

Adapting Overall Equipment Effectiveness to Evaluate Operational Performance in an Ophthalmology Outpatient Clinic

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ABSTRACT

Ophthalmology services are facing increasing operational pressures globally due to factors like aging populations and the rising prevalence of eye conditions such as cataracts and glaucoma. Operational inefficiencies, including long waiting times, clinic congestion, and process variability, negatively affect patient care quality and service capacity. To evaluate the operational performance of Mojoagung Eye Clinic using the Overall Equipment Effectiveness (OEE) framework, adapted for outpatient ophthalmology services, and identify the main operational bottleneck. A quantitative descriptive-evaluative study was conducted at Mojoagung Eye Clinic, Indonesia, over a six-month period (September 2025 to February 2026). OEE, comprising three core dimensions, availability, performance, and quality was applied to assess daily clinic operations. Data were collected from clinic records, direct observation, and structured managerial interviews. The clinic's OEE improved from 40% in September 2025 to 71% in February 2026. Performance showed the greatest improvement (+32 percentage points), while availability remained stable, and quality remained consistently high (96-98%). Despite improvements, performance remained the weakest component, indicating it as the main operational bottleneck. Performance improvement is critical to enhancing operational effectiveness in the clinic. The clinic should focus on optimizing service speed through better patient flow management, real-time monitoring, and extended service hours to reduce bottlenecks and improve overall efficiency.

ABSTRAK

Layanan oftalmologi menghadapi tekanan operasional yang meningkat secara global akibat faktor seperti penuaan populasi dan peningkatan prevalensi kondisi mata seperti katarak dan glaukoma. Ketidakefisienan operasional, termasuk waktu tunggu yang lama, kemacetan klinik, dan variabilitas proses, berdampak negatif pada kualitas perawatan pasien dan kapasitas layanan. Mengevaluasi kinerja operasional Klinik Mata Mojoagung menggunakan kerangka *Overall Equipment Effectiveness* (OEE), yang diadaptasi untuk layanan oftalmologi rawat jalan, dan mengidentifikasi hambatan operasional utama. Studi kuantitatif deskriptif-evaluatif dilakukan di Klinik Mata Mojoagung, Indonesia, selama periode enam bulan (September 2025 hingga Februari 2026). OEE, yang terdiri dari tiga dimensi inti ketersediaan, kinerja, dan kualitas digunakan untuk menilai operasi harian klinik. Data dikumpulkan dari catatan klinik, observasi langsung, dan wawancara manajerial terstruktur. OEE klinik meningkat dari 40% pada September 2025 menjadi 71% pada Februari 2026. Kinerja menunjukkan peningkatan terbesar (+32 poin persentase), sementara ketersediaan tetap stabil, dan kualitas tetap konsisten tinggi (96-98%). Meskipun ada perbaikan, kinerja tetap menjadi komponen terlemah, yang mengindikasikan sebagai hambatan operasional utama. Peningkatan kinerja sangat penting untuk meningkatkan efektivitas operasional klinik. Klinik sebaiknya fokus pada optimalisasi kecepatan layanan melalui manajemen alur pasien yang lebih baik, pemantauan *real-time*, dan perpanjangan jam layanan untuk mengurangi hambatan dan meningkatkan efisiensi keseluruhan.

1. Introduction

Ophthalmology services are facing increasing operational pressures globally [1], [2]. The combination of population aging, rising prevalence of cataract, glaucoma, diabetic retinopathy, and other chronic eye conditions, coupled with increasing service demand, has magnified the need for more efficient outpatient eye-care systems [3], [4], [5]. Simultaneously, operational issues such as long waiting times, clinic congestion, and

process variability continue to hinder patient experience, affect service capacity, and lower the perceived quality of care. Recent studies in ophthalmology have thus stressed that improving operational efficiency is not just a peripheral managerial task, but a core requirement for maintaining patient-centered and timely eye care [6], [7], [8], [9].

This challenge is also highly relevant in Indonesia, where healthcare quality is increasingly scrutinized

under the universal health coverage system. Service users are becoming more sensitive to not only clinical outcomes, but also to timeliness, convenience, clarity of information, and operational reliability [10], [11]. Current Indonesian policies continue to prioritize minimum service standards and quality-oriented health system improvements. However, operational performance assessment at the outpatient clinic level remains relatively underdeveloped, particularly in specialized services [12], [13]. For an outpatient eye clinic like Mojoagung Eye Clinic, which caters to both self-paying patients and those covered by the national health insurance system [14], operational performance must be evaluated not only in terms of patient volume, but also in terms of how consistently available clinic time is converted into timely, effective, and high-quality care [15], [16].

One performance framework that may help address this issue is Overall Equipment Effectiveness (OEE) [17], [18]. Originally developed in manufacturing, OEE integrates three core dimensions, availability, performance, and quality, into a single measure of operational effectiveness. It is widely used to identify bottlenecks and hidden losses in production systems [19], [20]. A review of OEE literature reveals that the method has expanded beyond manufacturing and is increasingly applied to logistics and service sectors [21], [22], [23]. Furthermore, several scholars have suggested

healthcare-specific adaptations of OEE, including its application to hospital operations and operating room performance. These developments imply that OEE is not limited to machines; it can serve as a structured framework for evaluating service processes, especially in settings where the focus is on time, capacity, throughput, and quality rather than industrial output alone [20], [24].

However, while studies in ophthalmology have concentrated on lean interventions and waiting-time reduction, most research has been limited to individual performance metrics [25], [26]. These studies generally focus on isolated indicators such as waiting times, clinic durations, or overall departmental efficiency [27], [28], [29] and do not integrate availability, performance, and quality into a unified operational index. This gap in literature forms the core research problem addressed in the current study. While OEE has been applied in healthcare contexts, its adaptation to specialty outpatient clinics, particularly in ophthalmology, remains underexplored [30], [31]. This study seeks to address this gap by applying OEE to evaluate day-to-day operational performance at Mojoagung Eye Clinic, an Indonesian specialist eye care provider. To clarify the conceptual position of the present study, Figure 1 illustrates how operational pressures in outpatient ophthalmology can be examined through an OEE-based service evaluation framework.

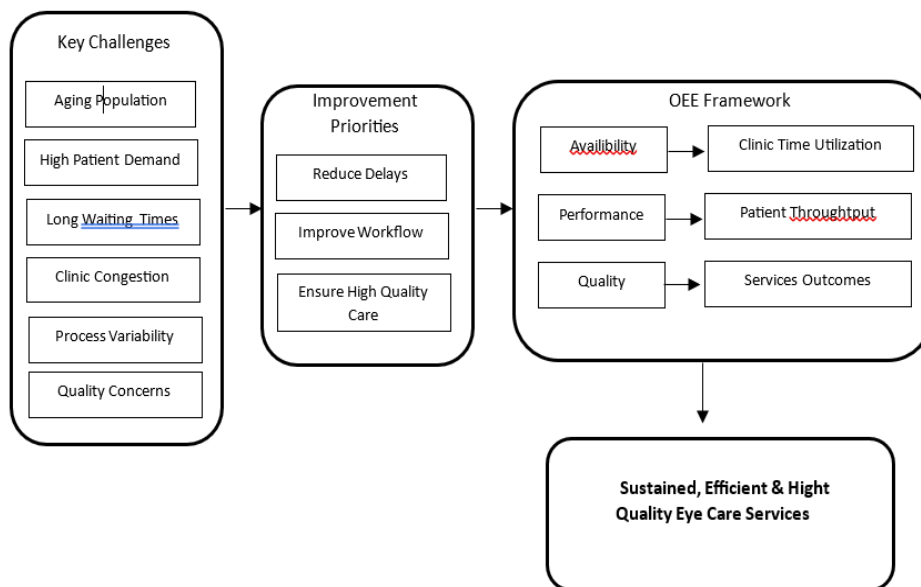


Figure 1. Conceptual Framework for Adapting Overall Equipment Effectiveness (OEE) to Outpatient Ophthalmology Services

Figure 1 illustrates the conceptual logic underlying this study. It shows that outpatient ophthalmology services are currently challenged by rising patient demand, population ageing, long waiting times, clinic congestion, process variability, and quality-related concerns. In response to these pressures, the study positions Overall Equipment Effectiveness (OEE) as an integrated evaluative framework for outpatient service operations.

The figure highlights the three core dimensions of OEE, namely availability, performance, and quality, and shows how these dimensions can be adapted from manufacturing to outpatient eye-care services. In this study, availability refers to the extent to which scheduled clinic time is actually usable for patient care, performance refers to the efficiency of patient throughput relative to the expected service standard, and

quality refers to the proportion of services completed without operational defects or complaints. Together, these three dimensions provide a structured basis for identifying operational bottlenecks and for evaluating whether clinic resources are being translated into timely, efficient, and high-quality care. The figure therefore visualises the study's central argument that OEE can be used as a service-process evaluation framework for improving outpatient ophthalmology performance.

Accordingly, this study evaluates the operational performance of Mojoagung Eye Clinic using an OEE-based approach. The study is novel in three respects. First, it shifts OEE from its conventional equipment-oriented manufacturing use into a service-process evaluation framework for ambulatory eye care. Second, it operationalises clinic performance through the simultaneous examination of availability, performance, and quality, rather than treating waiting time or patient volume as isolated indicators. Third, it provides context-specific evidence from an Indonesian specialist eye clinic, where the adaptation of OEE to outpatient care has not yet been sufficiently documented in the academic literature [32], [33]. In this sense, the study does not merely transfer an industrial metric into healthcare; it tests whether OEE can function as a practical and analytically useful tool for identifying operational bottlenecks in real outpatient service delivery. Based on this background, the study addresses the following research questions:

- RQ1. What is the level of operational performance of Mojoagung Eye Clinic when evaluated using Overall Equipment Effectiveness (OEE)?
- RQ2. How do the three OEE dimensions, availability, performance, and quality, contribute to the clinic's overall operational effectiveness?
- RQ3. Which OEE component represents the main operational bottleneck in the clinic's service process?

By addressing these questions, this study makes both theoretical and practical contributions. Theoretically, it extends the discussion of OEE from manufacturing and equipment-centred settings into specialty outpatient healthcare operations, thereby contributing to the broader literature on operational excellence in healthcare. Methodologically, it demonstrates how an OEE-based framework can be adapted to evaluate service capacity, process efficiency, and quality outcomes in one integrated model. Practically, it provides a structured basis for identifying operational bottlenecks in an ophthalmology clinic and offers managerial insight for service improvement, especially in settings where patient satisfaction, waiting time, and service consistency are increasingly central to healthcare competitiveness and accountability.

2. Research Method

2.1. Study Design and Setting

This study employed a quantitative descriptive-evaluative design to assess the operational performance of Mojoagung Eye Clinic's outpatient ophthalmology services using the Overall Equipment Effectiveness (OEE) approach [34], [35]. A descriptive design was chosen to portray the clinic's operational conditions throughout the study period, while the evaluative component enabled the determination of operational effectiveness based on OEE's three core dimensions: availability, performance, and quality [36], [37], [38], [39]. This approach was deemed appropriate as the goal was to evaluate routine service operations using objective indicators rather than to test causal relationships.

The study was conducted at the outpatient ophthalmology unit of Mojoagung Eye Clinic in Indonesia. The focus was on analyzing the clinic's daily operational performance. In line with recent developments in OEE service-based adaptations, the framework was applied not to a specific piece of equipment but to the clinic's service process, which includes planned service time, actual service time, patient throughput, waiting-time efficiency, and defect-free service delivery [40], [41].

2.2. Unit of Analysis and Study Period

The unit of analysis in this study was the clinic service day, rather than the individual patient or isolated service station. This decision was methodologically appropriate because OEE is calculated from aggregated operational indicators that reflect how the service system performs over a defined period of scheduled work [42], [43]. The study included all available daily operational records across six consecutive months of routine clinic operations, from September 2025 to February 2026. This six-month observation window was selected to provide a more stable picture of outpatient operational performance and to allow the identification of monthly trends in availability, performance, quality, and OEE. By treating each service day as the operational unit, the study was able to evaluate how planned service capacity was translated into actual service time, time efficiency, and service quality under real outpatient conditions [44], [45], [46].

2.3. Data Sources and Data Collection

The study used three complementary data sources, namely direct observation, document review, and a structured managerial interview. Direct observation was conducted to understand the actual patient service flow, including registration, nursing assessment, physician consultation, pharmacy service, and supporting procedures [47], [48]. This step helped the researchers interpret how operational time was used in practice and where delays or process interruptions were likely to

occur. The main quantitative dataset was obtained through document review of the clinic’s internal operational records, including scheduled service time, actual service time, average service or waiting time, number of patients served per day, and daily defect records.

In addition, a structured interview with clinic management was conducted to confirm the clinic’s operating schedule, the service-time benchmark used in the analysis, and the operational meaning of recorded defects. Using multiple operational data sources is consistent with performance evaluation practice because it strengthens the completeness and interpretability of service-process measurement in real healthcare settings [49], [50], [51].

2.4. Operationalisation of Variables and OEE Calculation

To assess outpatient operational performance, this study adapted the classical Overall Equipment Effectiveness (OEE) framework to a service-process context. In this adaptation, availability was defined as the proportion of scheduled clinic time that was effectively available for patient care, performance as the efficiency of actual service delivery relative to the clinic’s service-time standard, and quality as the proportion of patient encounters completed without recorded defects or complaints. These three dimensions were then integrated into a single OEE measure to represent overall outpatient operational effectiveness. The operational definitions were translated into four calculation formulas, as presented in Equations (1)–(4).

First, availability (A) was calculated as the ratio of actual service time to planned service time, multiplied by 100 percent, as shown in Equation (1). This formula was used to determine the extent to which scheduled clinic operating time was effectively available for patient service.

$$A = \frac{\text{Actual Service Time}}{\text{Planned Service Time}} \times 100\% \quad (1)$$

Second, performance (P) was calculated by comparing the standard service time with the actual average service time, as presented in Equation (2). This measure indicates how efficiently services were delivered relative to the clinic’s expected service benchmark.

$$A = \frac{\text{Standard Service Time}}{\text{Actual Average Service Time}} \times 100\% \quad (2)$$

Third, quality (Q) was calculated as the proportion of defect-free services relative to the total number of patients served, as shown in Equation (3). This dimension was used to evaluate whether service encounters were completed without operational errors or formally recorded patient complaints.

$$A = \frac{\text{Defect-free Services}}{\text{Total Patients Service}} \times 100\% \quad (3)$$

Finally, the overall value of OEE was obtained by multiplying the three dimensions of availability, performance, and quality, as formulated in Equation (4). This composite measure represents the overall effectiveness of the outpatient service process.

$$AOEE = A \times P \times Q \quad (4)$$

In this study, planned service time was defined as the clinic’s scheduled daily operating time after deducting routine break time, whereas actual service time referred to the amount of service time effectively available on each clinic day based on operational records. The standard service time was determined using the clinic’s service benchmark, which combined the applicable waiting-time standard and the clinic’s internal effective service target [52], [53]. For the quality dimension, internal defects referred to operational errors documented by staff, such as incorrect patient data entry, while external defects referred to patient complaints formally recorded by clinic management. Because the present study assessed a healthcare service process rather than an industrial production line, OEE values were interpreted as indicators of outpatient operational effectiveness rather than as strict manufacturing benchmarks [54], [55], [56].

2.5. Data Analysis

The data were analysed descriptively in several stages. First, all daily operational records were checked and organised into a dataset containing planned time, actual service time, average service time, number of patients served, and number of defects for each service day. Second, daily values of availability, performance, quality, and OEE were calculated. Third, the daily OEE components were aggregated to obtain the clinic’s average monthly operational performance.

The analysis then focused on three evaluative questions: the overall level of clinic operational effectiveness, the relative contribution of the three OEE dimensions, and the identification of the dominant operational bottleneck [30], [33]. The bottleneck was identified by examining which OEE component consistently showed the lowest value during the observation period, because OEE is not only a summary measure but also a diagnostic tool that helps reveal where the largest operational loss occurs [30], [57]. The findings were presented in tables and descriptive narratives to show the clinic’s operational pattern and to provide an evidence-based basis for service improvement.

2.6. Data Quality Assurance

Several procedures were used to strengthen data quality. First, the operational variables and calculation rules were defined a priori before the main analysis in order to ensure consistency in coding and interpretation. Second, the structured questionnaire and operational definitions used for supporting data collection were reviewed for relevance, comprehensiveness, and clarity,

in line with the COSMIN view of content validity [58], [59]. Third, a small pilot check was conducted to identify ambiguous wording, impractical data fields, or inconsistencies between recorded service events and the intended OEE indicators.

For grouped items, internal consistency was assessed using Cronbach’s alpha, which remains a commonly used indicator of internal consistency in questionnaire-based measurement [60], [61]. Finally, qualitative support materials such as interview notes and observational records were organised systematically so that interpretation of the operational data remained transparent and traceable [62], [63], [64]. This emphasis on methodological transparency is also consistent with

established reporting guidance for observational and qualitative health research, including STROBE and COREQ [58], [61], [65], [66].

3. Results and Discussions

3.1. Monthly OEE Profile of Outpatient Ophthalmology Operations

This study evaluated the operational performance of Mojoagung Eye Clinic over a six-month period, from September 2025 to February 2026, using an OEE-based service-process framework. Table 1 presents the monthly values of OEE and its three component dimensions: availability, performance, and quality.

Table 1. Monthly summary of OEE, availability, performance, and quality at Mojoagung Eye Clinic

Period	OEE	Availability	Performance	Quality	Diagnostic Interpretation
Sep-25	40%	92%	44%	97%	Slight OEE improvement, but performance remained the main loss source
Oct-25	42%	93%	47%	96%	Marginal improvement with persistent service-speed inefficiency
Nov-25	46%	93%	51%	98%	First month with performance above 50%, indicating gradual flow improvement
Dec-25	57%	94%	62%	97%	Marked operational improvement, mainly associated with higher performance
Jan-26	65%	95%	71%	96%	Stronger service efficiency with stable availability and quality
Feb-26	71%	95%	76%	98%	Best monthly result; performance still the lowest component, but substantially improved

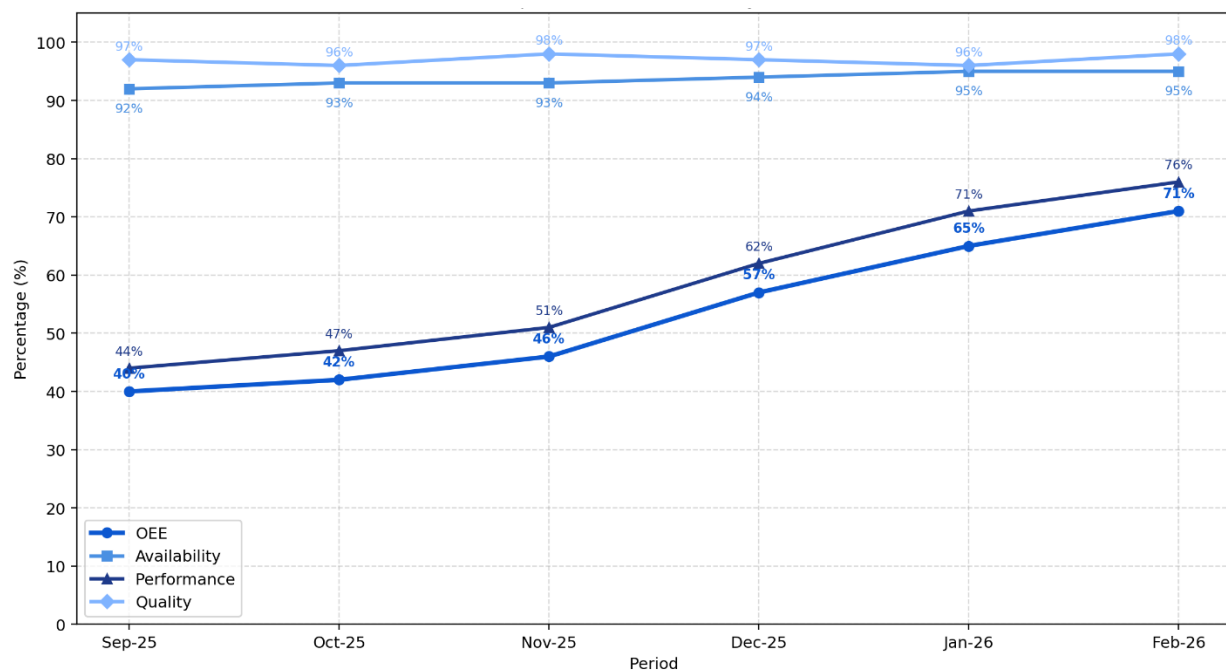


Figure 2. Monthly OEE, Availability, Performance, and Quality at Mojoagung Eye Clinic

As shown in Table 1 and Figure 2, the clinic demonstrated a consistent upward trend in overall operational effectiveness during the six-month observation period. The monthly OEE value increased from 40% in September 2025 to 71% in February 2026, indicating a gradual and sustained improvement in outpatient service operations. The availability dimension remained relatively stable and high

throughout the study period, increasing only slightly from 92% to 95%. This pattern suggests that the clinic was generally able to maintain actual service time close to its scheduled operating time. In other words, the service system showed relatively good control over planned operating capacity, with only limited monthly variation.

The most substantial change occurred in the performance dimension. Performance rose from 44% in September to 76% in February, representing the largest improvement among the three OEE components. This indicates that the clinic became progressively more efficient in translating available service time into actual patient throughput within the established service-time benchmark. Because performance remained the lowest component in every month, it can also be identified as the main operational bottleneck across the study period.

By contrast, the quality dimension remained consistently high, fluctuating only between 96% and 98%. This suggests that the proportion of services

completed without recorded defects or formal complaints was maintained at a relatively stable level, even while the clinic was improving its time-related operational efficiency. Taken together, these findings indicate that the increase in OEE was driven primarily by improvements in performance, while availability remained stable and quality was consistently preserved.

3.2. Magnitude of Change Across the Observation Period

To clarify the relative contribution of each OEE dimension, Table 2 compares the first and last months of the study period.

Table 2. Comparative Changes in OEE and Its Dimensions Between Sep-25 and Feb-26

Indicator	Sep-25	Feb-26	Absolute Change	Interpretation
OEE	40%	71%	+31 points	Substantial improvement in overall operational effectiveness
Availability	92%	95%	+3 points	Stable and consistently high service-time utilisation
Performance	44%	76%	+32 points	Largest improvement; main driver of OEE growth
Quality	97%	98%	+1 point	Quality remained high and operationally stable

Table 3 confirms that the six-month improvement in OEE was attributable mainly to the marked increase in performance, rather than to major changes in availability or quality. While availability and quality were already at relatively high levels at the beginning of the study period, performance started from a much lower baseline and improved substantially over time. This pattern indicates that the clinic’s principal operational challenge was not the preservation of service time or the prevention of defects, but the efficiency of service execution within available operational time.

3.3. Interpretation of the OEE Pattern in relation to the Research Questions

With regard to RQ1, the findings indicate that the operational performance of Mojoagung Eye Clinic improved considerably during the study period, with OEE rising from a low-to-moderate baseline to a substantially stronger level by the end of February 2026. Although the final value of 71% still suggests room for improvement, the trend demonstrates meaningful progress in outpatient service effectiveness.

Regarding RQ2, the three OEE dimensions did not contribute equally to overall effectiveness. Availability contributed by remaining stable and high, thereby preserving operational capacity. Quality contributed by maintaining a consistently high proportion of defect-free services. However, the most influential contributor to OEE improvement was performance, which showed the greatest increase and accounted for most of the growth in the overall OEE value.

For RQ3, performance was clearly the dominant bottleneck across all six months because it remained the lowest OEE component in every monthly observation. Thus, the main operational constraint at the clinic was not the availability of scheduled service time or the general maintenance of quality, but the speed and

efficiency with which services were delivered within the available clinic time.

3.3 Discussion

Interpretation of the OEE Pattern in relation to the Research Questions The present study evaluated the operational performance of Mojoagung Eye Clinic using an OEE-based framework adapted to outpatient ophthalmology services. Three main findings emerged. First, overall operational effectiveness improved consistently over the six-month period. Second, availability remained high and stable, while quality stayed consistently strong. Third, performance was the weakest OEE component throughout the observation period, yet it also showed the largest improvement and became the main driver of OEE growth. Taken together, these findings suggest that the clinic’s principal operational challenge was not maintaining opening time or preventing service defects, but improving how efficiently available service time was translated into completed outpatient care [30], [32].

The upward trend in OEE from 40% in September 2025 to 71% in February 2026 indicates that the clinic improved its ability to convert planned service capacity into effective outpatient care over time. This interpretation is consistent with the broader OEE literature, which increasingly treats OEE not only as an equipment productivity indicator, but also as a diagnostic framework that can be adapted to complex service environments when the relevant operational object is time, throughput, and defect-free delivery rather than machine output alone [20], [67], [68]. In this sense, the present study extends prior healthcare-oriented OEE discussions by demonstrating the usefulness of this framework in a specialist outpatient eye clinic, a context that has received far less attention than operating rooms, laboratories, or equipment-centered hospital functions [30], [32], [33], [69].

A particularly important finding is the stability of the availability dimension, which remained between 92% and 95% throughout the observation period. This suggests that the clinic was generally successful in preserving scheduled service time and limiting major disruptions to daily operations. In practical terms, the clinic's planned working hours were translated into actual service availability with relatively little monthly loss [70], [71], [72]. From an OEE perspective, this means that time-based capacity was not the clinic's primary weakness. This interpretation is also consistent with outpatient operations research showing that prolonged waits and access problems are not always caused by absolute resource shortages; they may also arise when existing slots, sessions, or staff time are not used optimally [30], [73]. The present finding therefore implies that managerial attention should be directed less toward preserving scheduled time per se and more toward improving what occurs within that already-preserved service time.

That issue becomes clearer in the performance results. Performance increased from 44% to 76%, making it both the lowest and the most improved OEE dimension. This indicates that the clinic's largest inefficiency lay in the relationship between available service time and actual service speed relative to the benchmark. In other words, the clinic was open and functioning, but it was not initially converting that available time into patient throughput as efficiently as possible. Ophthalmology-specific operations literature strongly supports this interpretation. Studies using Lean Six Sigma, electronic patient tracking, simulation, and data-driven scheduling in ophthalmology clinics have repeatedly shown that waiting inefficiencies, variable appointment lengths, coordination delays, and workflow interruptions are major determinants of clinic cycle time and throughput performance [30], [57], [68]. The pattern observed in the present study is therefore consistent with a service-flow problem rather than a simple shortage-of-time problem.

Conceptually, this pattern aligns with the theoretical logic of OEE as a diagnostic tool for locating the main source of operational loss within a system. In adapted OEE models, the dimension that remains consistently lowest is analytically meaningful because it indicates where losses are concentrated and where improvement is most likely to generate gains [30], [32]. This reading is further supported by the Six Big Losses framework, which distinguishes losses arising from downtime, speed, and quality. In the present study, availability remained high and quality remained stable, whereas performance stayed consistently lower, indicating that the dominant loss mechanism was speed loss rather than downtime loss or quality loss [74], [75]. Therefore, the relatively low OEE observed at the beginning of the study is best interpreted as a reflection of suboptimal use of available service time rather than insufficient operating hours or deteriorating service quality.

This interpretation also aligns with the concept of the Six Big Losses, specifically the category of speed losses, which are losses that occur when processes run slower than established standards. In the context of this study, relatively high availability indicates that losses due to downtime are likely small, while stable and high quality indicates that losses due to service defects or patient complaints are low. Therefore, the primary source of the overall decline in OEE lies not in limited operational time or service quality, but rather in inefficiencies in the speed of the service process [62], [63]. This finding confirms that strategies to improve clinical operational performance should prioritize improving performance dimensions as a representation of service flow efficiency.

The fact that performance remained the lowest monthly component even in February is analytically important. It suggests that although the clinic became more efficient over time, service-speed efficiency remained the core bottleneck in the system. This is an important distinction because operational improvement does not necessarily remove the dominant constraint; it may only reduce its severity. Previous ophthalmology and specialist outpatient studies similarly show that scheduling mismatches, patient-flow variability, and cycle-time inefficiencies often remain the main operational constraint even when services are otherwise functioning with reasonable continuity [6], [7], [76], [77]. It also fits the concern raised in the Introduction that waiting time and process variability remain central operational problems in eye-care services internationally. The present data therefore support the view that improving service flow and time discipline may produce greater gains than focusing only on broad resource expansion.

The quality dimension remained consistently high, fluctuating only between 96% and 98%. This is an important result because it indicates that the clinic's rising operational effectiveness was not achieved by sacrificing defect-free service delivery. In other words, greater efficiency did not appear to produce a parallel decline in service quality, at least as measured through the clinic's defect and complaint records. In service-based OEE adaptation, this is crucial, because a performance gain that comes at the cost of higher complaint rates or more service errors would represent a false operational improvement [54], [55], [56]. The findings therefore suggest that the clinic was able to improve throughput-related efficiency while keeping the quality dimension under reasonable control.

At the same time, the study also shows why direct comparison with manufacturing-style "world-class" OEE benchmarks should be approached cautiously. Although OEE values are often interpreted using industrial reference points, the present study evaluated a human service process, not a repetitive production line. Outpatient clinical work is shaped by patient complexity, interaction time, clinical judgment,

documentation needs, and variability in case load, all of which make strict manufacturing comparisons problematic [20], [30]. For this reason, the value of OEE in this study lies less in whether the clinic reaches an industrial benchmark and more in whether the metric successfully identifies the main operational loss. On that criterion, the method performed well: it clearly showed that performance, not availability or quality, was the clinic's principal operational constraint.

Another point worth noting is that several daily values in the raw dataset exceeded 100% for either availability or performance, especially in the later months. In operational terms, this likely indicates that on some days the clinic either extended actual service time beyond the original schedule or delivered services faster than the established benchmark. These values should not be interpreted as routine ideal conditions, but rather as signs of intensified operational adaptation under certain service-day conditions. Their presence reinforces the importance of interpreting OEE in healthcare contextually rather than mechanically, especially when the evaluated system is a service workflow instead of a production machine.

Overall, the findings suggest that the clinic's operational improvement during September 2025 to February 2026 was achieved primarily through better service-execution efficiency, while preserving already strong levels of availability and quality. The study therefore supports the broader argument that OEE can be adapted into a useful service-performance framework for specialist outpatient care, particularly when managers need a concise but analytically meaningful way to detect where the largest operational loss occurs. In the case of Mojoagung Eye Clinic, the evidence indicates that the most strategic area for continued improvement is not simply maintaining clinic opening time or controlling complaints, but reducing time inefficiencies within the service process itself. This makes performance the most relevant managerial target for future operational refinement in outpatient ophthalmology [78], [79], [80].

4. Conclusion

This study demonstrates that the operational performance of Mojoagung Eye Clinic improved significantly over a six-month period, as reflected in the increase of OEE from 40% to 71%. The findings indicate that performance is the primary driver of operational improvement, while availability remains stable and quality consistently high. Despite these improvements, performance remains the main operational bottleneck, highlighting the need for continued focus on service efficiency. Therefore, optimizing patient flow, improving scheduling and coordination, and implementing real-time monitoring systems are essential strategies to further enhance operational effectiveness without compromising service quality.

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