Assessing Healthcare Demand–Capacity Gaps through Stochastic Location–Allocation Optimization: A Case Study of Kabupaten Bandung, Indonesia

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Abstract

Equitable access to primary healthcare remains a challenge in Indonesia, where facility distribution is uneven and capacity is constrained. This study assesses healthcare demand–capacity gaps in Kabupaten Bandung and identifies priorities for facility development. A two-stage stochastic location–allocation model incorporates demand uncertainty across three scenarios. Demand for 2030 is estimated from population projections and epidemiological indicators for catastrophic diseases, while supply comprises puskesmas and clinics.

The optimized configuration covers up to 85.97% of demand, yet 14.03% remains beyond the 3-km accessibility threshold. With all 229 existing facilities open, aggregate capacity exceeds demand and capacity-related unmet demand is negligible (0–0.65%), so the overall gap is primarily spatial. Rancabali and Pasirjambu are the most underserved sub-districts, and capacity inequality reaches a Gini coefficient of 0.33.

Keywords: Healthcare demand–capacity gap, two-stage stochastic location–allocation model, spatial equity in healthcare access.

Introduction

Equitable access to primary healthcare remains a major challenge for Indonesia, where the population is projected to grow from 269.58 million (2022) to 337.57 million by 2050 and facilities are unevenly distributed. National facility counts say little about facility size, workforce, or geographical accessibility.

Location–allocation models (p-median, MCLP, LSCP, p-center, and FCLP) are widely used to plan healthcare facilities, but many rely on the current population and overlook future demand and morbidity. Few studies combine population projections, morbidity-based demand, facility capacity, spatial allocation, and demand uncertainty in one framework.

Kabupaten Bandung (3.78 million people in 2025; 3.92 million projected for 2030) combines urban and rural settlements with uneven facility distribution, which makes it a relevant case for this analysis.

Objectives

(1) Estimate 2030 healthcare demand from population projections and morbidity indicators of catastrophic diseases. (2) Assess the spatial alignment between demand and the capacity of existing facilities. (3) Identify areas with inadequate access or insufficient capacity. (4) Set priorities between building new facilities and expanding existing capacity.

Research Method

Study area and data. Kabupaten Bandung is divided into 435 grid cells of 2 × 2 km (projected 2030 population: 4,580,310). Supply data come from the 2024 facility survey of the West Java Provincial Health Office: 230 candidate facilities (169 clinics and 61 puskesmas) with at least one general practitioner.

Demand and capacity. Daily demand per cell is population × ASIR of catastrophic diseases (θ = 0.05732) ÷ time base. Capacity is physician-based: 480 min/day ÷ 10 min per consultation = 48 patients per physician per day. The coverage standard is 3 km (6 min at 30 km/h; SNI 03-1733-2004).

Model. Stage 1 (location set covering) finds the minimum number of facilities, ψ*, so that every coverable cell is within 3 km of an open facility. Stage 2 is a two-stage stochastic capacitated p-median: opening facilities is the first-stage decision, and allocating demand in each scenario is the recourse decision. It minimizes expected travel time plus a penalty on unmet demand, and is solved as a MILP with Gurobi (verified with CBC).

Scenarios. Demand multipliers are 0.85, 1.00, and 1.15 (probabilities 0.25, 0.50, and 0.25). S1: θ is an annual rate (÷365) with physician capacity. S2: θ is a monthly rate (÷30) with physician capacity. S3: monthly demand with uniform capacity (480 patients/day per puskesmas, 100 per clinic).

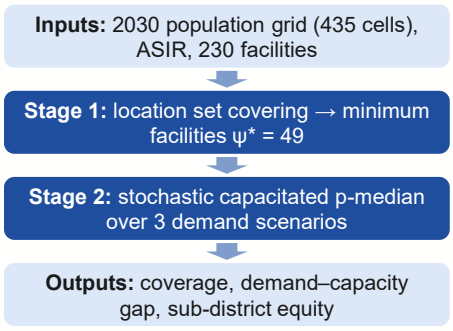


Figure 1. Overview of the modeling framework.

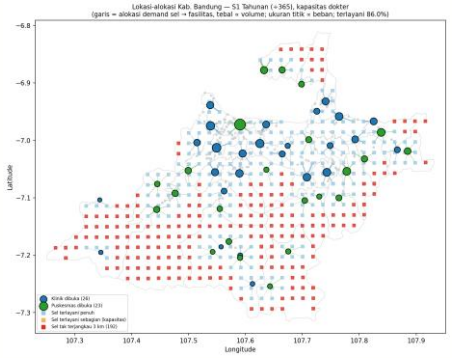


Figure 2. Location–allocation for ψ = 49 under S1 (26 clinics, 23 puskesmas). Blue: served cells; red: cells beyond 3 km.*

Discussion & Result

Spatial coverage. At least ψ* = 49 facilities (26 clinics and 23 puskesmas) are needed for every coverable cell to be within 3 km. Of 435 cells, 192 (14.03% of demand) have no candidate facility within 3 km, mainly in the southern and eastern highlands and along the western edge. Including puskesmas raises attainable coverage from 74.5% (clinics only) to 85.97%.

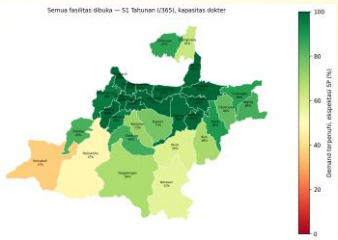


Figure 3. Share of demand met by sub-district with all facilities open (S1).

Table 1. Demand served (%) with 49 open facilities.

Demand level	S1	S2	S3
Low (φ = 0.85)	85.97	74.46	84.34
Moderate (φ = 1.00)	85.97	69.24	83.13
High (φ = 1.15)	85.97	63.37	81.89
Expected value	**85.97**	**69.08**	**83.13**

Demand uncertainty. In S1, capacity far exceeds demand, so 85.97% is served in every scenario. In S2, capacity binds: coverage falls from 74.46% (low demand) to 63.37% (high demand). The higher capacity of S3 holds coverage at 81.89–84.34%. VSS is at most 0.20% and EVPI is below 0.5%.

Demand–capacity gap. With all 229 facilities open, capacity is 3.8–46 times demand and capacity-related unmet demand is only 0–0.65%, so the gap is mainly spatial. Fifteen sub-districts (51.0% of the population) are representative, 14 (42.3%) partially served, and 2 (6.7%) underserved: Rancabali (37% met) and Pasirjambu (47%). Cimenyan has a capacity shortfall under S2, and capacity per 1,000 inhabitants varies 16-fold (Gini = 0.33).

Conclusion

This study develops a stochastic location–allocation framework to assess future primary healthcare demand–capacity gaps in Kabupaten Bandung. Disparities are predominantly driven by geographical accessibility and the uneven spatial distribution of facilities rather than insufficient aggregate capacity. Optimized allocation achieves approximately 86% coverage, while 14.03% of demand remains geographically underserved. Rancabali and Pasirjambu show the most critical accessibility gaps, and Cimenyan has localized capacity constraints under S2. Planning priorities should combine new facilities in underserved areas with targeted capacity expansion at existing facilities.