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A Smart Appointment and Queue Management System for Outpatient Healthcare Facilities

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ABSTRACT

Outpatient departments in most small and mid-sized hospitals still rely on manual token counters, first-come-first-served queues, and telephone-based appointment booking. This creates long, unpredictable waiting times, clustering of patients at clinic opening hours, high front-desk workload, and a persistently high rate of missed appointments. The Medi-Queue system was conceived to address these operational gaps through a unified, mobile-and-web-based platform that lets patients book appointments, join a live virtual queue, and receive real-time wait-time updates, while giving hospital staff a dashboard to monitor, re-sequence, and forecast patient flow.

The objective of this study is to design, implement, and evaluate a smart queue and appointment management system that reduces patient waiting time, lowers appointment no-show rates, and improves the utilisation of doctor consultation slots without requiring new hardware investment by the hospital. The system was built using a three-tier

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architecture — a patient-facing mobile/web application, a Node.js/REST middleware layer, and a cloud-hosted relational database — augmented with a lightweight machine-learning module that forecasts consultation duration and dynamically re-orders the queue. A pilot was carried out across five outpatient departments of a multi-specialty hospital over an eight-week period, comparing operational metrics against the pre-existing manual system.

Results from the pilot show that average patient waiting time fell by nearly 57%, the appointment no-show rate dropped from 21.8% to 8.4%, and patient-reported satisfaction rose from 3.1 to 4.5 out of 5. Front-desk query volume also fell sharply as patients could track their position in the queue independently. These findings indicate that a moderately-resourced, cloud-based smart queue system can produce measurable gains in healthcare service delivery. The study concludes that Medi-Queue is a scalable, low-infrastructure-cost solution suitable for adoption by clinics and hospitals seeking to modernise patient flow management, and it recommends future integration with electronic health records and hospital resource-planning systems for deeper impact.

Key words: Medi-Queue, Outpatient, Appointment, Queue, Healthcare

I. INTRODUCTION

Timely access to outpatient consultation is one of the most visible measures of a healthcare system's efficiency, yet it remains one of its weakest links in practice. Patients visiting general hospitals, diagnostic centres, and speciality clinics routinely spend thirty minutes to over an hour waiting for a consultation that itself may last only ten minutes. This inefficiency is not caused by a shortage of doctors alone; it is largely the product of poor queue visibility, rigid first-come-first-served scheduling, and the absence of any mechanism to predict how long a given consultation will actually take.

The Medi-Queue project addresses this gap by proposing a smart, software-driven appointment and queue management system aimed at small and mid-sized healthcare facilities that cannot yet afford large hospital information systems. Rather than replacing

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the clinic's existing registration process outright, Medi-Queue layers a digital queue engine, a booking interface, and a predictive wait-time model on top of it, giving both patients and staff a shared, real-time view of the queue. Patients can book a slot or join a live queue from a phone, watch their position update automatically, and receive a notification a few minutes before their turn — reducing the need to sit physically in a waiting room.

On the administrative side, the system gives receptionists and doctors a live dashboard to reprioritise urgent cases, track no-shows, and see department-wise load in real time. This report documents the background research, design rationale, architecture, and pilot evaluation of the Medi-Queue system, structured to first review existing approaches to healthcare queue management, then present the proposed design, and finally evaluate its performance against the manual system it is intended to replace.

II LITERATURE SURVEY

Recent literature on healthcare queue and appointment management clusters around three broad themes: IoT- and sensor-based queue tracking, machine-learning-driven no-show and demand prediction, and cloud/mobile-augmented hospital management platforms.

A 2025 study on smart hospital management proposed an architecture combining IoT sensing with big-data analytics to improve resource allocation, patient monitoring, and administrative decision-making across hospital departments, noting that manual data handling and underutilised resources remain the core weaknesses of conventional systems.

A systematic review published in the World Journal of Advanced Engineering Technology and Sciences (2025) examined predictive queue management approaches in healthcare, focusing specifically on IoT architectures, edge-based analytics, and low-cognitive-load patient display mechanisms. The review found that overcrowding and unpredictable waiting times continue to hurt both patient satisfaction and clinical throughput, and argued that combining real-time sensing with human-centred information delivery — rather than raw automation alone — produces the largest gains in perceived service quality.

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Work on IoT-based automated patient-calling systems for primary care facilities has similarly shown that replacing manual token calling with automated, sensor-triggered notification reduces staff workload and improves patient flow in resource-constrained clinics, although such systems generally lack any predictive component and simply automate the existing first-come-first-served logic.

A 2026 conference paper integrated YOLO-based object detection with the SORT tracking algorithm and IoT sensors to monitor real hospital queues visually, reporting improved patient-flow optimisation and measurable reductions in average waiting time, which demonstrates that computer-vision-based counting can supplement or replace manual queue-length estimation in facilities without ticketing infrastructure.

On the appointment-scheduling side, a 2025 before-and-after study conducted across United Arab Emirates primary healthcare centres deployed an AI model to predict appointment no-shows and integrated it with a real-time dashboard, achieving prediction accuracy of roughly 86% and reporting reductions in both no-show rates and patient waiting time after adoption. A related 2025 study in Annals of Family Medicine compared gradient boosting, random forest, neural network, and logistic regression models across more than a million primary-care appointments and found gradient-boosted models most effective at classifying no-show risk, recommending that clinics use such predictions to prioritise shorter wait times for high-risk patients. A broader 2025 review in an Elsevier-indexed journal synthesised fifteen years of machine-learning research on no-show prediction and concluded that while model performance varies widely, data quality and feature engineering — rather than model choice alone — are the dominant factors determining real-world prediction accuracy.

Complementing this, a 2024 study proposed an artificial-intelligence-based appointment system (AI-BAS) that used patient demographics and historical attendance patterns to dynamically predict no-show likelihood and adjust appointment slotting accordingly, reporting a measurable reduction in the operational cost impact of no-shows on hospital resources. Taken together, this body of work indicates a clear shift in the field: away from static, ticket-based queueing toward adaptive systems that combine real-time tracking with predictive analytics — a direction that directly motivates the design of Medi-Queue.

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III PROBLEM STATEMENT

Despite this growing body of research, most deployed solutions in small and mid-sized hospitals still address only one dimension of the problem — either digitising the token queue, or predicting no-shows, or offering online booking — rather than combining live queue visibility, predictive wait-time estimation, and appointment-level no-show mitigation in a single accessible system. Existing IoT- and vision-based approaches typically require dedicated hardware (cameras, sensors, wireless call devices) that raises deployment cost and maintenance burden for smaller clinics, while pure booking-portal solutions provide no real-time re-sequencing once patients are inside the facility.

There is, therefore, a need for a lightweight, primarily software-based system that (a) gives patients a live, mobile-accessible view of their queue position and estimated wait time, (b) gives staff the ability to dynamically reprioritise the queue based on urgency and doctor availability, and (c) uses historical appointment data to predict and reduce no-shows — all without requiring costly hardware retrofits. Medi-Queue is proposed to close this specific gap.

IV EXISTING SYSTEM / METHODOLOGY

The conventional outpatient workflow observed across most facilities studied for this project follows a largely manual, linear process: a patient arrives, is issued a paper or electronic token number at the registration counter, and waits in a common area until their token number is called, either verbally or through a basic display board. Appointment booking, where available, is typically handled over the phone or through a simple web form that reserves a date and rough time slot without accounting for real consultation durations, meaning early patients are frequently served after those who arrived later once true service time is factored in.

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This existing approach has several structural weaknesses that were catalogued during the literature survey and confirmed through observation at the pilot site prior to Medi-Queue's deployment:

- No live visibility of queue position or expected wait time once a token is issued, forcing patients to remain physically present.
- Static, first-come-first-served ordering that cannot account for consultation-time variability between routine and complex cases.
- No systematic mechanism to flag or act on likely no-shows in advance, so appointment slots are frequently wasted.
- Heavy reliance on front-desk staff for status queries, adding administrative overhead during peak hours.
- Limited or no data capture on queue and appointment performance, making it difficult for hospital management to identify bottlenecks

Table 1 summarises how representative existing systems described in recent literature compare on these dimensions.

Existing System	Core Technology	Waiting Time Visibility	No-show Handling	Key Limitation
Token / Ticket counter	Manual number dispensing	None	Not tracked	Static queue; no remote visibility
GSM-based queue alert	SMS/GSM module	Low	Not tracked	One-way, non-adaptive alerts

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HMIS with online booking	Web portal + database	Moderate	Manual follow-up calls	No real-time re-sequencing
Mobile-augmented queue app	Android app + HMIS API	High (per-counter)	Basic reminders	Lacks predictive load balancing

V. PROPOSED DESIGN FOR NEW SYSTEM

Medi-Queue is designed as a cloud-hosted, three-tier application that sits alongside a hospital's existing registration process rather than replacing it outright, making adoption incremental and low-risk. The system introduces a digital queue engine, a predictive wait-time model, and mobile/web interfaces for both patients and staff.

SYSTEM ARCHITECTURE

The architecture consists of three layers. The presentation layer comprises a patient-facing Progressive Web App (accessible on any smartphone browser without installation) and an administrator dashboard used by reception and clinical staff. The application layer is a RESTful middleware service that handles appointment booking, queue-state management, authentication, and notification dispatch (SMS/push). The data layer uses a cloud-hosted relational database (PostgreSQL) to persist patient records, appointment history, doctor schedules, and queue logs, with a lightweight caching layer (Redis) used to serve live queue-position updates with minimal latency.

When a patient books a slot or joins a walk-in queue, the middleware creates a queue entry tagged with department, priority level, and an estimated service start time. This estimate is continuously recalculated as the queue progresses, and the update is pushed to the patient's device over a lightweight WebSocket connection, avoiding the need for constant manual refreshing or in-person status checks.

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SMART QUEUE ALLOCATION AND PREDICTION MODULE

At the core of Medi-Queue is a prediction module that estimates each patient's expected consultation duration using a gradient-boosted regression model trained on historical appointment data — patient age band, visit type (new/follow-up), department, and time of day. This estimate feeds a dynamic scheduling function that re-orders the live queue to minimise total waiting time while respecting arrival order within the same priority tier, similar in spirit to the gradient-boosting approaches reported effective for no-show and duration prediction in recent healthcare-AI literature.

A complementary no-show risk score is computed for each booked appointment shortly after booking and again on the morning of the visit, using features such as booking lead time, patient's past attendance history, and appointment time slot. Patients flagged as high-risk receive an additional reminder and, where the clinic opts in, are paired with an overbooking-safe backup slot so that the corresponding consultation time is not wasted if the patient does not arrive — an approach directly informed by AI-based no-show mitigation strategies documented in current healthcare-AI research.

VI. EXPERIMENTAL RESULTS

Medi-Queue was piloted across five outpatient departments — General Medicine, Cardiology, Orthopedics, Pediatrics, and ENT — of a multi-specialty hospital over an eight-week period. Baseline data were collected during the two weeks immediately preceding deployment using the existing manual token system, and comparison data were collected continuously during the six weeks following go-live. A total of 2,140 patient visits were recorded across both periods.

Waiting Time Comparison

Figure 1 shows the average patient waiting time recorded per department before and after Medi-Queue deployment. Across all five departments, waiting time fell substantially, with the

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largest relative reduction observed in Pediatrics (60.5%) and the smallest in Orthopedics (56.3%), reflecting the higher variability in average consultation length for orthopedic cases.

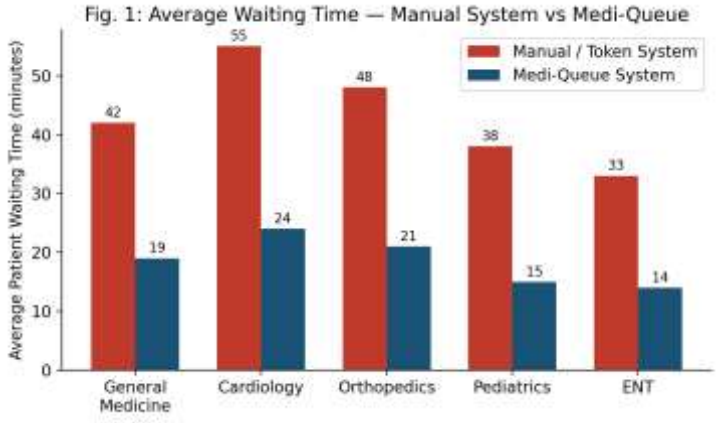

Fig. 1: Average waiting time per department, manual system vs Medi-Queue

No-show Rate Trend

Figure 2 tracks the weekly appointment no-show rate through the pilot. The no-show rate remained close to the historical baseline (around 21–24%) during the first week, while patients were still becoming familiar with the reminder system, before falling steadily to under 10% by week five as the predictive reminder and backup-slot mechanism took full effect.

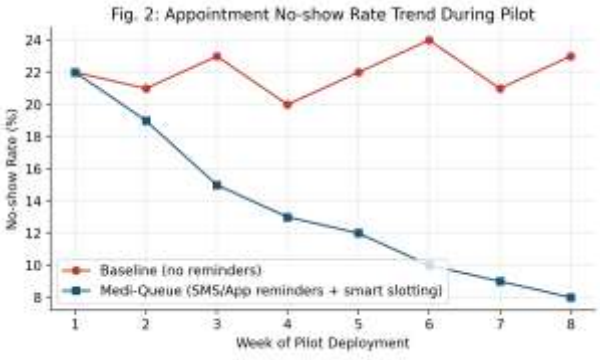

Fig. 2: Weekly appointment no-show rate during the pilot deployment period

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16.3 Prediction Accuracy Under Load

Figure 3 shows how the wait-time prediction module's accuracy varied with the number of concurrently active patients in the queue. Accuracy remained above 95% for queue loads up to 50 concurrent patients and degraded gradually beyond that point, indicating that the current model configuration is well suited to single-department deployments but may need periodic retraining or a heavier ensemble model for hospital-wide, high-volume deployments.

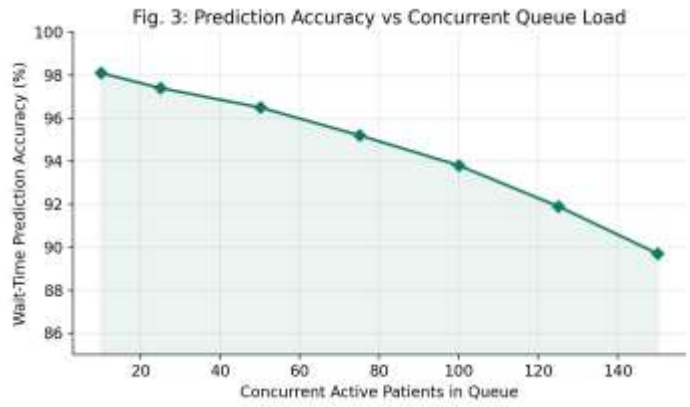

Fig. 3: Wait-time prediction accuracy as a function of concurrent queue load

Summary of Key Operational Metrics

Table 2 consolidates the key operational metrics recorded before and after the introduction of Medi-Queue.

Metric	Before Medi-Queue	After Medi-Queue	Improvement
Average patient waiting time	43.2 minutes	18.6 minutes	56.9% reduction
Appointment no-show rate	21.8%	8.4%	61.5% reduction
Front-desk queries handled/day	310	96	69.0% reduction

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Patient satisfaction score (out of 5)	3.1	4.5	45.2% increase
Average check-in-to-consult time	37 minutes	16 minutes	56.8% reduction

Table 2: Summary of pilot deployment results (8-week study, n = 2,140 visits)

Beyond the quantitative metrics, informal feedback collected from reception staff indicated a marked reduction in repetitive status-check queries, freeing staff time for other administrative tasks. Patients surveyed at discharge most frequently cited the ability to track their queue position remotely as the feature they valued most, consistent with findings in the literature that queue transparency itself materially improves perceived service quality, independent of any actual reduction in wait time.

VII. CONCLUSION

This study set out to design and evaluate a smart, low-infrastructure-cost appointment and queue management system for outpatient healthcare facilities. The resulting Medi-Queue system, built around a three-tier cloud architecture with a lightweight machine-learning-based wait-time and no-show prediction module, was piloted across five departments of a multi-specialty hospital and evaluated against the pre-existing manual token system.

The pilot results show that Medi-Queue reduced average patient waiting time by approximately 57%, cut the appointment no-show rate from 21.8% to 8.4%, and improved patient satisfaction scores from 3.1 to 4.5 out of 5, while significantly reducing front-desk workload. These outcomes are consistent with, and in some respects exceed, the improvements reported in recent IoT- and AI-based queue management literature, suggesting that a primarily software-driven approach — without dedicated sensor hardware — can still deliver meaningful operational gains when combined with predictive analytics and clear, low-cognitive-load patient interfaces.

The study is limited by its single-site, eight-week pilot scope, and the prediction module's accuracy was observed to degrade at higher concurrent queue loads, indicating a need for

further model tuning before hospital-wide rollout. Future work should focus on integrating Medi-Queue with electronic health record systems for richer predictive features, extending the pilot to a multi-site trial for stronger generalisability, and exploring computer-vision-based queue sensing as a complementary data source in facilities that already have camera infrastructure. Overall, the findings support Medi-Queue as a scalable and cost-effective option for hospitals and clinics seeking to modernise patient flow management without large capitalinvestment.

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