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A comprehensive study on healthcare system efficiency with special reference to primary health centers in Kanyakumari district, Tamilnadu: An update review

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Abstract

Efficiency in healthcare systems—producing the best possible health outcomes using available resources—has become a central policy concern in low- and middle-income countries (LMICs). In India, Primary Health Centres (PHCs) are the backbone of rural and semi-urban service delivery, including in Tamil Nadu's Kanyakumari district, which combines coastal, peri-urban, and hilly geographies. This review synthesizes conceptual definitions of technical and allocative efficiency; summarizes empirical methods used to assess PHC performance (e.g., Data Envelopment Analysis, Stochastic Frontier Analysis, Pabon Lasso); and compiles determinants of efficiency relevant to PHCs: human resources, infrastructure, supply chains, digital systems, governance, financing, and community engagement. We also collate Indian and Tamil Nadu evidence on cost, quality, and productivity, highlight district-specific considerations (seasonal tourism, disaster-prone coastline, high literacy, and mixed public–private ecology), and propose a pragmatic indicator framework for assessing PHC efficiency in Kanyakumari. The review concludes with actionable strategies—team-based care, task-sharing, appointment systems, essential drug availability, eHealth integration, and continuous quality improvement—to improve efficiency without compromising equity.

Keywords: efficiency, primary health care, PHC, Tamil Nadu, Kanyakumari, data envelopment analysis, quality improvement, health systems.

I. Introduction

Health systems aim to maximize population health while ensuring financial protection and responsiveness (Murray & Frenk, 2000; World Health Organization [WHO], 2000). Efficiency—doing "more health with the same resources" or "the same health with fewer resources"—matters particularly at the primary level, where most conditions can be prevented or managed early (Starfield, 1994; Kruk & Freedman, 2008). India's recent reforms (National Health Policy, 2017; Ayushman Bharat—Health and Wellness Centres) explicitly prioritize comprehensive primary care, risk reduction, and continuity of care (Government of India, 2017; Government of India, 2018).

Tamil Nadu is widely recognized for strong public health performance, robust supply chains, and quality assurance programs (Rao et al., 2011; Mavalankar et al., 2009). Within Tamil Nadu, Kanyakumari district presents a distinctive mix: high literacy, a dense network of roads, significant private sector presence, seasonal tourism, and coastal vulnerability to cyclones and floods. These features shape service demand patterns and resource needs at PHCs and Health & Wellness Centres (HWCs). This review clarifies how "efficiency" can be operationalized for such a setting, what determinants are most influential, which measurement approaches are feasible for district managers, and what strategies are supported by the literature.

II. Materials and Methods

This review followed a narrative design to examine healthcare system efficiency with emphasis on primary health care centres (PHCs) in Kanyakumari district. Literature was searched in PubMed, Scopus, Web of Science, and Google Scholar, supplemented with WHO and Government of India reports. Keywords used included *"healthcare efficiency," "primary health care," "Tamil Nadu," "India," "DEA," "SFA,"* and *"quality of care."* Inclusion criteria were English-language studies (1957–2025), peer-reviewed articles, and policy documents focusing on PHC performance and health system efficiency. Studies unrelated to PHCs or without methodological rigor were excluded. Data were extracted on study setting, methodology, determinants of efficiency (e.g., human resources, financing, supply chain, digital health), and outcomes. Findings were synthesized using Donabedian's structure–process–outcome model and Starfield's primary care framework. As this review used only secondary data, ethical approval was not required.

III. Conceptualizing Efficiency in PHCs

Technical efficiency refers to producing maximum output (e.g., consultations, immunizations, antenatal visits) from a given set of inputs (e.g., staff, equipment, drugs) or minimizing inputs for a given output (Farrell, 1957; Hollingsworth, 2008). Allocative efficiency concerns using inputs in cost-minimizing proportions, given their prices, to achieve a target output mix (Färe et al., 1994). Scale efficiency examines whether facilities are operating at an optimal scale—too small PHCs may underutilize resources, whereas overly large ones may face congestion and quality issues (Coelli et al., 2005). For PHCs, outputs should reflect both service volumes and quality (Starfield, 1994; Donabedian, 1988). Efficiency must also be interpreted alongside equity—improving efficiency should not reduce access for remote or vulnerable groups (WHO, 2008; Kruk & Freedman, 2008). Therefore, any district-level efficiency assessment needs to incorporate contextual modifiers (e.g., travel time, disaster exposure) and quality-of-care signals (e.g., adherence to clinical standards).

IV. Methods to Measure Efficiency at the PHC Level

Common quantitative approaches include:

1. **Data Envelopment Analysis (DEA):** A non-parametric, frontier method that benchmarks each facility against the "best performers" with similar inputs (Charnes et al., 1978; Hollingsworth, 2008). DEA can be input-or output-oriented and can accommodate multiple inputs and outputs—ideal for PHCs that deliver a wide service mix (Zeng & Zhang, 2019).
2. **Stochastic Frontier Analysis (SFA):** A parametric approach that separates random noise from inefficiency in estimating a production function (Aigner et al., 1977; Kumbhakar & Lovell, 2000). SFA requires stronger distributional assumptions but provides statistical inference on determinants of inefficiency.
3. **Pabon Lasso Diagram:** Plots bed occupancy rate against turnover for inpatient units to categorize efficiency quadrants (Pabon Lasso, 1986). While more suited to hospitals, it can inform PHC-attached inpatient or delivery units.
4. **Productivity Indicators:** Average length of stay (ALOS), bed occupancy rate (BOR), outpatient visits per provider day, immunization coverage per vaccinator, and stock-out days for essential medicines (O'Neill et al., 2008; Prinja et al., 2014).
5. **Quality-Adjusted Outputs:** Incorporate adherence to guidelines (e.g., hypertension control rates at HWCs), preventive coverage (immunization, antenatal care), and patient-reported experience (Donabedian, 1988; Kruk et al., 2018).
6. For district managers, a **hybrid dashboard** that combines a DEA score (to flag outliers) with a concise set of productivity and quality indicators is practical and informative.

V. Determinants of PHC Efficiency

Evidence from LMICs and Indian states highlights several modifiable factors:

- **Human Resources for Health (HRH):** Skill mix (presence of medical officer, staff nurse, community health officer, pharmacist, lab technician), team-based care, task-sharing, and stable staffing patterns improve throughput and guideline adherence (Campbell et al., 2013; Agarwal et al., 2019).
- **Infrastructure & Equipment:** Functional diagnostics (hemoglobin, glucose, urine tests, ECG where relevant), cold chain for vaccines, and basic emergency equipment reduce referrals and delays (WHO, 2008; Rao et al., 2011).
- **Essential Medicines & Supply Chains:** Predictable availability and minimal stock-outs are central to productivity and trust; Tamil Nadu's pooled procurement model is frequently cited (Mavalankar et al., 2009).
- **Digital Health & Information Systems:** Electronic health records, teleconsultation, decision support, and real-time dashboards can increase provider efficiency and continuity of care (Bates & Singh, 2018; Government of India, 2018).

- **Governance & Accountability:** Supportive supervision, performance feedback, facility-level micro-planning, and community oversight (Rogi Kalyan Samiti or equivalent) correlate with better outcomes (Peters et al., 2008; Scott et al., 2018).
- **Financing & Incentives:** Adequate, flexible operational budgets; strategic purchasing for diagnostics; and performance-linked incentives (where carefully designed) can reduce waste (Prinja et al., 2014; Government of India, 2017).
- **Community Engagement & Health Literacy:** Demand-side determinants—health-seeking behavior, cultural norms, and trust—affect utilization patterns and thus apparent efficiency (Kruk & Freedman, 2008; Peters et al., 2008).

VI. Contextual Considerations for Kanyakumari District

Kanyakumari coastal geography implies exposure to extreme weather, requiring resilient infrastructure (backup power, water, communication), disaster-preparedness drills, and surge capacity planning for PHCs. High literacy and tourism create fluctuating demand, weekend peaks, and a relatively high expectation for prompt, courteous care. The mixed public–private provider landscape can mean rapid referrals and potential duplication unless coordinated. Transport links are generally better than in interior districts, so supply logistics can be optimized, but remote fishing hamlets may still face access barriers during monsoon or cyclone alerts. Implications for efficiency include: (i) the need for flexible staffing and appointment systems to manage seasonal surges; (ii) telemedicine and community outreach to maintain continuity during weather events; (iii) coordination with private providers for referral loops and data sharing; and (iv) targeted outreach for high-risk groups (e.g., elderly with NCDs, pregnant women).

VII. Proposed Indicator Framework for Assessing PHC Efficiency in Kanyakumari

A balanced dashboard can allow benchmarking across PHCs while acknowledging case-mix and context.

Inputs (resources):

- HRH availability by cadre; absenteeism rate.
- Operational hours per week; functional equipment checklist completion.
- Essential drug availability (% of days in stock for top 25 medicines); vaccine stock integrity.
- Operating budget execution (% utilized).

Service Outputs and Productivity:

- OPD visits per provider day; median patient waiting time.
- Proportion of same-day consultations for acute conditions.
- Antenatal care (≥4 visits) coverage; institutional delivery rate (if applicable).
- Immunization sessions held as planned; full immunization coverage in catchment.
- NCD control rates (e.g., % of registered hypertensives with BP <140/90 over last quarter).
- Referral appropriateness ratio (referred cases meeting referral criteria / total referrals).

Quality & Outcomes:

- Adherence to standard treatment guidelines (audit sample).
- Patient experience score (short validated tool).
- AEFI/AEFI-like events investigated; pharmacovigilance reporting compliance.
- UHC tracer: % of households reporting no catastrophic expenditure for common PHC-amenable conditions (periodic survey).

Efficiency Metrics:

- DEA score per PHC using inputs above and outputs (OPD visits, ANC, immunization, NCD control).
- Stock-out days avoided vs. previous quarter (supply reliability index).
- Cost per OPD visit and per fully immunized child (from micro-costing templates).

This framework can be implemented quarterly, with color-coded heat maps to highlight priority facilities for supportive supervision.

VIII. Strategies to Improve PHC Efficiency in Kanyakumari.

1. **Team-Based, Protocol-Driven Care:** Empower community health officers and nurses to manage stable NCDs using algorithmic pathways, reserving medical officer time for complex cases (Campbell et al., 2013; Government of India, 2018).

2. **Task-Sharing and Skill Mix Optimization:** Train pharmacists and lab technicians for fast-track services (repeat prescriptions, POC tests), supervised by clinicians.
3. **Appointment & Triage Systems:** Introduce simple appointment slots for chronic care days; implement nurse-led triage to reduce waiting time and crowding.
4. **Robust Supply Chain and Inventory Control:** Adopt ABC-VEN analysis, minimum–maximum stock levels, and e-logistics to reduce stock-outs, building on Tamil Nadu's procurement strengths (Mavalankar et al., 2009).
5. **Digital Health Integration:** Use electronic registries for NCDs, teleconsultation links to CHCs/DH, and SMS reminders for follow-ups; dashboards for managers to review productivity and quality.
6. **Continuous Quality Improvement (CQI):** Monthly huddles reviewing indicator dashboards; root-cause analysis of delays/referrals; small tests of change (Plan-Do-Study-Act cycles).
7. **Community Engagement:** Strengthen Village Health, Sanitation, and Nutrition Days; use ASHA networks for outreach in fishing communities and during monsoon disruptions.
8. **Disaster Preparedness:** Facility-specific contingency plans, including backup power, safe water storage, cold-chain resilience, and referral transport agreements for cyclone days.
9. **Public–Private Coordination:** Local referral compacts, shared clinical pathways, and periodic data exchange meetings to reduce duplication and inappropriate referrals.
10. **Costing and Strategic Purchasing:** Use simple micro-costing to identify high-cost bottlenecks; selectively purchase diagnostics locally when cost-effective and timely.

IX. Discussion:

Efficiency in primary health care (PHC) delivery represents not only a technical challenge of maximizing outputs with limited resources but also an ethical obligation to ensure equitable and quality care. The literature highlights that PHCs are most efficient when they balance service volumes, continuity, and patient-centeredness rather than focusing on throughput alone (Starfield, 1994; Donabedian, 1988). In many low- and middle-income countries, including India, resource constraints make efficiency essential for sustaining universal health coverage goals (WHO, 2008). However, efficiency must be contextualized—factors such as geographic vulnerability, socioeconomic diversity, and health-seeking behavior strongly influence the degree to which PHCs can optimize inputs and outputs (Kruk & Freedman, 2008). In the case of Kanyakumari district, distinctive contextual realities—high literacy, strong transport networks, tourism-driven population surges, and coastal disaster risks—shape PHC efficiency differently than in more remote or underdeveloped regions of Tamil Nadu. High literacy can facilitate better health literacy, adherence to preventive care, and effective use of services. At the same time, a strong private sector presence can create both opportunities and inefficiencies: opportunities through faster referrals and complementary services, but inefficiencies if patient flow is fragmented or duplicative (Rao et al., 2011). The efficiency of PHCs in such settings thus depends on coordinated public–private interactions, integrated digital systems, and strong referral mechanisms.

Another key insight is that technical efficiency cannot be separated from quality of care. Studies across LMICs have shown that facilities appearing "efficient" in terms of volume may compromise on guideline adherence, safety, or patient satisfaction (Kruk et al., 2018). This is especially critical in managing chronic diseases, where continuity of care and medication adherence determine long-term outcomes. Incorporating quality-adjusted indicators—such as blood pressure control rates or patient-reported satisfaction—ensures that efficiency metrics reflect meaningful health outcomes, not just numerical targets (Donabedian, 1988). Furthermore, human resources for health (HRH) remain a decisive factor in PHC efficiency. Research from India and other LMICs consistently links team-based care, task-sharing, and skill mix optimization to better service delivery without increasing costs (Campbell et al., 2013; Agarwal et al., 2019). In Kanyakumari, where staff shortages may be less severe than in remote regions, efficiency gains could come from process redesign—such as appointment systems, nurse-led triage, or pharmacist-managed repeat prescriptions—rather than simply increasing staff numbers.

The role of supply chains and digital health is equally critical. Tamil Nadu's pooled procurement system is frequently cited as a best practice for reducing drug stock-outs and improving patient trust (Mavalankar et al., 2009). Expanding this with digital inventory tools and linking it to electronic health records can further minimize waste and ensure timely access. Digital registries for non-communicable diseases, telemedicine for remote hamlets, and mobile-based reminders represent scalable strategies that can raise both efficiency and quality (Bates & Singh, 2018). Finally, efficiency improvement must be embedded within a continuous quality improvement (CQI) culture at the facility level. Evidence shows that supportive supervision, facility-level performance dashboards, and iterative problem-solving cycles (Plan-Do-Study-Act) drive sustained improvements (Peters et al., 2013; Scott et al., 2018). In disaster-prone Kanyakumari, resilience planning—such as backup power, surge staffing and emergency referral protocols—should be part of efficiency strategies, since disruptions compromise both output and trust in the system.

In sum, PHC efficiency is not a static property but a dynamic outcome of how resources, processes, and contextual factors are aligned. For Kanyakumari, the pathway forward involves integrating technical improvements (DEA-based benchmarking, supply chain optimization) with people-centered reforms (team-based care, patient experience measures), while embedding resilience to coastal risks. Such an approach ensures that efficiency gains translate into sustainable improvements in population health and equity.

X. Conclusion

Improving PHC efficiency in Kanyakumari hinges on aligning people, processes, and platforms: a competent team working at the top of their licenses; streamlined patient flow and supply chains; and digital tools that enhance—not burden—care. With a balanced indicator dashboard and a CQI culture, district managers can identify bottlenecks, target supportive supervision, and sustain gains that translate into better health outcomes and higher patient trust—core goals of universal health coverage.

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Table 1. Shows the Key Dimensions of Healthcare System Efficiency in PHCs

S. No	Study Setting	Focus Area	Method/ Framework	Key Findings	Relevance to Efficiency	Application to PHCs	Notes for Kanyakumari	References
1	Global	Technical efficiency	Frontier analysis	Defined productive efficiency concept	Basis for DEA/SFA	Benchmarking PHCs	Useful for input-output comparisons	Farrell, M. J. 1957
2	Global	DEA methodology	Data Envelopment Analysis (DEA)	Non-parametric efficiency assessment	Evaluates PHCs against best performers	Identifies inefficient PHCs	Can apply to district PHCs	Charnes, A., Cooper, W. W., & Rhodes, E. 1978
3	Global	Quality of care	Structure–process–outcome model	Quality is central to efficiency	Prevents volume vs. quality trade-offs	Quality indicators for PHCs	Critical in NCD, maternal care	Donabedian, A.1988
4	USA	Primary care	Conceptual analysis	Primary care essential for health outcomes	Supports PHC efficiency as UHC foundation	Strengthens gatekeeping role	Relevant for Kanyakumari PHCs	Starfield, B. 1994
5	Tamil	Drug	Case study	Tamil Nadu	Supply	Ensures	Replicable	Mavalank

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	Nadu, India	procurement		pooled procurement reduced stock-outs	chain as efficiency driver	medicine availability at PHCs	in Kanyakumari	ar, D., Puwar, T., & Murtaza, A. 2009
6	India	HRH	Workforce analysis	Workforce shortages limit efficiency	Skill mix & HRH balance improve productivity	Optimize PHC staff use	Supports team-based care	Rao, K. D., Bhatnagar, A., & Berman, P. 2011
7	North India	Costing of PHCs	Micro-costing	Cost per service varies widely	Identifies financial inefficiencies	Guides PHC budgeting	Can estimate local costs	Prinja, S., Bahuguna, P., et al. 2014
8	Global LMICs	Quality + UHC	Lancet Commission	High-quality systems = efficiency	Quality-adjusted efficiency metrics	Patient experience & guideline adherence	Apply for NCD and ANC outcomes	Kruk, M. E., Gage, A. D., et al. 2018
9	India	Health policy	National framework	Emphasis on comprehensive PHC	Policy driver for efficiency	Guides HWC transformation	Kanyakumari PHCs must align	Government of India (NHP) 2017
10	USA/global	Digital health	Safety & digitalization	Digital tools improve safety and efficiency	Supports e-registries, telemedicine	PHC digital dashboards	Key in disaster-prone coasts	Bates, D. W., & Singh, H. 2018