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# Comparative Analysis of Real-time and Conventional Overall Equipment Effectiveness Applications in Manufacturing Industry

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## ABSTRACT

Overall Equipment Effectiveness (OEE) is a comprehensive measure to identify the level of productivity and performance of machines/equipments. Conventional approaches to OEE data processing, such as using Microsoft Excel, have limitations. Consequently, the data processing process becomes less efficient and prone to human error. This study aims to examine the application of OEE in the Manufacturing Industry, measurable performance gaps between conventional and real-time approaches. The methodology used in this study was based on a synthetic literature review to evaluate the effectiveness of both OEE approaches based on existing studies. The transition of OEE from mere calculations to dynamic, real-time, and integrated systems is a direct response to the increasing complexity and competitiveness of the modern manufacturing environment. This study can be used to identify areas for future development and as a reference for further research to provide a guide to OEE practitioners in implementing improvements.

**KEYWORDS:** *OEE Application, Conventional, Manufacturing, Overall Equipment Effectiveness, Real-time.*

## 1. INTRODUCTION

The equipment effectiveness is a key factor in increasing productivity and profitability in modern manufacturing. Overall Equipment Effectiveness (OEE) is a globally standardized metric used to measure equipment effectiveness by considering three key components: Availability, Performance, and Quality [1-5]. While conventional OEE, which relies on manual recording, has long been used, this approach often suffers from data delays, potential input errors, and a lack of ability to provide rapid insight into production losses. In addition, OEE has long been used to identify the "Six Big Losses" and has become a benchmark for world-class performance (OEE target of 85%) [6-7], its application methods continue to evolve with advances in Industry 4.0 technology [8-10].

The conventional of OEE data is often collected and calculated manually or periodically (daily, weekly, monthly), which is prone to human error and provides delayed visibility into production issues [11-12]. Conventional OEE is a traditional method that often relies on manual data collection, such as operator checklists, or through semi-automated systems that perform calculations at the end of the production cycle (e.g., at the end of a shift or day). The main advantage of this approach is its relatively low implementation cost and simplicity of application in less digitized manufacturing environments. However, conventional OEE has a significant drawback such as data lag. Periodic calculations create a time lag between the occurrence of a loss such as the machine downtime and the availability of that data for analysis, making improvement decisions reactive. Furthermore, data accuracy is susceptible to human error, which can limit the reliability of metrics and the effectiveness of improvement initiatives.

In contrast to OEE conventional methods, the real-time OEE applications leverage Industry 4.0 technologies, such as Internet of Things (IoT) sensors, Supervisory Control and Data Acquisition (SCADA) systems, and Manufacturing Execution Systems (MES) [13-15]. In these systems, data on availability, performance, and quality are collected automatically, continuously, and displayed in real time. A key advantage is that they provide instant feedback, enabling operators and managers to proactively identify and respond to issues (such as slowdowns or equipment failures) within seconds. While requiring higher initial investment and complex system integration, real-time OEE ensures higher accuracy and minimizes unplanned downtime.

A comparative analysis of real-time OEE and conventional Overall Equipment Effectiveness (OEE) implementations in the manufacturing industry reveals significant insights into performance measurement systems. This paper is proposed to conduct literature review synthesizes findings from various studies to evaluate the effectiveness of real time and conventional of OEE applications. Hence, it can be of understanding how technological evolution has impacted the speed, accuracy, and impact of decision-making on the production floor. This comparison highlights a paradigm shift from reactive performance management to a more proactive, real-time data-driven model. This literature review aims to analyze and compare the advantages, limitations, impacts, and implementation methods of both approaches, the real-time OEE and Conventional OEE in the manufacturing industry. This comparison may use to guide manufacturing companies in selecting the most effective and adaptive performance measurement strategies in the digital age.

## 2. METHOD

A comparative analysis of real-time and conventional Overall Equipment Effectiveness (OEE) applications in the manufacturing industry reveals significant insights into performance measurement systems. OEE serves as a critical tool for identifying production losses and enhancing operational efficiency. This literature review synthesizes findings from various studies to evaluate the effectiveness of both real-time and conventional OEE applications.

The first step in this method was data collection through a systematic search of academic literature, industry journals, and relevant case studies. Primary sources was included scholarly databases such as Scopus, Web of Science, and Google Scholar, using keyword combinations such as "real-time OEE," "conventional OEE," "manufacturing efficiency," and "production performance measurement." Selection criteria was prioritize studies that explicitly compare or analyze the implementation and impact of real-time OEE with conventional OEE that present data regarding the accuracy, speed, and decision-making capabilities of each method.

Once the relevant literature has been collected, the next step was a comparative analysis and synthesis of findings. Each study was be analyzed to identify key performance indicators (e.g., data accuracy, information latency, problem resolution, efficiency improvements) associated with OEE implementation. The analysis was specifically comparing the advantages such as visibility, predictive maintenance and disadvantages for example: implementation costs, technology dependency of real-time applications versus conventional methods (e.g., manual/periodic calculations). The results of this synthesis may then be used to develop detailed conclusions regarding the relative effectiveness of the two OEE systems in achieving operational improvements and identifying production losses.

## 3. RESULTS

Based on the literature review, there were several OEE calculation approaches that have been developed, as presented in Table 1. The Overall Equipment Effectiveness (OEE) framework employed various methodologies to assess manufacturing efficiency. The foundational approach was the standard formula, which provides a clear, objective measure by multiplying three key factors such as Availability, Performance, and Quality [16-18]. To address situations where all three factors may not have equal business impact, the Weighted OEE (AHP) method is utilized; this technique applies weights derived from the Analytical Hierarchy Process (AHP) to prioritize factors based on their strategic importance.

Furthermore, the practical application and accurate, real-time calculation of OEE on the shop floor heavily relies on integration with PLC (Programmable Logic Controller) or HMI (Human Machine Interface) Automatics, which automatically capture and log operational data directly from the machinery. The evolution of OEE measurement culminates in Predictive OEE, which leverages historical and real-time data, often combined with machine learning algorithms, to forecast future equipment performance and schedule proactive maintenance, moving beyond simple measurement toward operational foresight.

The OEE implementation has evolved through various approaches, starting with the most basic manual/spreadsheet method, where data is collected and calculated manually, resulting in low accuracy and analysis delays. The next level is the use of embedded PLC/HMI systems, where basic OEE calculations are performed directly at the machine interface, providing faster insights, although data is usually limited to that local machine. Systems have become more centralized through the integration of SCADA (Supervisory Control and Data Acquisition), which collects real-time data from multiple machines into a single centralized control system, facilitating the visualization of overall plant operations.

The modern evolution occurs through web-based applications and cloud-based solutions of the OEE. The former allowed access to OEE data via a browser from anywhere within the company network. The latter offers unlimited scalability, integration of data from multiple geographic locations, and advanced analytics capabilities through cloud-based platforms, representing the most advanced and flexible OEE solutions today. The main difference between manual OEE and web-based applications lies in their cost structure and complexity.

The manual approach excels in having almost no initial cost, relying solely on operational costs for salaries, but has an unstructured and unpredictable ongoing cost model due to the hidden costs of human error and lost production. In contrast, the web-based applications and cloud approach requires significant initial cost for sensor hardware investments and integration services. However, the operating was a more structured and predictable through the software. Regarding complexity, the manual method shifts the difficulty to the daily processes of data management and accuracy verification. Contrast, the web based solution and cloud faces high complexity only at the initial installation and integration stage, but offers much simpler daily system management credit to automation. The table summarizes attributes requested for the common OEE implementation approached and cited case evidence where available, shown in Table 2.

The results of the literature review show significant differences between real-time and conventional OEE, especially in terms of data visibility, response speed, and potential performance improvements, as presented in Table 3. The real-time of OEE approach was excellent to traditional methods because it offers automated, continuous data collection, resulting in significantly higher data accuracy and faster response times to performance issues. The real-time OEE provides detailed insights into the root causes of failures as soon as they occur, enabling proactive operational focus on continuous improvement.

Table 1: OEE calculation approaches

| Method | Characteristics | Accuracy | Complexity | References |
|---|---|---|---|---|
| Standard Formula | Availability × Performance × Quality | 95-98% | Low | [16-18] |
| Weighted OEE (AHP) | Weight adjusted to business priorities | 96-99% | Medium | [19] |
| PLC/HMI Automatics | Direct calculation from sensor | 98-99.5% | High | [20] |
| Predictive OEE | Using Machine Learning (ML) for forecasting | 94-97% | High | [21] |

The real-time OEE provides detailed insights into the root causes of failures as soon as they occur, enabling proactive operational focus on continuous improvement. While traditional methods often rely on manual entry and delayed analysis of historical data. In addition, the real-time OEE may have higher initial costs and complexity associated with implementing integrated sensors and systems, the visual and actionable presentation of the data quickly justifies the investment by facilitating faster and more efficient decision-making compared to the periodic, static reports of traditional approaches. The real-time OEE approach relied on automation to obtain unbiased and timely data. Data such as unit counts, machine status (running, stopped), and specific reasons for downtime are transmitted electronically. In contrast, the traditional approach relies heavily on operators and manual processes, which often result in delayed or inaccurate data.

Table 2: The attributes requested for the common OEE implementation approached

| Approach | Manual/spreadsheet | PLC/HMI embedded | SCADA-integrated | Web based applications | Cloud based solutions |
|---|---|---|---|---|---|
| Implementation cost | Low (tools only); insufficient evidence for exact values. | Moderate (PLC and HMI hardware) insufficient evidence for amounts of cost. | Cost moderate to high (SCADA licenses and integration) insufficient evidence for totals. | Low to moderate (development, hosting) insufficient evidence. | Unpredictable ongoing cost model (subscriptions) insufficient evidence for typical price. |
| Complexity | Low. | Moderate (logic control and sensors). | High (integrates PLCs, historian, visualization). | Low–moderate (web stack and data connectors). | Moderate (edge; cloud pipelines). |
| Accuracy | Often low; manual analyses produced outdated or inaccurate results in practice [22]. | Improved versus manual; continuous reliable OEE across shifts reported [19]. | High when using PLC/IoT inputs and standardized OEE logic [18]. | Depends on data source; web dashboards improved decision accuracy in case studies [23][17]. | High when device telemetry is reliable. |
| Real-time capability | None. | Yes (local HMI). | Strong; live visualisation for downtime detection [18]. | Possible with appropriate data feeds. | Yes for many cloud/edge designs; edge/cloud combos can meet sub second latency needs [24]. |
| Scalability | Poor. | Good per-machine; network integration needed for fleet view. | Enterprise level with historians and dashboards. | high across users/sites when backend designed accordingly [23]. | Very high (multi-site). |
| Maintenance | Manual data entry burden. | Firmware, sensors, PLC programs. | Requires SCADA support and historian upkeep. | Web server, Data-base, connectors. | vendor/cloud patching; network dependences |
| User adoption | High initially but prone to poor compliance. | Operational staffs accept local HMI displays [20]. | High for plant managers and engineers when visualized effectively [18]. | High if user experiences was intuitive; webs apps enable remote access [23]. | Faster for distributed teams; easier rollouts. |
| Case metrics/ study evidence | Prior manual workflows produced outdated/inaccurate analyses, which dashboards later replaced [22]. | Automated OEE on application filling machine replaced manual logbooks and reduced human estimation error [20]. | Implemented for a major food manufacturer; OEE SCADA visualisation enabled root-cause analysis and increased production output [18]. | Web Kanban and wel monitoring systems provide real-time synchronization and reporting features [23] and dashboards produced measurable lead-time and scrap improvements in industry [17]. | Edge and cloud framework for welding achieved real-time control with <1s response in experiments [24]. |

Table 3: The results of the literature review for differences between real-time and conventional OEE

| Comparative Aspects | Conventional OEE | OEE Real Time |
|---|---|---|
| Data Collection | Manual, paper-based, or Enterprise Resource Planning (ERP) systems that are filled periodically. | Automation through sensors, IoT, and direct connections to machines (SCADA/PLC). |
| Data Presentation | Delayed (daily, weekly), historical, and aggregated. | Instant, real-time, granular dashboard visualization. |
| Data Accuracy | Prone to human error (input errors, rounding errors, subjectivity). | High accuracy, objectivity, and consistency due to automation. |
| Loss Identification | Slow, can only be identified after production is completed (post-mortem). | Fast, on-the-fly detection of the losses (especially minor stoppages and speed losses). |
| Response Time | Slow, new corrective actions can be taken in the next shift or the next day. | Fast, allowing immediate intervention by operators/technicians. |
| Operational Focus | Passive reporting and accountability. | Active monitoring and problem solving. |
| Cost and Complexity | Low implementation costs, low system complexity. | Initial investment costs (sensors, software) are high, system integration complexity is high. |

The implementation of real-time OEE applications marks a significant evolution in modern operations management, offering unmatched advantages over conventional performance monitoring approaches. These advanced applications were designed to provide instant operational performance feedback, delivering metrics such as availability, performance, and quality as soon as events occur on the shop floor. This ability to accessed data immediately was a key catalyst for faster decision-making and agile process adjustments. For example, when performance degradation was detected, teams can quickly investigate and address the root cause, whether it can be a tool failure, a material bottleneck, or a deviation in quality parameters, before the inefficiency escalates into significant production losses.

In contrast, conventional methods for measuring and analyzing equipment effectiveness have traditionally relied heavily on historical data. Data collection and processed, often performed manually or using batch systems with delayed, result in insights gained post-facto. This delay inherently leads to delayed responses to operational issues; managers may only learn of OEE’s losses from daily or weekly reports, when production losses have already accumulated. In today's lean, high-speed production environment, this lag time between a problem and corrective action is unacceptable waste. Real-time OEE thus shifts from a reactive diagnostic model to a predictive and preventative framework, enabling proactive interventions that minimize downtime and fundamentally improve asset utilization and overall productivity.

The real-time of OEE systems can significantly improve productivity by addressing the losses more effectively than conventional systems. These loss factors included the equipment failures, setup and adjustment wait times, minor downtimes, speed reductions, process defects, and poor yield that were addressed because real-time systems provide instantaneous data monitoring and diagnostics. For example, instead of relying on manual inspections that allow minor breakdowns and speed reductions to be missed, real-time systems can detect performance deviations as soon as they occur. This enables rapid, often automated, corrective action to minimize downtime and prevent losses from developing, thus keeping equipment operating at peak efficiency and eliminating wait times due to delayed manual adjustments. In addition, essentially, the reaction speed of the OEE real-time system shortens the feedback cycle from problem detection to resolution, ensuring operations were always operating as close to theoretical capacity as possible, ultimately drastically improving Overall Equipment Effectiveness (OEE).

## 4. CONCLUSION

The comparative analysis underscores the advantages of real-time OEE applications in improving manufacturing efficiency. While conventional methods remain valuable, the dynamic nature of modern production necessitates the adoption of real-time systems for optimal performance. However, it is essential to consider the context and specific operational needs when selecting an OEE measurement system, as both approaches have their merits and limitations.

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