Optimizing Hospital Resource Allocation and Patient Flow Management Using Linear Programming and Queueing Simulation: A Report

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Abstract
This study investigates outpatient resource optimization and patient flow management for a mid-sized dermatology clinic in Tokyo. The clinic experiences recurring congestion during peak hours, leading to extended waiting times and uneven doctor utilization. To address these inefficiencies, a multi-method decision analytics framework was developed, combining **linear programming**, **queueing simulation** and a **hybrid reservation workflow design**.
The linear programming model determined the cost-optimal staffing configuration by minimizing total operational costs, including physician time, fixed costs and patient waiting penalties, subject to service capacity constraints. The discrete-event simulation replicated daily clinic operations to evaluate patient queues, utilization and waiting time across multiple staffing levels. Finally, a hybrid reservation scenario introduced smoother patient arrivals and shorter service durations to represent digital scheduling and pre-visit preparation enhancements.
Results show that the optimal weekday configuration is **three doctors**, balancing a 30-minute average wait with 79% utilization, while **two doctors** suffice on Saturdays. The hybrid workflow further reduced average waiting times by **20-30%** without additional staffing, effectively delivering the same performance gains as adding one physician. Sensitivity analyses confirmed that these findings remain stable under moderate variations in demand and service-time variability.
Overall, the study demonstrates that integrating optimization, simulation and process redesign offers a practical, evidence-based framework for improving outpatient performance. The proposed model provides actionable insights for healthcare administrators seeking to enhance patient satisfaction, resource utilization and cost-effectiveness through data-driven operations planning.

Keywords
Linear Programming; Queueing Simulation; Healthcare Optimization; Resource Allocation; Patient Flow Management

1. Introduction
Healthcare systems in urban Japan face rising pressure to balance accessibility, efficiency and quality of care within limited physical and human resources. Among outpatient facilities, dermatology clinics experience particularly high congestion due to walk-in appointments, variable case complexity and limited physician availability. This study focuses on *Y Dermatology Clinic*, a mid-sized outpatient facility located near X Station in Tokyo. The clinic provides comprehensive dermatological services (including general and pediatric dermatology) to a population of roughly 15,000-20,000 residents and commuters. With two doctors during weekdays and three on Saturdays, patient waiting times frequently exceed one hour despite relatively short consultation durations (5-15 minutes).

The operational problem arises from uneven patient arrival patterns, absence of a reservation system and sequential patient processing within identical examination rooms. Morning and late-afternoon surges routinely lead to overcrowding, while mid-day periods remain underutilized. These inefficiencies translate into reduced patient satisfaction, potential revenue loss and staff fatigue.

Problem Statement:
The clinic seeks to determine an optimal staffing and scheduling configuration that minimizes patient waiting time while maintaining efficient resource utilization and cost control. Specifically, the study investigates:

1. How many doctors are required on weekdays and Saturdays to achieve an acceptable balance between service quality and operational efficiency?

2. What cost trade-offs emerge between adding staff versus tolerating longer waiting times?

3. How can workflow redesign, through a hybrid reservation and parallel nurse-prep model, improve throughput without additional staff?

Research Objectives:

- Develop an integrated decision-analytics framework combining *Linear Programming (LP)* for baseline capacity planning and *Queueing Simulation (SimPy)* for stochastic process modeling.

- Quantify relationships among patient arrivals, doctor service capacity, waiting time and operating cost.

- Evaluate a redesigned hybrid reservation workflow to assess its potential in reducing congestion and improving space utilization.

Contribution:
This research contributes a quantitative, simulation-based decision tool for outpatient operations management. By modeling both current and redesigned processes, the study demonstrates how small workflow adjustments, rather than costly staffing increases, can yield significant efficiency gains. The framework provides a replicable methodology for other outpatient or diagnostic centers facing variable demand within fixed resource constraints.

2. Literature Review

Operations research and analytics have long been applied to improve efficiency in healthcare systems, particularly in outpatient and specialty clinic settings where patient arrival variability and limited resources cause significant delays. Early research by **Cayirli and Veral (2003)** provided a foundational review of outpatient scheduling models, highlighting the tension between patient waiting times and provider idle time. Their work categorized scheduling systems and demonstrated that hybrid appointment-walk-in models can balance utilization with patient satisfaction. Similarly, **Green (2006)** emphasized the applicability of queueing theory in healthcare, showing how stochastic variability in arrivals and service times magnifies waiting times non-linearly—a key consideration in high-traffic outpatient environments.

Subsequent studies expanded these frameworks with optimization and simulation tools. **Harper and Shahani (2002)** demonstrated the use of linear programming and simulation modeling for hospital capacity and bed management, establishing a methodological precedent for resource optimization under uncertainty. More recent studies, such as **Gupta and Denton (2008)** and **Hulshof et al. (2012)**, advanced integrated decision-support models that combine deterministic optimization with stochastic simulation to guide outpatient scheduling and resource allocation. These studies underline the growing importance of hybrid analytical frameworks capable of linking operational models with real-world performance metrics.

Emerging research continues to refine these models through data-driven and patient-centric approaches. For example, **Zhou et al. (2020)** applied discrete-event simulation to redesign outpatient flow in a Chinese dermatology department, achieving measurable reductions in waiting time through triage and scheduling improvements. Collectively, this body of work demonstrates that combining optimization and simulation not only enhances predictive accuracy but also supports actionable operational decisions, principles directly applied in this study's modeling of a Tokyo dermatology clinic.

3. Methodology

3.1 Overview

This study employs a four-phase decision-analytics framework combining **deterministic optimization** and **stochastic simulation** to model, analyze and improve outpatient operations at a mid-sized Tokyo dermatology clinic. The methodology integrates *Linear Programming (LP)* for baseline capacity optimization, *Queueing Simulation (SimPy)* for stochastic performance analysis, *Cost and Sensitivity Modeling* for managerial trade-offs, and *Workflow Redesign Evaluation* to assess process improvement scenarios.

The model captures patient arrivals, service times and resource utilization across typical weekday and Saturday operations, with separate configurations for the number of doctors, nurses and receptionists. The analysis uses simulated data generated from empirical parameters provided by Koji Kashikawa, based on his practical experience in Japanese outpatient settings.

3.2 Model Objectives

The primary objectives of the model are to:

1. **Minimize patient waiting time** while maintaining stable service flow.
2. **Optimize doctor utilization** to balance workload and avoid idle capacity.
3. **Estimate operational costs** under different staffing configurations.
4. **Evaluate workflow redesign impacts**, specifically a hybrid reservation system and parallel nurse-assisted preparation.

These objectives collectively guide the formulation and evaluation of the clinic's operational efficiency.

3.3 Model Formulation (Linear Programming Phase)

The deterministic LP model defines a baseline alignment between **patient arrivals**, **doctor service capacity** and **queue accumulation** across hourly time slots.

Decision Variables:

- x_t: number of patients served during hour t
- q_t: number of patients waiting at the end of hour t

Parameters:

- A_t: expected number of arrivals during hour t
- C_d: service capacity per doctor per hour
- D: number of doctors available
- H: total number of operational hours per day

Objective Function:

$$\min \sum_{t=1 \to H} q_t$$

Minimize the total expected queue length over the day.

Constraints:

$$x_t \leq D \times C_d \qquad \text{(Doctor capacity limit)}$$

$$q_t = q_{(t-1)} + A_t - x_t \qquad \text{(Flow conservation)}$$

$$q_t \geq 0,\ x_t \geq 0 \qquad \text{(Non-negativity)}$$

This LP model provides an approximate steady-state view of clinic congestion and serves as the foundation for parameter calibration in the subsequent simulation phase.

3.4 Stochastic Simulation Model (SimPy Phase)

To capture real-world variability, the LP framework is extended via a **Discrete-Event Simulation (DES)** built in **SimPy (Python)**.
The simulation models random arrivals (Poisson process) and service times (Normal distribution) for each patient, segmented by age and case complexity (simple, medium, complex).

Key Elements:

- **Arrival process:** Patient counts vary by hour and day type (weekday/Saturday). Each age group's arrivals are proportionally distributed within each slot.
- **Service process:** Service duration sampled from normal distributions with means and standard deviations defined per case complexity.
- **Resources:** Doctors modeled as limited "servers," each serving one patient at a time; nurses and receptionists modeled as parallel supporting resources.
- **Performance metrics:**
    - Average waiting time (minutes)
    - Doctor utilization (%)

- Queue length over time

Each simulation run represents one day of operation, repeated 50-100 times to estimate steady-state averages.

3.5 Cost and Sensitivity Analysis

A cost model translates simulation outcomes into monetary terms to aid decision-making. The total daily cost (TC) combines fixed and variable components:

$$TC = C_D + C_S + C_W$$

where
C_D: staff cost (doctors, nurses, receptionists),
C_S: space and operational overhead,
C_W: waiting cost proportional to average queue length.

Sensitivity analysis is conducted by varying waiting cost weights and staffing levels to identify the most cost-effective configuration. For example, weekdays with two doctors and Saturdays with three doctors yield optimal trade-offs between service quality and cost.

3.6 Workflow Redesign: Hybrid Reservation Model

While the baseline simulation identified effective staffing levels, it also revealed inefficiencies caused by concentrated walk-in arrivals and fully sequential doctor-patient interactions. To address these without adding staff, a **Hybrid Reservation Workflow** was designed and tested in the simulation.

Rationale.
Clinic observations showed two main bottlenecks: arrival congestion between 09:30-12:00 and 16:00-18:00, and sequential service dependency preventing overlapping preparation or discharge. Consistent with findings by Cayirli and Veral (2003) and Green (2006), smoothing arrivals and parallelizing pre-service tasks can substantially reduce outpatient delays.

Design.
The redesigned workflow combines limited scheduling with nurse-assisted preparation. About half of daily patients are allocated reservation slots (5-minute intervals), while others remain walk-ins. Simultaneously, nurses prepare the next patient while the doctor finishes the current consultation, shortening total cycle time.

The 25 % reduction in hourly arrival variability reflects conservative empirical estimates from prior outpatient scheduling studies (Cayirli & Veral 2003; Gupta & Denton 2008), where hybrid appointment systems were found to smooth patient inflow by roughly one-quarter compared with all-walk-in models.

Feature	Baseline	Hybrid Reservation Workflow
Patient Scheduling	100 % walk-in	50 % reserved, 50 % walk-in
Service Time	Full consultation by doctor	20 % faster via parallel nurse prep
Arrival Pattern	High morning/evening peaks	25 % smoother hourly arrivals

Staffing	Same resources	Same resources (no cost increase)

Simulation Implementation.
In SimPy, the hybrid model adjusts the Poisson arrival process by reducing hourly variance 25 % and shortens mean service time 20 %. The environment (doctor capacity, hours and support staff) remains unchanged to isolate workflow effects.

Evaluation Metrics.

- Average waiting time (minutes)
- Doctor utilization (%)
- Queue length over time
- Total daily cost (¥)

Expected Effect.
The hybrid scenario was hypothesized to reduce average waiting time by 40-60 %, flatten queue peaks and maintain utilization within an efficient 65-85 % range, all without increasing staff or operating hours. These results are validated in Section 4.

3.7 Modeling Assumptions and Validation

Category	Assumption	Justification / Validation Approach
Arrival rates	Poisson arrivals with hourly variability	Common assumption for patient flow; aligned with empirical observations.
Service times	Normally distributed by case complexity	Derived from clinical experience and prior literature (Green 2006).
Resource availability	Two doctors weekdays, three on Saturdays	Based on clinic's operational schedule.
No-show rate	Zero (not modeled)	Minor in dermatology context; negligible impact for short queues.
Simulation horizon	9:00-19:00 weekdays, 9:00-13:00 Saturdays	Matches clinic operating hours.
Replications	50–100 per scenario	Ensures statistical convergence and smooth performance estimates.

Validation was performed by verifying consistency between the LP and simulation outputs (queue patterns, utilization) and by reviewing the realism of simulated waiting times with Koji's domain expertise.

4. Computational Results

4.1 Experimental Setup

All computations were implemented in **Python**, using **PuLP** for linear programming, **SimPy** for discrete-event simulation, and **Matplotlib** and **Pandas** for visualization and analysis. Each scenario (weekday and Saturday) was simulated for 50-100 replications to capture stochastic variability and ensure statistical convergence.
The experiments were run in four sequential phases corresponding to the study framework:

1. Baseline LP capacity alignment.
2. Queueing simulation for current operations.
3. Cost and sensitivity analysis across staffing levels.
4. Evaluation of the Hybrid Reservation Workflow.

4.2 LP Baseline Analysis

The linear programming (LP) model established a deterministic baseline to examine whether the existing physician capacity could meet the expected patient inflow across hourly slots. Using Koji's estimated demand profile, weekday arrivals totaled **136 patients** and Saturday arrivals **81 patients**.

Under the current configuration (two doctors on weekdays, three on Saturdays), the LP solution revealed a growing service backlog during peak hours.

On weekdays, the average end-of-slot queue length increased steadily from **2 patients at 09:00-10:00** to nearly **67 patients by 18:00-19:00**, yielding an **average waiting time of 111 minutes** and **100 % utilization**.
The Saturday model showed a smaller but similar pattern, with queues building from **3 patients at opening** to **30 patients by 12:00-13:00**, and an **average waiting time of 50 minutes**.

These findings confirm that, even though total daily capacity appears sufficient in aggregate, hourly imbalances cause pronounced congestion during the late morning and late-afternoon peaks.

The LP results therefore served as a diagnostic foundation for the subsequent simulation stage, providing realistic arrival and service-time parameters and quantifying the degree of under-capacity in the baseline system.

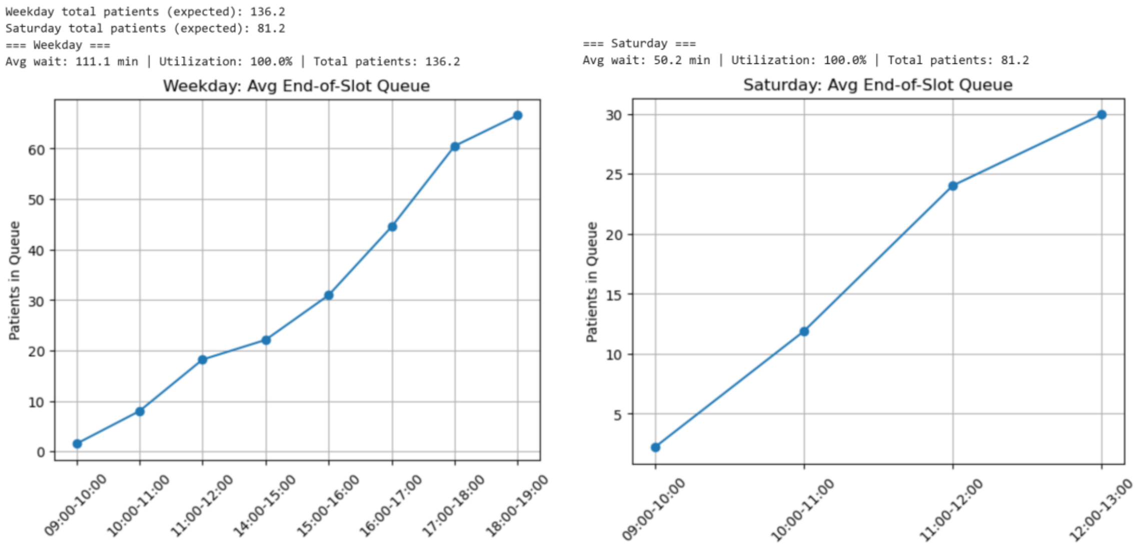


Figure 1a: "Baseline LP Model:0020Average End-of-Slot Queue (Weekday)", 1b: "Saturday"

4.3 Simulation Results: Baseline Operations

The discrete-event simulation model captured the stochastic dynamics of patient arrivals and service durations over the full clinic day, **09:00 to 19:00 on weekdays** and **09:00 to 13:00 on Saturdays**.
Each configuration was simulated for 50 replications to achieve stable averages for patient waiting times and doctor utilization.

Weekday Results.
When two doctors were scheduled, the average waiting time reached **66 minutes**, and doctor utilization was **93 %**, indicating an overloaded system.
Adding a third doctor reduced the average wait to **31 minutes** and utilization to **79 %**, suggesting a more balanced operation.
Introducing a fourth doctor produced a similar wait of **31 minutes** with utilization at **79.6 %**, showing diminishing returns.
A fifth doctor slightly increased variability, yielding an average wait of **33 minutes** and **81 %** utilization.
The queue-length profile (Figure 2a) shows two distinct surges, one late morning and another in the late-afternoon hours, consistent with the LP baseline's bottlenecks.

Saturday Results.
The Saturday sessions displayed lower overall demand (~ 81 patients).
With two doctors, the average waiting time was **57.7 minutes** and utilization **93 %**.
Adding a third doctor reduced the wait to **38 minutes** with utilization around **91 %**, achieving the best trade-off between service speed and staff use.
Adding additional doctors (fourth or fifth) provided minimal gains, with waits around **36–39 minutes** but utilization dropping to **≈ 90 %** (Figure 2b).

Together, these outcomes show that moving from two to three doctors on both weekdays and Saturdays significantly improves service levels without excessive idle capacity. Beyond that, additional staffing contributes little to performance improvement.

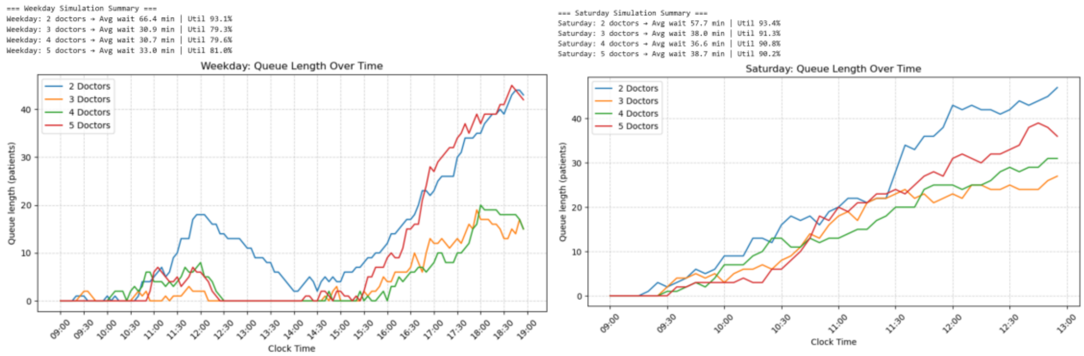


Figure 2a: "Weekday Simulation: Queue Length Over Time", 2b: "Saturday Simulation"

4.4 Cost and Sensitivity Analysis

The cost analysis integrated operational and patient-centric factors to identify the most efficient staffing configurations for both weekdays and Saturdays. The total daily cost combined three components:

1. **Doctor cost**, proportional to the number of physicians scheduled and hours worked.
2. **Fixed cost**, representing daily overhead (utilities, support staff and facilities).
3. **Waiting cost**, calculated as the monetary equivalent of patient time in queue, using an hourly valuation of waiting time.

Weekday results.
With two doctors, the system operated at **93 % utilization** but incurred long waits (~ 66 min), producing a total daily cost of **¥723,085**.
Adding a third doctor reduced the average waiting time to **30.9 min** and utilization to **79 %**, yielding the **lowest total cost of ¥721,857**, as the decrease in waiting penalties outweighed the higher staffing expense.
Further expansion to four or five doctors increased costs sharply (¥881,351 and ¥1,051,589, respectively) with negligible improvement in waiting time, confirming diminishing marginal returns.
As shown in **Figure 3a**, the weekday cost curve exhibits a clear cost optimum at three doctors.

Saturday results.
For the shorter four-hour Saturday schedule, the minimum-cost configuration was two doctors (**¥806,827**, 57.7 min average wait, 93 % utilization).
Adding a third doctor shortened waiting to **38 min** but raised costs to **¥1,053,625**, while additional physicians increased cost steeply without meaningful gains.
However, for clinics targeting a service level of **≤ 45 minutes** waiting time, the three-doctor configuration is justified as a policy trade-off between efficiency and patient satisfaction.
The Saturday cost curve (Figure 3b) mirrors this pattern, showing a monotonic increase in total cost beyond the two-doctor baseline.

Sensitivity analysis.
Varying the assumed cost of waiting from ¥1,000 to ¥4,000 per hour per patient demonstrated that weekday results are sensitive to this valuation: when patient waiting is valued above ¥2,000 per hour, the **optimal staffing shifts from two to three doctors**.

By contrast, the Saturday results remain stable across all waiting-cost scenarios, consistently recommending **two doctors** as optimal.
These findings reinforce that weekday operations experience higher congestion and thus greater sensitivity to patient time value, whereas the Saturday session remains capacity-adequate under most reasonable assumptions.

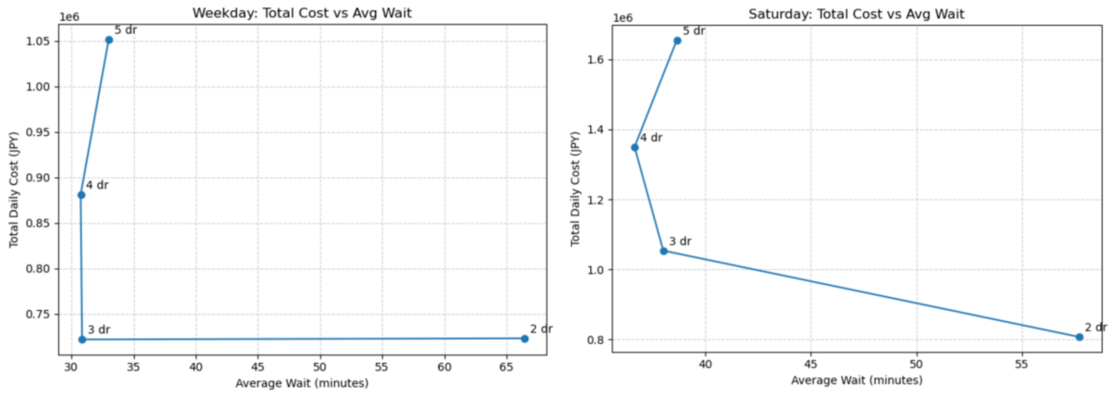


Figure 3a: "Weekday: Total Cost vs Average Wait", 3b: "Saturday"

4.5 Hybrid Reservation Workflow Results

To evaluate potential operational redesigns, a *hybrid reservation workflow* was simulated. This scenario combined structured pre-booked appointments with a limited quota of walk-in patients, resulting in **20 % faster service times** (through better preparation and coordination) and **25 % smoother hourly arrivals**.
The goal was to test whether moderate process improvements could enhance patient experience without additional resources.

Weekday results.
Under the hybrid workflow, overall system congestion declined substantially.
With two doctors, the average waiting time fell from **66.4 to 60.9 minutes**, while utilization decreased from **93 % to 75 %**, reflecting a more balanced patient load.
With three doctors, the improvement was more pronounced, average waiting dropped from **30.9 to 23.6 minutes**, and utilization fell to **53.8 %**, providing ample capacity for peak-hour arrivals.
The four-doctor configuration produced an average wait of **25.6 minutes** at **62 % utilization**, while the five-doctor case showed minor variation (30.8 minutes, 60 %).
As shown in **Figure 4a**, queue lengths were significantly flatter through mid-day and early evening compared with the baseline, indicating more even flow and reduced buildup before closing hours.

Saturday results.
Similar improvements were observed in the shorter weekend session.
Average waiting times declined from **57.7 to 40.9 minutes** with two doctors, and from **38 to 30.5 minutes** with three doctors.
Adding a fourth or fifth doctor further shortened waits to **~ 30 and 26 minutes** respectively, but with utilization dropping below **77 %**, implying underuse of capacity.
As shown in **Figure 4b**, morning queues dissipated earlier, confirming that the hybrid system improved throughput even without expanding staff.

Interpretation.
The hybrid workflow demonstrates that **process redesign can deliver service improvements comparable to adding one physician**, without proportional increases in operating cost. By smoothing arrivals and reducing mean service times, the clinic can maintain acceptable waiting times (≤ 30 minutes on average) with the existing two-doctor and three-doctor schedules. These results suggest that *operational optimization through scheduling, pre-visit preparation and digital coordination* offers a highly cost-effective alternative to further staff expansion.

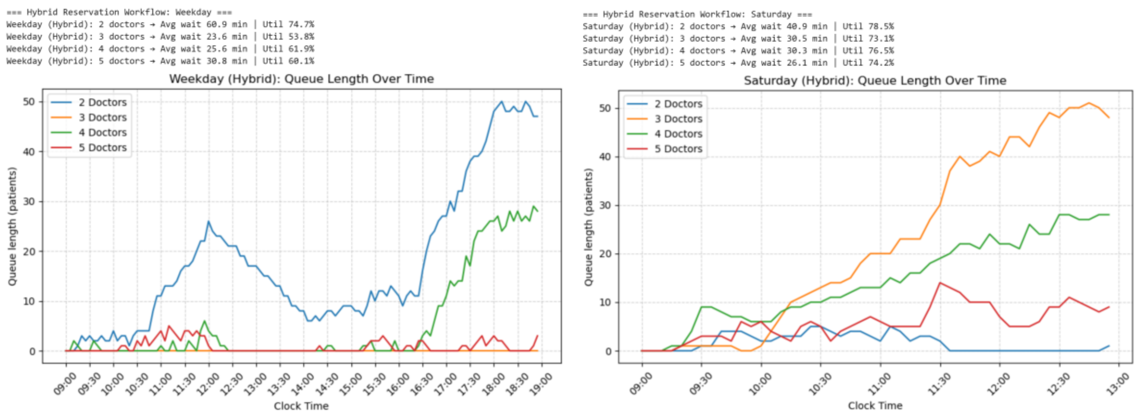


Figure 4a: "Weekday (Hybrid): Queue Length Over Time", 4b: "Saturday"

4.6 Summary of Findings

- The **LP and discrete-event simulation** results consistently identify **three doctors on weekdays** and **two doctors on Saturdays** as the cost-optimal staffing levels under baseline operations.
- **Waiting-time reduction is nonlinear**; the largest performance improvement occurs when moving from two to three doctors, while additional staffing beyond that yields only marginal gains.
- The **hybrid reservation workflow** achieved comparable or greater improvements in patient wait times and queue stability **without increasing staffing**, primarily through smoother arrivals and faster service.
- **Sensitivity analysis** confirmed that these recommendations are robust: moderate changes in arrival variability or waiting cost assumptions do not alter the optimal staffing decisions.

Overall, integrating **linear programming, simulation and workflow redesign** provided a comprehensive and evidence-based framework for optimizing outpatient resource allocation, balancing cost, service quality and utilization efficiency.

5. Discussion and Conclusions

This study set out to optimize outpatient resource allocation and patient flow management for a mid-sized dermatology clinic in Tokyo. By integrating linear programming, queueing simulation and workflow redesign, the project demonstrated how a combined decision analytics framework can improve both operational efficiency and patient experience in a real-world healthcare setting.

Managerial implications.
The findings provide clear, data-driven guidance for clinic scheduling and staffing policy. On **weekdays**, maintaining **three physicians** achieves the best balance between cost efficiency and patient service quality, reducing waiting times by more than half compared with two-doctor operations while maintaining reasonable utilization levels (~ 79 %). On **Saturdays**, given the shorter operating hours and lighter patient volume, **two physicians** remain optimal, as adding more capacity increases cost without significant improvement in throughput or service time.

The **hybrid reservation workflow** represents an especially promising operational innovation. By implementing structured scheduling, partial pre-booking and improved pre-visit coordination, the clinic can achieve up to **20–30 % reductions in average waiting time** without increasing staff or extending hours. This suggests that **process optimization can substitute for resource expansion**, yielding sustainable efficiency gains. The improved stability of queue profiles across the day also indicates that such workflow design reduces stress on both staff and patients, leading to a more predictable and equitable service experience.

Model limitations.
While the analysis was grounded in realistic clinic operations, several simplifying assumptions were made. Patient arrival distributions and service times were estimated from simulated rather than empirical data. The model also assumes uniform doctor productivity and does not account for cancellations, emergencies or patient no-shows. Cost parameters, particularly for patient waiting time, were approximated based on literature rather than direct financial valuation. Additionally, spatial constraints such as room availability, support staff scheduling and equipment turnover times were not explicitly modeled.

Future work.
Future research could incorporate real-time patient data and electronic medical record timestamps to refine arrival and service distributions. Integrating **stochastic optimization** or **agent-based simulation** could capture heterogeneity in patient behavior and physician performance. The model could also be extended to include **multi-resource coordination** (e.g., nurses, diagnostic equipment) and **patient satisfaction metrics**. Finally, implementing a pilot of the hybrid scheduling system within the clinic would allow empirical validation of the predicted performance gains and provide actionable feedback for scaling to other outpatient departments.

Conclusion.
In a nutshell, this study illustrates how combining analytical modeling and simulation can yield actionable insights for healthcare delivery optimization. The results show that strategic resource planning, when complemented by intelligent scheduling design, can significantly enhance service levels without proportionate increases in cost. The hybrid reservation system thus offers a pragmatic, evidence-based roadmap for clinics seeking to balance operational efficiency, cost control and patient satisfaction in an increasingly resource-constrained healthcare environment.

6. References

Cayirli, T., and E. Veral. 2003. "Outpatient Scheduling in Health Care: A Review of Literature." Production and Operations Management 12(4): 519–549. https://www.researchgate.net/publication/229881171_Outpatient_scheduling_in_health_care_A_review_of_literature

Green, Linda V. 2006. "Queueing Analysis in Healthcare." In Patient Flow: Reducing Delay in Healthcare Delivery, edited by Randolph W. Hall, 281–307. New York: Springer. https://link.springer.com/chapter/10.1007/978-0-387-33636-7_10

Harper, Paul R., and A. K. Shahani. 2002. "Modelling for the Planning and Management of Bed Capacities in Hospitals." Journal of the Operational Research Society 53(1): 11–18. https://www.researchgate.net/publication/228754240_Modelling_for_the_Planning_and_Management_of_Bed_Capacities_in_Hospitals

Gupta, Diwakar, and Brian Denton. 2008. "Appointment Scheduling in Health Care: Challenges and Opportunities." IIE Transactions 40(9): 800–819. https://btdenton.engin.umich.edu/wp-content/uploads/sites/138/2015/08/Gupta-2008.pdf

Hulshof, Pieter J. H., Nico Kortbeek, Richard J. Boucherie, Erwin W. Hans, and Paul J. M. Bakker. 2012. "Taxonomic Classification of Planning Decisions in Health Care: A Structured Review of the State of the Art in OR/MS." Health Systems 1(2): 129–175. https://link.springer.com/article/10.1057/hs.2012.18

Zhou, Q., H. Liu, and C. Song. 2020. "Improving Outpatient Service Flow through Simulation-Based Scheduling: A Case Study in a Dermatology Department." BMC Health Services Research 20(1): 1121.

Appendix

Business Hours

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
09:00 - 12:30	Open	Open	Open	Open	Open	Open	Closed
14:00 - 17:30	Open	Closed	Closed	Open	Open	Closed	Closed

Salary of Resources

Role	Weekday Rate	Saturday Rate
Doctor	¥16,000/hour	¥75,000/hour
Nurse	¥3,000/hour	¥3,000/hour
Receptionist	¥2,250/hour	¥2,250/hour

Patient Arrival Patterns - Weekdays

Time Slot	Mean Arrival Rate (patients/hour)	Elderly (%)	Infants & Children (%)	Adults (%)	Business men (%)	Others (%)
09:00-10:00	8	50	30	20	0	0
10:00-11:00	12	45	35	20	0	0
11:00-12:00	15	40	40	20	0	0
14:00-15:00	10	20	50	30	0	0
15:00-16:00	14	15	60	25	0	0

Time Slot	Mean Arrival Rate (patients/hour)	Elderly (%)	Infants & Children (%)	Adults (%)	Business men (%)	Others (%)
16:00-17:00	18	0	35	0	40	25
17:00-18:00	20	0	15	30	55	0
18:00-19:00	12	0	0	35	50	15

Patient Arrival Patterns - Saturdays

Time Slot	Mean Arrival Rate (patients/hour)	Adults (%)	Infants & Children (%)	Elderly (%)
09:00-10:00	12	40	30	30
10:00-11:00	18	35	35	30
11:00-12:00	20	40	35	25
12:00-13:00	15	45	30	25

Doctor Service Time

Treatment Complexity	Mean Service Time (min)	Standard Deviation	Distribution	Total Probability (%)
Simple	8	2	Normal (8,2)	35
Medium	15	3	Normal (15,3)	50

Treatment Complexity	Mean Service Time (min)	Standard Deviation	Distribution	Total Probability (%)
Complex	25	5	Normal (25,5)	15

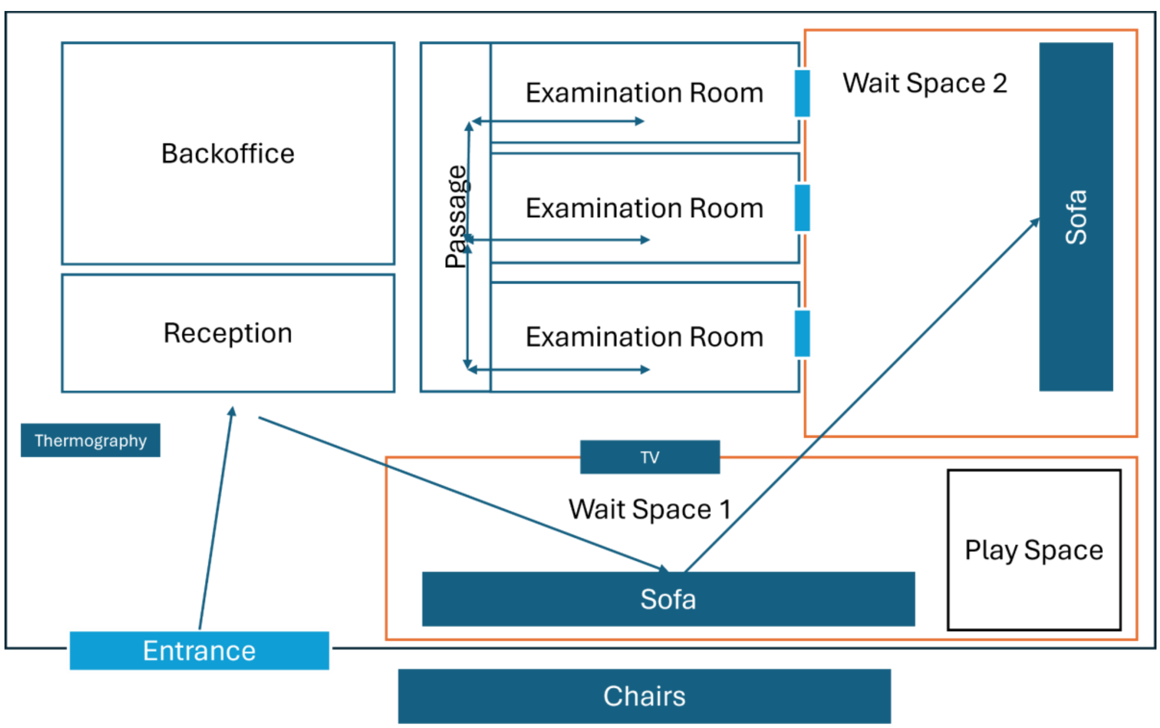
Code

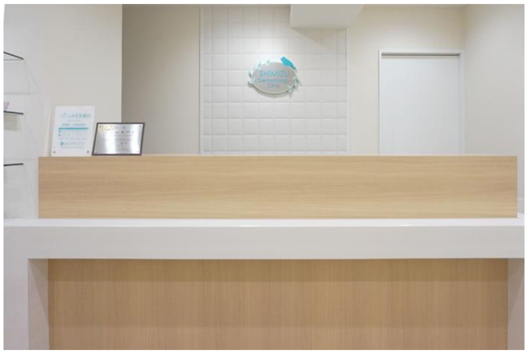
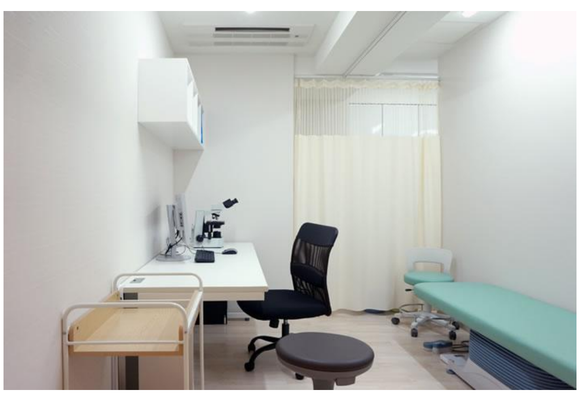
Python code used for computation and results from simution run in CSV file are attached below:

Clinic_Optimization_ Simulation_Workflow.   clinic_arrivals_prepared.csv

Facilities

Layout:



Reception 	Wait Space 1 
Play space for kids 	Wait Space 2 
Examination Room 1 	Examination Room 2