure 1.

Process Carried Out in a Steel Industry

As seen in Figure 2, the process begins with Hot Rolled (HR) coils, which are made at high temperatures and have comparatively greater thickness and surface oxide scale.

In order to prepare them for further processing, these coils are first delivered to the HR slitter, where they are chopped into smaller widths. In the pickling and cold rolling processes, slitting guarantees dimensional appropriateness and seamless handling. Following slitting, the material moves onto the pickling line, where acid solutions—typically hydrochloric acid—are used to remove the oxide scale that was created during hot rolling. To have a clean steel surface for cold rolling, this step is essential. The Acid Regeneration Plant (ARP) recovers and reuses spent acid, making the process economical and environmentally sustainable.

After that, the descaled strip is processed in cold rolling mills, such 4-Hi or 6-Hi cold rolling mills, where the thickness is drastically decreased at room temperature. While the 6-Hi mill offers superior control for narrower gauges and better flatness, the 4-Hi mill is often utilized for modest reductions. In order to preserve roll surface quality and guarantee consistent thickness and surface polish, roll grinding is done on a regular basis during this phase. At this point, the product is referred to as Cold Rolled Full Hard (CRFH) coil, which has minimal ductility but great strength.

The CRFH coil travels through an Electrolytic Cleaning Line (ECL), which uses electric current and alkaline solutions to eliminate any remaining rolling oils and surface impurities before the material is annealed. Consistent material characteristics and efficient heat treatment depend on clean surfaces. The cleaned strip next undergoes annealing, a heat treatment technique that restores ductility by reducing internal tensions caused during cold rolling. Steel's grain structure can recrystallize after annealing, enhancing its softness and formability—two qualities required for subsequent processing and end-use applications.

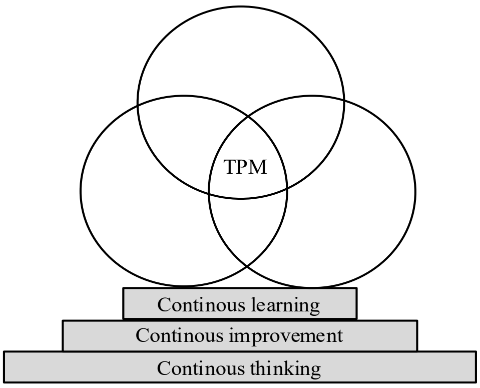

Figure 1. Pillar of TPM.

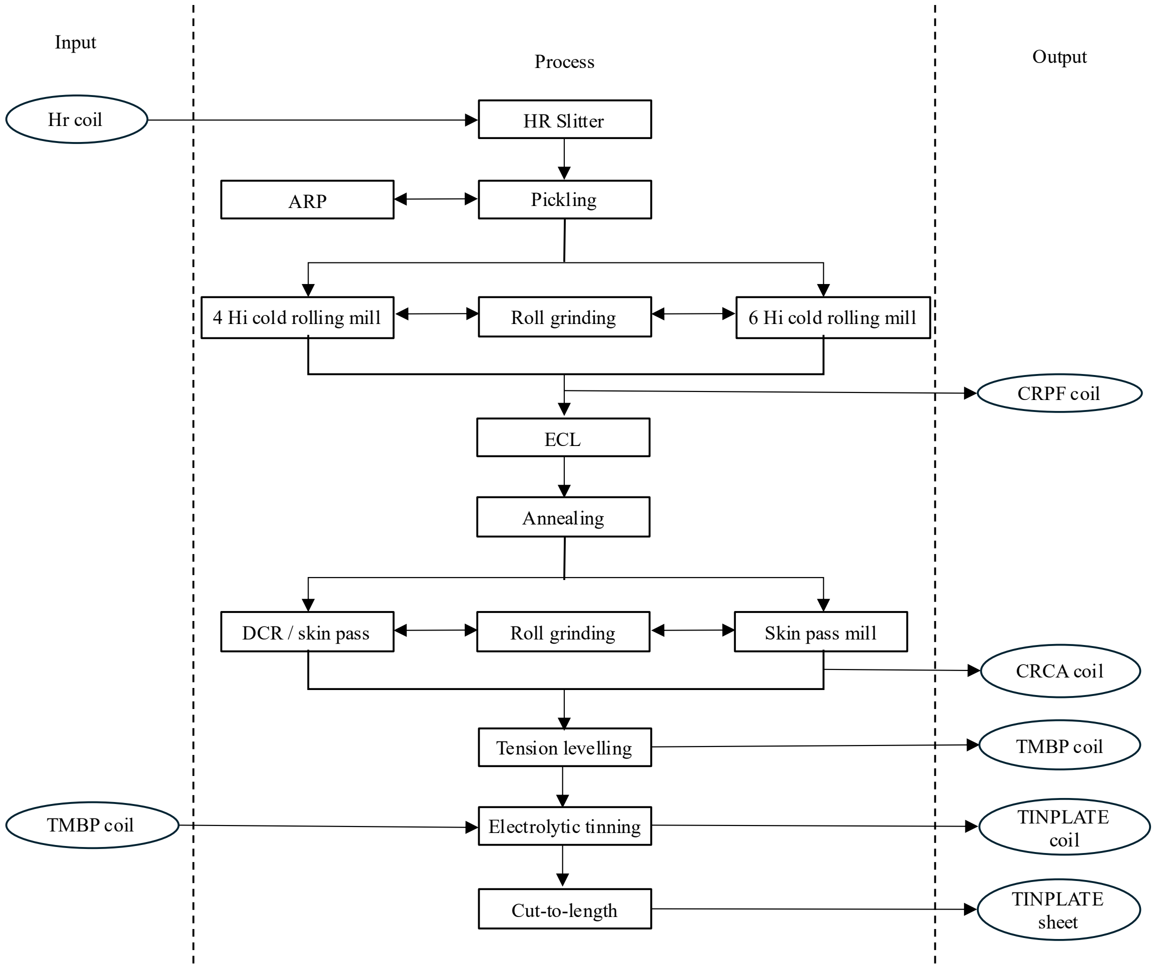

Figure 2. The detail process in a steel power plant.

Double Cold Reduction (DCR) or skin pass rolling are applied to the strip following annealing. While DCR adds extra strength where needed, skin pass rolling uses a very slight decrease to improve surface smoothness, flatness, and reduce yield point elongation. Once more, roll grinding is employed to preserve accuracy and surface quality. The output from this step is Cold Rolled Close Annealed (CRCA) coil. After that, the CRCA coil goes through tension leveling, which eliminates form flaws including coil set, edge waves, and buckles by applying controlled tension and bending. This results in Tin Mill Black Plate (TMBP) coil, a stable, flat product that is used as the foundation for tinplate manufacturing.

The TMBP coil is next treated in the electrolytic tinning line, where an electrolytic procedure is used to deposit a thin, consistent layer of tin on both sides of the steel strip. The material is appropriate for food packaging and container applications because to its tin coating, which also offers superb surface attractiveness and exceptional corrosion resistance. Tinplate coils are the current product.

The tinplate coil is then delivered to the cut-to-length machine, where it is cut into sheets that meet client specifications. The finished product is these tinplate sheets, which are frequently utilized in cans, containers, and other packaging applications.

OBSERVATIONS ON MAINTENANCE OF STEEL INDUSTRY

- For any type of maintenance problem whether small or big only maintenance, people are called for to solve the problem.
- The concept of Autonomous maintenance is not followed closely.
- The record keeping procedure requires modification.

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- The placement of tools and tackles vis-à-vis the maintenance activity requires modification.
- Operational inefficiency due to old technology leading to high cost of production.
- Ageing of equipment is requiring replacement or renovation.

METHODOLOGY

The primary reasons for time wastage and output losses in the industrial sector were found and examined over the study period. Overall Equipment Effectiveness (OEE) was employed as a key performance metric to measure the effect of these losses on equipment performance and overall output. OEE is a commonly used indicator in Total Productive Maintenance (TPM) that assesses how well manufacturing equipment is used by combining three crucial elements: product quality, availability, and performance efficiency. For the analysis, a 24-hour shift duration was taken into account. This was used to compute projected production time by removing planned production breaks. The actual operating time was then calculated by subtracting machine downtime, which is defined as times when the equipment was not in use because of malfunctions, maintenance, or other stoppages, from the scheduled production time. The total number of units produced each day and the number of units rejected because of flaws were taken into account while evaluating production performance. Rejected units were subtracted from the overall output to determine the final quantity of high-quality products. By dividing the overall operating time by the total number of units produced, cycle time—which is the amount of time needed to generate one unit—was determined. In order to represent optimal equipment usage, the planned production time was also used to calculate the valuable operating time per unit. The degree to which the equipment was available for production was determined by calculating the ratio of operating time to scheduled production time. By comparing the actual cycle time with the useful operating time per unit, which indicates the production process' efficiency, the performance rate was assessed. The percentage of good units produced in relation to the total number of units manufactured was used to calculate the quality rate, which indicated how well the machinery produced goods free of flaws.Lastly, availability, performance rate, and quality rate were multiplied to determine Overall Equipment Effectiveness (OEE). By highlighting the main regions of loss and offering a clear picture of equipment use, this comprehensive statistic made it possible to identify chances for improvement through TPM adoption.

RESULT & DISCUSSION

Calculation of OEE Before Implementing TPM

Using above-mentioned variables and equation we calculate the OEE of this industry from Oct 2022 to Dec 2022 that shown below in the Table 1. After calculating the OEE of this industry, it is observed that the OEE of this industry is not acceptable as per the industry profit. So it is advisable for the implementation of TPM Pillars in this industry.

Calculation of OEE for the Month of Oct.22

Total shift time: 24hrs = 24*31 = 44640min
Machine down Time: 8220min
Total units manufacturing: 4424.95MT
Total units Rejection: 135MT
Total Planned Production Time: 44640min
Total Operating Time: (44640-8220)min = 36420min
Final Goods = 4429.95-135 = 4289.95 MT
Cycle Time (Time taken to produce one unit): 36420/4424.95 = 8.23
Valuable Operating Time per unit: 44640/4424.95 = 10.09
Availability = 36420/44640 = 81%
Performance Rate = 8.23/10.09 = 81%
Quality Rate = (4429.95-135)/4429.95 = 97%
OEE = .81*.81*.97 = 64%

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Table 1. Calculation of OEE before Implementation of TPM.

Parameters/Months	Oct'22	Nov'22	Dec'22
Shift time	44640min	43200min	44640min
Breakdown Time	8220min	6000min	6900min
Units Manufactured	4424.95MT	3681MT	4009.39MT
Units Rejected	135MT	123MT	90MT
Final Goods	4289.95	3558	3919.39
Planned production Time	44640min	43200min	44640min
Operating Cost	36420min	37200min	37740min
Cycle time	8.23	10.10	9.41
Valuable operating Times Per Units	10.09	11.74	11.13
Availability	81%	86%	84%
Performance Rating	81%	86%	84%
Quality Rate	97%	96%	98%
OEE	64%	71%	70%

Similarly for the month of Nov and Dec' 22, OEE can be calculated and the results are shown in the corresponding columns of Table 1.

SUGGESTIONS AND IMPLEMENTATION OF TPM

AFTER TPM IMPLEMENTATION

Calculation of OEE for the Month of Jan 23

Total shift time: 24hrs = 24*31 = 44640min
Machine down Time: 2340min
Total units manufacturing: 4711.89MT
Total units Rejection: 82MT
Total Planned Production Time: 44640min
Total Operating Time: (44640-2340) min = 42300
Final Goods = (4711.89-82) MT = 4629.89
Cycle Time (Time taken to produce one unit): 42300/4711.89 = 8.98
Valuable Operating Time per unit: 44640/4711.89 = 9.47
Availability = 42300/44640 = 95%
Performance Rate = 8.98/9.47 = 95%
Quality Rate = (4711.89-82)/4711.89 = 98%
OEE = .95*.95*.98 = 88%

Similarly, OEE for other two months (Feb & March) can also be calculated following the above method and the results are specified in corresponding columns of Table 2

COMPARATIVE STUDY OF BOTH IMPLEMENTATIONS

Graph 1 compares OEE, Performance Rate, Quality Rate, and Availability prior to and following installation. It shows that the proper utilization of resources rises and the OEE, Performance Rate, Quality Rate, and Availability drop when TPM is properly applied.

Performance Rate, Quality Rate, and Availability were therefore lower before TPM Implementation OEE and increased after Implementation OEE, as the graph makes clear.

The plot demonstrates that OEE, Performance Rate, Quality Rate, and Availability all rose after TPM adoption. OEE increases by roughly 20% after three months of adoption.

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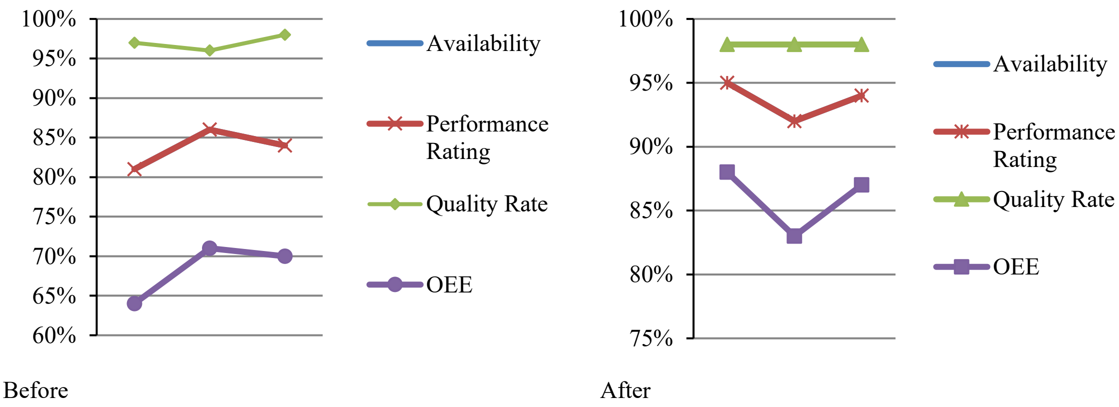

Graph 1. Comparison of implementing TPM.

Table 2. OEE after Implementation.

Parameters/Months	**Jan'23**	**Feb'23**	**March'23**
Shift time	44640 min	41760min	44640min
Breakdown Time	2340min	3300min	2820min
Units Manufactured	4711.89MT	5203.11MT	5314.68MT
Units Rejected	82MT	95MT	92MT
Final Goods	4629.89	5108.11	5222.68
Planned Production Time	44640min	41760min	44640min
Operating Time	42300	38460	41820
Cycle time	8.98	7.39	7.87
Valuable operating Times Per Units	9.47	8.02	8.40
Availability	95%	92%	94%
Performance Rating	95%	92%	94%
Quality Rate	98%	98%	98%
OEE	88%	83%	87%

CONCLUSION

A manufacturing facility was studied to analyze TPM implementation issues, the roadmap followed, and the key benefits achieved. The research highlights how TPM initiatives in Indian industry provide strategic advantages to meet global competition. The study shows that TPM has a greater impact on manufacturing performance than traditional maintenance practices, helping build organizational capabilities for sustained competitiveness.

Systematic TPM interventions improved productivity, quality, safety, and workforce morale while ensuring cost-effective manufacturing. Effective TPM initiatives can support strategic manufacturing improvements in dynamic global markets.

In a three-month study at Power & Steel Industry, the initial OEE was around 70%. Several operational and worker-related weaknesses were identified, and specific measures were implemented. After TPM implementation, the OEE increased to an average of 86%, indicating a substantial improvement in productivity, working environment, and profitability.

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