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# A DEA-Based Efficiency Analysis of Odisha's Healthcare System: Measuring District-Level Healthcare Performance and Identifying Best Practices

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**Abstract**

In this study, data envelopment analysis (DEA) models are used to assess the efficiency of the healthcare system in the districts of Odisha and to determine whether the system can handle the increase in demand for healthcare services caused by the expanding population. This study used multiple DEA models, including BCC, CCR, SBM (VRS), and super efficiency, to evaluate the relative efficiency of the delivery of health services in Odisha districts. The results revealed substantial variation in performance across the state. The study considered number of sub-centers (SCs), the number of primary health centers (PHCs), the number of community health centers (CHCs), expenditure, bed strength and doctors as input parameters and the average population covered, industrial delivery, life expectancy, and infant mortality rates as output parameters to analyze the performance of the rural healthcare systems. In the results, several districts consistently achieved full efficiency under different DEA models, indicating optimal utilization of resources. The districts such as Cuttack, Bhadrak, Khordha, and Puri frequently appeared on the efficiency frontier in multiple models, suggesting strong healthcare management and service delivery mechanisms. However, districts such as Rayagada, Nabarangpur, and Malkangiri exhibited notably low efficiency scores in traditional and slack-based models.

**Keywords:** Data Envelopment Analysis, Efficiency Analysis, Healthcare Sector, CCR model, BCC model, SBM model, Super efficiency model.

# 1|Introduction

Healthcare systems around the world are under increasing pressure to deliver high-quality services while managing limited resources. This challenge is particularly pronounced in developing countries such as India, where the large size of the population and the regional disparities exacerbate the difficulty of achieving efficient healthcare delivery. As the demand for healthcare services increases, especially with the increase in non-communicable

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diseases, improving the efficiency of healthcare systems has become critical to ensure that health resources are optimally used. Efficiency in healthcare refers to maximizing health outcomes given a set of inputs, such as human resources, capital, and infrastructure. In this context, measuring healthcare efficiency is essential to enhance the quality of healthcare services and ensure that financial and human resources are used effectively to meet public health needs.

India's healthcare system, which operates within a federal framework, experiences significant disparities in access, quality, and outcomes in healthcare across different states and regions. States such as Kerala and Tamil Nadu are often cited as models for efficient healthcare delivery, achieving remarkable health outcomes with relatively lower resource expenditure. In contrast, other states like Odisha face challenges in translating available resources into high-quality healthcare services. Odisha, a state in eastern India, has made notable progress in health indicators such as immunization rates and institutional deliveries; however, inefficiencies in resource utilization remain a major concern [1]. The *motivation* behind this study stems from the need to better understand the efficiency of healthcare delivery in Odisha, especially in the face of resource constraints and geographical challenges. While the state has made progress in improving health outcomes, there is considerable scope for enhancing the effectiveness of healthcare delivery. A comprehensive analysis of healthcare efficiency can help identify bottlenecks, areas for improvement, and potential policy interventions. The findings of this study can provide valuable insights for policymakers, healthcare administrators, and other stakeholders to better allocate resources and improve the quality of care.

**Importance of Health Efficiency Measurement**

The importance of measuring healthcare efficiency cannot be overstated. Efficient healthcare systems are essential for achieving *universal health coverage*, one of the key targets under the United Nations Sustainable Development Goals (SDGs). Efficiency in healthcare refers to both *technical efficiency*, which involves maximizing health outputs from given inputs, and *allocative efficiency*, which concerns the optimal distribution of resources across various health services [2]. In resource-constrained settings, such as Odisha, achieving both technical and allocative efficiency is critical to ensuring equitable access to essential health services without overburdening the financial system.

Research has shown that healthcare systems that achieve higher efficiency levels tend to have better health outcomes, even when operating under similar financial constraints. For instance, studies in countries such as the UK and the US have demonstrated that health systems with higher efficiency scores are able to provide better services at lower costs [3]. In India, several studies have highlighted that efficiency is a significant determinant of state-level health outcomes, where some states, such as Kerala, have been able to achieve higher health indicators with more efficient resource use, compared to states like Uttar Pradesh and Odisha [4]. Therefore, measuring healthcare efficiency is an essential step toward ensuring that the resources invested in healthcare yield the best possible results.

Efficient healthcare systems also provide a framework for identifying areas where *wastage* occurs, such as in the underutilization of available facilities or the misallocation of healthcare resources. Given that healthcare spending in India continues to increase, understanding where inefficiencies lie can help in policymaking and provide guidance on where to direct investment to improve overall performance [5]. In particular, the state of Odisha, with its varied socio-economic conditions and health infrastructure challenges, would benefit significantly from an in-depth efficiency assessment.

The primary objective of this study is to assess the healthcare efficiency of Odisha at the district level using *Data Envelopment Analysis (DEA)*. DEA is an advanced technique that allows for a comprehensive comparison of multiple healthcare facilities based on their input-output ratios, without needing a predefined functional relationship. The specific objectives of the study are as follows:

- To evaluate the technical and allocative efficiency of healthcare facilities in Odisha, examining how effectively resources are being utilized in terms of health outcomes.
- To identify factors that contribute to the variations in healthcare efficiency across districts in Odisha, focusing on socio-economic and infrastructural determinants.

- To benchmark the healthcare efficiency of Odisha against more efficient states in India, such as Kerala and Tamil Nadu, and identify best practices that can be adapted to Odisha's context.
- To provide actionable recommendations for improving the efficiency of healthcare delivery in Odisha, targeting areas with the greatest potential for improvement.

This study will employ *Data Envelopment Analysis (DEA)*, a non-parametric technique used to evaluate the relative efficiency of decision-making units (DMUs). DEA will allow for the measurement of *technical efficiency* (the ability to produce maximum outputs from given inputs) and *allocative efficiency* (how well resources are allocated among different health services). DEA does not require a specific functional form for the relationship between inputs and outputs, which makes it particularly suitable for healthcare systems where outputs are multidimensional and difficult to quantify [6].

The study will collect data on various inputs such as healthcare expenditures, human resources, and infrastructure (e.g., hospital beds, medical equipment) and outputs such as health outcomes like life expectancy, infant mortality rate, and institutional delivery rates. Using DEA, efficiency scores for healthcare facilities in each district of Odisha will be calculated and analyzed. Additionally, a regression analysis will be employed to identify the socio-economic and infrastructural factors that contribute to differences in efficiency across districts.

# 2|Litracture Review

Efficiency in healthcare is crucial for ensuring that limited resources are utilized to produce the best possible health outcomes. It is particularly significant in developing countries like India, where public health systems face mounting pressure due to population growth, changing disease patterns, and budget constraints [7]. Efficiency studies help policymakers identify best practices, allocate resources effectively, and design interventions tailored to regional needs. Globally, numerous studies have employed quantitative techniques to assess efficiency in healthcare delivery. Two of the most commonly used approaches are Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). While SFA is a parametric method that assumes a specific functional form and separates inefficiency from random noise, DEA is a non-parametric approach that constructs a frontier from observed data and measures relative efficiency against this frontier [8]. Data Envelopment Analysis (DEA), introduced by Charnes, Cooper, and Rhodes [9], is a widely used method for evaluating the relative efficiency of Decision Making Units (DMUs) such as hospitals, primary health centers, and regional health systems. DEA can accommodate multiple inputs and outputs without requiring a predetermined production function, making it particularly suitable for the complex and multifaceted nature of healthcare services [10]. Liu et al. [11] study is the first literature survey that focuses on DEA applications, covering DEA papers published in journals indexed by the Web of Science database from 1978 through August 2010. Chaubey et al. [12, 13] explained that agricultural productivity states and UTs in India were obtained using the Malmquist-based DEA technique, and the efficiency score for each year was found using the CCR model.

In the healthcare sector, inputs typically include the number of physicians, nurses, hospital beds, and expenditures, while outputs may include patient visits, number of surgeries, recovery rates, and life expectancy. DEA models have evolved to incorporate both technical and allocative efficiency, and different model specifications such as CCR (Charnes, Cooper, and Rhodes), BCC (Banker, Charnes, and Cooper), and SBM (Slack-Based Measure) have been developed to capture different dimensions of performance [14]. DEA has been applied extensively in both developed and developing countries. For example, it has been used to benchmark hospitals in the United States, evaluate district-level health performance in China, and analyze the impact of health sector reforms in African countries [8, 15]. India, with its vast geographical and socio-economic diversity, offers a complex landscape for efficiency analysis. A number of studies have assessed inter-state variations in healthcare performance using DEA. Dash and Mohanty [16] applied a DEA framework to measure technical efficiency in Indian states, revealing significant disparities in health infrastructure and service utilization. Their study showed that states with better administrative systems and higher public investment often performed more efficiently. Mohanta et al. [17] measured the performance of 32 states and union territories (UTs) of India against COVID-19 disease using efficiency score which was calculated by data envelopment analysis (DEA) and compared the efficiency score with the different models which are used in many articles to evaluate the efficiency of healthcare system. Panda et al. [18] analyzed public healthcare efficiency in Odisha using DEA in a more region-specific study. They considered inputs such as the number of doctors, nurses, and health expenditures, and outputs such as outpatient visits and institutional deliveries. Their findings indicated that several districts in Odisha were operating below the efficiency frontier, suggesting potential for improvement through better management and resource allocation. Chaubey et al. [19] measured the relative efficiency and productivity change over time in rural healthcare systems in the presence of fuzzy data. The suggested ranking technique is used to construct the fuzzy data envelopment analysis (FDEA), Malmquist fuzzy DEA (Mal-FDEA), and undesirable Malmquist fuzzy DEA (UN-Mal-FDEA ) models.

Odisha's healthcare landscape is characterized by uneven distribution of services, with rural and tribal regions often facing significant barriers to access. Mohapatra and Behera [20] used DEA along with the Malmquist Productivity Index to study productivity changes in Odisha's health sector over time. They concluded that while technological progress had improved, efficiency scores remained stagnant due to underutilization of resources and workforce shortages. Such studies are important because they highlight specific inefficiencies within local contexts and offer a basis for targeted interventions. For instance, addressing the lack of trained health personnel or improving supply chain logistics can substantially enhance overall system performance. Despite its widespread use, DEA has certain limitations, especially in healthcare settings. The choice of inputs and outputs is often subjective and context-dependent. If key variables are omitted or if the data is of poor quality, the results may not accurately reflect true efficiency [15]. Moreover, DEA assumes that all deviations from the frontier are due to inefficiency, not accounting for statistical noise or random shocks, which can be significant in healthcare environments [14]. Another challenge is the heterogeneity of healthcare systems. For example, a rural primary health center and an urban tertiary hospital may serve very different populations and health needs. Comparing such units directly can lead to misleading conclusions unless the analysis accounts for contextual variables. Some researchers have proposed using bootstrapped DEA models to address these issues, as they allow for more robust estimation and statistical inference [21].

# 3|Methodology

## Fundamentals of DEA

Data Envelopment Analysis (DEA) is a non-parametric method used to evaluate the relative efficiency of decision-making units (DMUs) such as hospitals, schools, or firms that use multiple inputs to produce multiple outputs. The core idea of DEA is to assess how efficiently a DMU transforms inputs (like labor, capital, or equipment) into outputs (such as services or products) by comparing it with a constructed "best practice frontier" formed by the most efficient units.

DEA models can be input-oriented, focusing on minimizing inputs while maintaining output levels, or output-oriented, aiming to maximize outputs with given inputs. Two common DEA models include the CCR model, which assumes constant returns to scale, and the BCC model, which allows for variable returns to scale. Each DMU receives an efficiency score between 0 and 1, where a score of 1 indicates full efficiency.

DEA also distinguishes between technical efficiency (maximizing output from given inputs) and scale efficiency (operating at an optimal size). Widely used across sectors such as healthcare, education, and banking, DEA helps identify performance gaps and best practices for improvement.

In super-efficiency models, Efficiency scores are obtained from these models by eliminating the data for the decision-making unit (DMU) DMUh to be evaluated from the solution set. This can result in values which are regarded as according DMUh, the status of being 'super-efficient.' These values can then be used to rank the DMUs and thereby eliminate some (but not all) of the ties that occur for efficient DMUs.

## The CCR Model

Charnes et al. [9] created the CCR model, a DEA model, to compare how efficient DMUs are at using a common set of different inputs to produce a common set of different outputs. Let us consider n DMUs and m inputs products s outputs. Then the input and output vectors for $DMU_j$ where $j = 1, 2, \cdots,$ n can be defined as $x_j = (x_{j1}, x_{j2}, \cdots, x_{jm}) \in \mathbb{R}^m$ and $y_j = (y_{j1}, y_{j2}, \cdots, y_{js}) \in \mathbb{R}^s$ respectively.

The dual of the linear programming problem with a real variable $\theta_o$ and non-negative vector $\lambda = (\lambda_1, \lambda_2, \cdots, \lambda_n)$, then the production possibility set is defined as

$$\mathrm{P}_{\mathrm{CCR}} = \left\{ (x, y) \mid x \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ y \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ \lambda_j \geq 0,\ j = 1, 2, \cdots, n \right\},$$

where $i = 1, \cdots, m,\ r = 1, \cdots, s.$
Then, the input-oriented CCR model (CCR-I) in dual form for $DMU_o$ is defined as

$$\begin{aligned} &(\text{Dual CCR-I})\ min\ \theta_o \\ &\text{s.t.}\quad \theta_o x_{io} \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ i = 1, 2, \cdots, m, \\ &y_{ro} \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ r = 1, 2, \cdots, s, \\ &\text{and } \lambda_j \geq 0,\ j = 1, 2, \cdots, n. \end{aligned} \tag{1}$$

And the output-oriented CCR model (CCR-O) in dual form for $DMU_o$ is defined as

$$\begin{aligned} &(\text{Dual CCR-O})\ max\ \theta_o \\ &\text{s.t.}\quad x_{io} \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ i = 1, 2, \cdots, m, \\ &\theta_o y_{ro} \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ r = 1, 2, \cdots, s, \\ &\text{and } \lambda_j \geq 0,\ j = 1, 2, \cdots, n. \end{aligned} \tag{2}$$

# The BCC Model

Banker et al. [22] proposed a DEA model, in short, called the BCC model. The BCC model is an extension of the CCR model, where a convexity requirement is incorporated. In other words, the convexity condition is introduced into the CCR model, creating the BCC model. Then, the production possibility set is defined as

$$\mathrm{P}_{\mathrm{BCC}} = \left\{ (x, y) \mid x \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ y \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ \sum_{j=1}^{n} \lambda_j = 1,\ \lambda_j \geq 0,\ j = 1, 2, \cdots, n \right\}.$$

The input oriented BCC model (BCC-I) for $DMU_o$ (where o=1,2,$\cdots$,n) is defined as

$$\begin{aligned} &(\text{Dual BCC-I})\ min\ \theta_o \\ &\text{s.t.}\quad \theta_o x_{io} \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ i = 1, 2, \cdots, m, \\ &y_{ro} \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ r = 1, 2, \cdots, s, \\ &\sum_{j=1}^{n} \lambda_j = 1, \\ &\text{and } \lambda_j \geq 0,\ j = 1, 2, \cdots, n. \end{aligned} \tag{3}$$

The output oriented BCC model (BCC-O) for $DMU_o$ (where o=1,2,·,n) is defined as

$$\text{(Dual BCC-O) } max\ \theta_o \tag{4}$$

$$\text{s.t.}\quad x_{io} \geq \sum_{j=1}^{n} \lambda_j x_{ij},\ i = 1, 2, \cdots, m,$$

$$\theta_o y_{ro} \leq \sum_{j=1}^{n} \lambda_j y_{rj},\ r = 1, 2, \cdots, s,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\text{and } \lambda_j \geq 0,\ j = 1, 2, \cdots, n.$$

**Definition 1** ([23])**.** *Let $\theta_o^*$ be the optimal value of $\theta_o$ obtained from CCR and BCC models. Then $\theta_o^*$ is called the Efficiency score of DMUo. A DMU is considered CCR efficient if the optimal value $\theta_o^*$ is equal to 1, and there is at least one optimal pair of weights $(u^*, v^*)$ where $u^* > 0$ and $v^* > 0$, otherwise DMUo is CCR-inefficient if $\theta_o^* < 1$.*

## The SBM Model

The SBM model was introduced by Tone [24] (see also Pastor *et al.* [25]). It has three variations, namely input-, output-, and non-oriented. The non-oriented model is both input- and output-oriented.

Let the set of DMUs be $J = \{1, 2, \ldots, n\}$, each DMU having $m$ inputs and $s$ outputs.

We denote the vectors of inputs and outputs for $\text{DMU}_j$ by

$$\mathbf{x}_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T, \quad \mathbf{y}_j = (y_{1j}, y_{2j}, \ldots, y_{sj})^T,$$

respectively. We define input and output matrices $\mathbf{X}$ and $\mathbf{Y}$ by

$$\mathbf{X} = (\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n) \in \mathbb{R}^{m\times n}, \quad \mathbf{Y} = (\mathbf{y}_1, \mathbf{y}_2, \ldots, \mathbf{y}_n) \in \mathbb{R}^{s\times n} \tag{5}$$

We assume that all data are positive, that is, $\mathbf{X} > 0$ and $\mathbf{Y} > 0$.

The production possibility set is defined using a non-negative combination of the DMUs in the set $J$ as

$$P = \left\{ (\mathbf{x}, \mathbf{y}) \mid \mathbf{x} \geq \sum_{j=1}^{n} \lambda_j \mathbf{x}_j, \quad 0 \leq \mathbf{y} \leq \sum_{j=1}^{n} \lambda_j \mathbf{y}_j, \quad \lambda \geq 0 \right\} \tag{6}$$

where $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n)^T$ is called the intensity vector.

The inequalities in equation (6) can be transformed into equalities by introducing slacks as follows:

$$\mathbf{x} = \sum_{j=1}^{n} \lambda_j \mathbf{x}_j + \mathbf{s}^- \tag{7}$$

$$\mathbf{y} = \sum_{j=1}^{n} \lambda_j \mathbf{y}_j - \mathbf{s}^+ \tag{8}$$

$$\mathbf{s}^- \geq 0, \quad \mathbf{s}^+ \geq 0 \tag{9}$$

where $\mathbf{s}^- = (s_1^-, s_2^-, \ldots, s^-)$T$\in \mathbb{R}$ and $\mathbf{s}^+ = (s_1^+, s_2^+, \ldots, s^{+s})$T$\in \mathbb{R}$ are called the input and output slacks, respectively.

In order to evaluate the relative efficiency of DMUh = $(x h y h)$, we solve the following linear program. This process is repeated $n$ times for $h = 1, \ldots, n$.

The input-oriented SBM efficiency $\rho_I^*$ of $\text{DMU}_h = (x_h, y_h)$ is defined by

$$\text{[SBM-I]} \quad \rho_I^* = \min_{\lambda, s^-, s^+} \left( 1 - \frac{1}{m} \sum_{i=1}^{m} \frac{s_i^-}{x_{ih}} \right) \tag{10}$$

$$\text{subject to} \quad x_{ih} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-, \quad (i = 1, \ldots, m)$$

$$y_{rh} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+, \quad (r = 1, \ldots, s)$$

$$\text{and} \quad \lambda_j \geq 0 \quad (\forall j), \quad s_i^- \geq 0 \quad (\forall i), \quad s_r^+ \geq 0 \quad (\forall r)$$

$\rho_I^*$ is called the SBM-input efficiency. The SBM VRS model is developed by including the convexity condition $\sum_{j=1}^{n} \lambda_j = 1$ in the above SBM-I model.

The output-oriented SBM efficiency $\rho_O^*$ of $\text{DMU}_h = (x_h, y_h)$ is defined by

$$\text{[SBM-O]} \quad \frac{1}{\rho_O^*} = \max_{\lambda, s^-, s^+} \left( 1 + \frac{1}{s} \sum_{r=1}^{s} \frac{s_r^+}{y_{rh}} \right) \tag{11}$$

$$\text{subject to} \ x_{ih} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-, \quad (i = 1, \ldots, m)$$

$$y_{rh} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+, \quad (r = 1, \ldots, s)$$

$$\text{and} \ \lambda_j \geq 0 \quad (\forall j), \quad s_i^- \geq 0 \quad (\forall i), \quad s_r^+ \geq 0 \quad (\forall r) \tag{12}$$

Let an optimal solution of **[SBM-O-C]** be $(\lambda^*, s^{-*}, s^{+*})$.

A $\text{DMU}_h = (x_h, y_h)$ is called SBM-output-efficient if $\rho_O^* = 1$ holds. This means $s^{+*} = 0$, that is, all output slacks are zero. However, the input slacks may be non-zero.

The VRS model of SBM-O can be obtain by including the convexity condition $\sum_{j=1}^{n} \lambda_j = 1$ in the above SBM-O model.

## Super Efficiency Model

To expand the capabilities of DEA, [26] was at the forefront of introducing a mechanism that distinguished efficient DMUs even further. A super-efficiency DEA model's configuration can be radial or non-radial. Let DMUo be an efficient DMU. Then the input-oriented radial super-efficiency model under the VRS assumption is defined as follows:

$$\text{(Super-I)} \ min \ \psi \tag{13}$$

$$\text{s.t.} \quad \psi x_{io} \geq \sum_{j \neq 0, j=1}^{n} \lambda_j x_{ij}, \ i = 1, 2, \cdots, m,$$

$$y_{ro} \leq \sum_{j \neq 0, j=1}^{n} \lambda_j y_{rj}, \ r = 1, 2, \cdots, s,$$

$$\sum_{j \neq 0, j=1}^{n} \lambda_j = 1,$$

$$\text{and} \ \psi \in \mathbb{R}, \ \lambda_j \geq 0, \ j = 1, 2, \cdots, n.$$

# 4|Data Collection and Description

The choice of inputs and outputs is critical for accurate DEA results. Common inputs and outputs in healthcare efficiency analysis include:

(1) **Inputs:** Number of doctors, number of nurses, number of hospital beds, medical equipment, total expenditure.

(2) **Outputs:** Number of treated patients, patient recovery rates, bed occupancy rate, patient satisfaction.

## Data Sources

The input data used in this study is obtained from the official Odisha government website. The study focuses on all districts of Odisha. All the input and output variables are defined in Table 1.

Table 1. Sources of health data for Odisha.

| **Data** | **Source** |
|---|---|
| Number of Sub-centres | National Health Mission, Odisha (2024) [27] |
| Number of PHCs | National Health Mission, Odisha (2024) [27] |
| Number of CHCs | National Health Mission, Odisha (2024) [27] |
| Expenditure (in cr) | Finance Department, Government of Odisha (2024) [28] |
| Bed Strength | Department of Health and Family Welfare, Odisha (2024) [29] |
| Doctor | Department of Health and Family Welfare, Odisha (2024) [29] |
| Infant Mortality Rate (IMR) | National Health Mission, Odisha (2024); Ministry of Health and Family Welfare [27], Government of India (2021) [30] |
| Institutional Delivery (ID) (in %) | National Health Mission, Odisha (2024); Ministry of Health and Family Welfare [27], Government of India (2021) [30] |
| Life Expectancy | National Health Mission, Odisha (2024) [27]; Office of the Registrar General Census Commissioner, India (2024) [31] |
| Population (in Lakhs) | Office of the Registrar General Census Commissioner, India (2024)[31] |

## Selection of Districts for Analysis

The input and output data used for efficiency measurement of the healthcare system of districts of Odisha are provided in Table 2. In the Table 3 describe about the variable used in this study with their details descriptions and data source. These are the follwowing abbreviations used for the districts of Odisha. These districts include: Angul (AN), Balangir (BL), Balasore (BA), Bargarh (BR), Bhadrak (BH), Boudh (BO), Cuttack (CU), Deogarh (DE), Dhenkanal (DH), Gajapati (GA), Ganjam (GN), Jagatsinghpur (JS), Jajpur (JJ), Jharsuguda (JR), Kalahandi (KA), Kandhamal (KD), Kendrapara (KP), Keonjhar (KJ), Khordha (KH), Koraput (KO), Malkangiri (MA), Mayurbhanj (MY), Nabarangpur (NA), Nayagarh (NY), Nuapada (NU), Puri (PU), Rayagada (RA), Sambalpur (SA), Subarnapur (SU), Sundargarh (SN).

Table 2 provides the descriptive statistics for the selected input and output variables across the districts of Odisha. The data reflects significant variation in healthcare infrastructure and outcomes among districts.

The observation from the statstical descriptive table are given as

(1) Districts with higher population generally have greater numbers of sub centers and doctors.

(2) There is a strong variation in healthcare spending among districts, indicating disparities in resource allocation.

(3) Despite similar levels of infrastructure in some districts, health outcomes such as Infant Mortality Rate and Life Expectancy differ significantly, suggesting potential inefficiencies in service delivery.

(4) Institutional delivery rates are relatively high overall, but a few districts still lag below 70%, which may impact maternal and child health indicators.

Table 2. Inputs and outputs data.

| District | Input | | | | | | Output | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sub-centers | PHCs | CHCs | Expenditure (Cr) | Bed strength | Doctor | IMR | ID (%) | Life expectancy | Population Covered |
| AN | 166 | 31 | 10 | 38.5 | 392 | 91 | 48 | 84.6 | 62 | 1273821 |
| BL | 226 | 42 | 15 | 67.42 | 554 | 145 | 98 | 80.1 | 55 | 1648997 |
| BA | 275 | 69 | 15 | 76.58 | 630 | 142 | 47 | 86.3 | 64 | 2320529 |
| BR | 204 | 46 | 14 | 41.74 | 293 | 98 | 62 | 86.5 | 64 | 1481255 |
| BO | 67 | 12 | 5 | 13.73 | 169 | 48 | 60 | 67.6 | 61 | 441162 |
| BH | 178 | 50 | 7 | 37.26 | 399 | 76 | 51 | 81.9 | 65 | 1506337 |
| CU | 332 | 57 | 18 | 105.58 | 708 | 208 | 61 | 91.3 | 68 | 2624470 |
| DE | 42 | 7 | 4 | 12.38 | 104 | 36 | 62 | 78.3 | 66 | 312520 |
| DH | 167 | 32 | 10 | 46.44 | 412 | 88 | 69 | 84.1 | 67 | 1192811 |
| GA | 136 | 20 | 8 | 29.01 | 273 | 81 | 61 | 66.1 | 52 | 577817 |
| GN | 460 | 89 | 30 | 106.72 | 943 | 152 | 59 | 87.6 | 60 | 3529031 |
| JS | 189 | 37 | 9 | 38.97 | 268 | 75 | 51 | 95.9 | 59 | 1136971 |
| JJ | 260 | 56 | 12 | 50.87 | 442 | 106 | 50 | 88.6 | 62 | 1827192 |
| JR | 66 | 15 | 6 | 19.33 | 252 | 55 | 47 | 85.8 | 66 | 579505 |
| KA | 242 | 43 | 16 | 61.22 | 565 | 128 | 56 | 67.0 | 61 | 1576869 |
| KD | 172 | 36 | 14 | 46.65 | 494 | 122 | 86 | 80.4 | 59 | 733110 |
| KP | 227 | 45 | 9 | 42.15 | 446 | 77 | 61 | 81.8 | 57 | 1440361 |
| KJ | 351 | 61 | 17 | 77.39 | 551 | 132 | 57 | 71.3 | 58 | 1801733 |
| KH | 202 | 46 | 13 | 42.72 | 408 | 129 | 72 | 92.9 | 63 | 2251673 |
| KO | 307 | 48 | 16 | 72.4 | 475 | 150 | 53 | 53.4 | 62 | 1379647 |
| MA | 158 | 25 | 8 | 31.99 | 326 | 79 | 52 | 52.6 | 53 | 613192 |
| MY | 589 | 82 | 28 | 125.72 | 826 | 209 | 50 | 79.7 | 63 | 2519738 |
| NA | 289 | 39 | 11 | 39.6 | 268 | 103 | 51 | 53.6 | 63 | 1220946 |
| NY | 166 | 37 | 12 | 36.06 | 645 | 98 | 65 | 70.4 | 65 | 962789 |
| NU | 95 | 17 | 6 | 20.53 | 202 | 59 | 52 | 89.1 | 62 | 610382 |
| PU | 241 | 45 | 16 | 67.8 | 764 | 119 | 78 | 95.5 | 68 | 1698730 |
| RA | 235 | 36 | 11 | 41.04 | 309 | 102 | 61 | 62.3 | 56 | 967911 |
| SA | 167 | 31 | 11 | 58.29 | 509 | 100 | 52 | 83.2 | 66 | 1041099 |
| SU | 89 | 18 | 6 | 21.14 | 222 | 66 | 52 | 83.4 | 63 | 610183 |
| SN | 390 | 56 | 20 | 81.84 | 636 | 133 | 49 | 80.9 | 60 | 2093437 |

Table 3. Descriptive statistics of input and output variables.

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Sub centers | 42 | 589 | 222.92 | 136.75 |
| PHC's | 7 | 89 | 40.93 | 20.5 |
| CHC's | 4 | 30 | 12.57 | 6.5 |
| Expenditure | 12.38 | 125.72 | 51.70 | 28.34 |
| Bed Strength | 104 | 943 | 428 | 209.75 |
| Doctor | 36 | 209 | 106.9 | 43.25 |
| Infant Mortality Rate | 47 | 98 | 59.1 | 12.75 |
| Institutional Delivery | 52.6 | 95.9 | 78.92 | 10.83 |
| Life Expectancy | 52 | 68 | 61.67 | 4 |
| Population | 312520 | 3529031 | 1363356.267 | 804127.75 |

# 5|Result and Discussion

To evaluate the performance of Odisha's health sector across districts, various Data Envelopment Analysis (DEA) models were applied, including the CCR, BCC, SBM (Input- and Output-Oriented), and Super Efficiency models. These methodologies assess how effectively healthcare resources are utilized to produce health outcomes, providing insight into both technical and scale efficiencies.

Table 4. Results of the DEA models.

| District | CCR | BCC Input | BCC Output | SBM Input | SBM Output | SBM Input (VRS) | SBM Output (VRS) | Mean Efficiency Score | Ranking | Super Efficiency | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Anugul | 0.882 | 0.8827 | 0.9486 | 0.7798 | 0.6228 | 0.7818 | 0.8642 | 0.823128571 | 13 | 0.882 | 14 |
| Balangir | 0.8148 | 1 | 1 | 0.7011 | 0.3977 | 1 | 1 | 0.8448 | 11 | 0.8148 | 20 |
| Balasore | 0.8744 | 0.9699 | 0.9926 | 0.7526 | 0.4651 | 0.8371 | 0.8751 | 0.823828571 | 12 | 0.8744 | 15 |
| Bargarh | 0.9797 | 0.9803 | 0.9955 | 0.7778 | 0.9069 | 0.7782 | 0.9668 | 0.912171429 | 5 | 0.9797 | 9 |
| Boudh | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.0242 | 5 |
| Bhadrak | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.3676 | 3 |
| Cuttack | 0.9406 | 1 | 1 | 0.7263 | 0.4943 | 1 | 1 | 0.880171429 | 7 | 0.9406 | 10 |
| Deogarh | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.9772 | 1 |
| Dhenkanal | 0.8655 | 1 | 1 | 0.7239 | 0.658 | 1 | 1 | 0.892485714 | 6 | 0.8655 | 16 |
| Gajapati | 0.6364 | 0.6446 | 0.8364 | 0.5664 | 0.4986 | 0.5742 | 0.7635 | 0.645728571 | 21 | 0.6364 | 27 |
| Ganjam | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.206 | 4 |
| Jagatsinghapur | 0.9996 | 1 | 1 | 0.8285 | 0.8492 | 1 | 1 | 0.9539 | 3 | 0.9996 | 7 |
| Jajpur | 0.929 | 0.9345 | 0.9793 | 0.8007 | 0.7173 | 0.8016 | 0.9097 | 0.867442857 | 8 | 0.929 | 11 |
| Jharsuguda | 0.9879 | 1 | 1 | 0.8523 | 0.8576 | 1 | 1 | 0.956828571 | 2 | 0.9879 | 8 |
| Kalahandi | 0.7534 | 0.7546 | 0.9127 | 0.627 | 0.3713 | 0.6318 | 0.7981 | 0.6927 | 18 | 0.7534 | 21 |
| Kandhamal | 0.511 | 1 | 1 | 0.4632 | 0.3643 | 1 | 1 | 0.762642857 | 15 | 0.511 | 30 |
| Kendrapara | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.0032 | 6 |
| Keonjhar | 0.7289 | 0.7402 | 0.8827 | 0.5927 | 0.3921 | 0.6008 | 0.8068 | 0.677742857 | 19 | 0.7289 | 22 |
| Khordha | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.4468 | 2 |
| Koraput | 0.5924 | 0.593 | 0.9224 | 0.5182 | 0.2596 | 0.5217 | 0.6931 | 0.585771429 | 25 | 0.5924 | 28 |
| Malkangiri | 0.5913 | 0.6295 | 0.795 | 0.5074 | 0.4509 | 0.5425 | 0.6624 | 0.597 | 24 | 0.5913 | 29 |
| Mayurbhanj | 0.6568 | 0.6733 | 0.935 | 0.5258 | 0.2381 | 0.586 | 0.8738 | 0.641257143 | 22 | 0.6568 | 25 |
| Nabarangapur | 0.9145 | 0.9195 | 0.9707 | 0.6902 | 0.6293 | 0.6938 | 0.7899 | 0.801128571 | 14 | 0.9145 | 12 |
| Nayagarh | 0.6643 | 0.6781 | 0.9899 | 0.5557 | 0.4486 | 0.5563 | 0.8311 | 0.674857143 | 20 | 0.6643 | 24 |
| Nuapada | 0.9047 | 1 | 1 | 0.829 | 0.7603 | 1 | 1 | 0.927714286 | 4 | 0.9047 | 13 |
| Puri | 0.8428 | 1 | 1 | 0.6581 | 0.5638 | 1 | 1 | 0.866385714 | 9 | 0.8428 | 18 |
| Rayagarh | 0.6562 | 0.6691 | 0.8688 | 0.5712 | 0.3939 | 0.5819 | 0.7465 | 0.641085714 | 23 | 0.6562 | 26 |
| Sambalpur | 0.7073 | 0.7754 | 0.9826 | 0.5901 | 0.4467 | 0.6935 | 0.8541 | 0.721385714 | 17 | 0.7073 | 23 |
| Sonepur | 0.8614 | 0.9021 | 0.9745 | 0.7786 | 0.7422 | 0.8341 | 0.9087 | 0.857371429 | 10 | 0.8614 | 17 |
| Sundargarh | 0.8374 | 0.8414 | 0.9252 | 0.6407 | 0.4534 | 0.6449 | 0.8344 | 0.739628571 | 16 | 0.8374 | 19 |

**Analysis of CCR DEA Model Results for Odisha's Health Sector:**

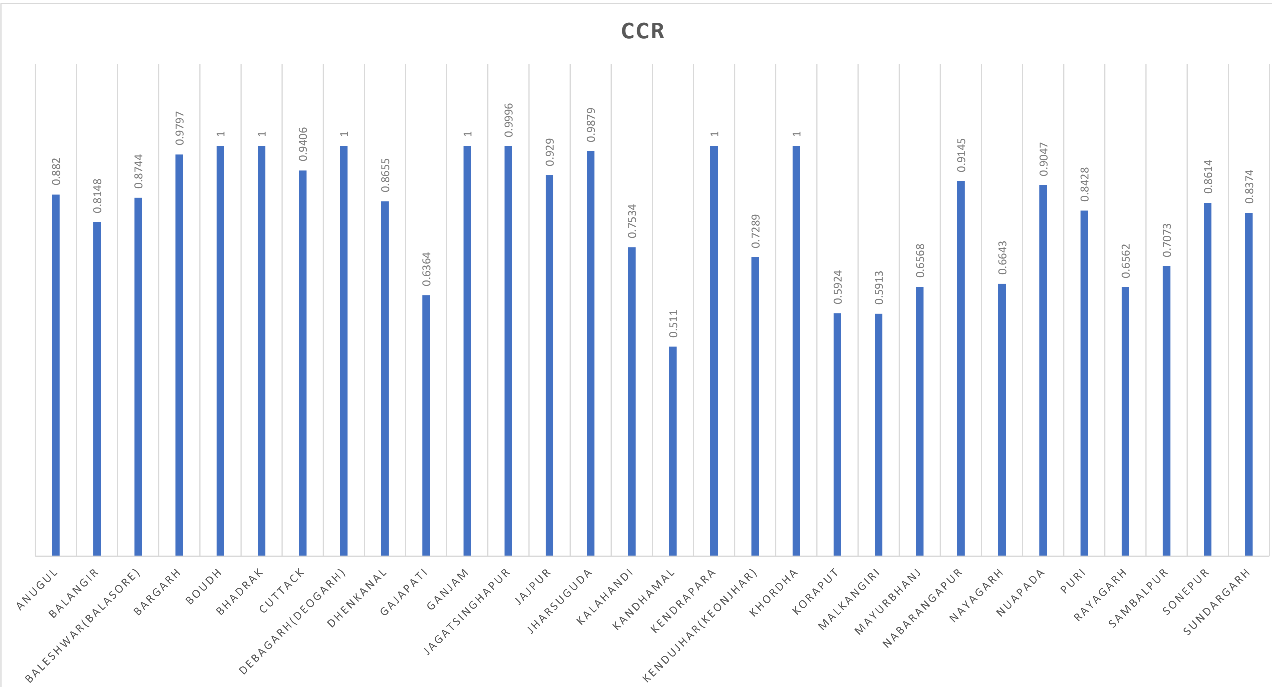


Figure 1. Efficiency score of the districts using CCR model.

The CCR (Charnes, Cooper, and Rhodes) model was applied to evaluate the relative technical efficiency of various districts within Odisha's health sector. This assessment was based on constant returns to scale, focusing on both input and output efficiency. In Figure 1, Several districts achieved the maximum efficiency score of 1, indicating they lie on the efficient frontier and demonstrate optimal use of health sector resources relative to their counterparts. These districts include Balasore, Bhadrak, Cuttack, Ganjam, Jagatsinghpur, Khordha, and Puri. Their performance reflects effective management of healthcare inputs—such as infrastructure, manpower, and expenditures—resulting in strong health outcomes.

On the other hand, some districts displayed suboptimal efficiency scores, suggesting room for enhancement in health service delivery. For instance, districts like Koraput (0.511), Kandhamal (0.592), and Malkangiri (0.636) showed relatively low efficiency scores, indicating potential inefficiencies in resource utilization. The lowest score was recorded in Rayagada at 0.511, pointing to significant scope for performance improvement in that district's health services.

This analysis highlights the uneven performance across districts in Odisha's health sector and emphasizes the need for focused policy efforts and resource reallocation in underperforming regions. By addressing the inefficiencies, the state can work towards a more equitable and effective health system.

**Analysis of BCC DEA Model Results for Odisha's Health Sector**

In Figure 2, A considerable number of districts achieved an efficiency score of 1 under both orientations, suggesting that these districts are performing at the efficiency frontier. These efficient districts are effectively converting health inputs—such as medical staff, infrastructure, and expenditures—into optimal health outcomes relative to their peers.

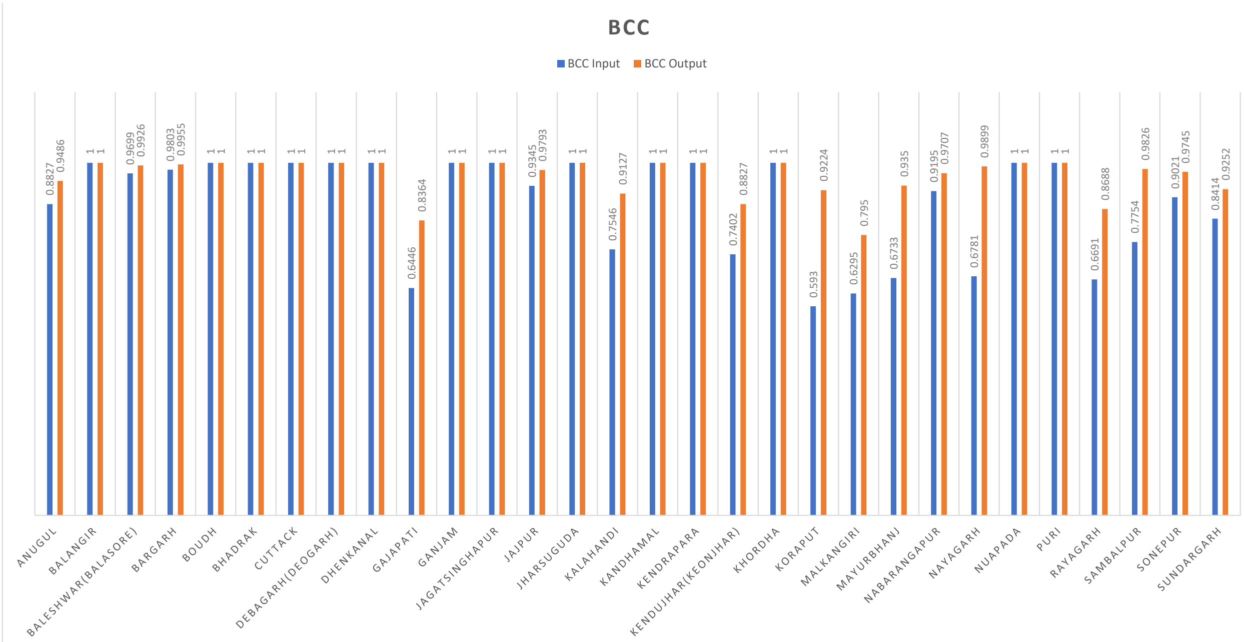


Figure 2. Efficiency score of the districts using BCC model.

Districts such as [insert efficient districts] with a score of 1 indicate full efficiency and provide potential benchmarks for others to emulate. On the other hand, some districts showed lower efficiency scores, implying room for improvement in terms of better resource utilization or outcome enhancement.

For instance, districts like [insert low-efficiency districts and their scores], with efficiency scores significantly below 1, highlight a need for targeted interventions. The lowest observed efficiency score was approximately 0.5930, suggesting that health service delivery in some areas may be improved by either increasing health outcomes or reducing unnecessary input usage.

These findings highlight the disparities in health sector performance across Odisha and suggest the need for district-specific strategies. Policymakers can leverage these insights to allocate resources more effectively and develop initiatives that address the unique challenges of underperforming districts, ultimately fostering a more equitable health system across the state.

**Analysis of SBM DEA Model Results for Odisha's Health Sector**

The Slack-Based Measure (SBM) model was applied to evaluate the relative efficiency of health service delivery across districts in Odisha. This model captures inefficiencies in both input excesses and output shortfalls, offering a comprehensive view of how efficiently each district utilizes healthcare resources to achieve desired outcomes.

In Figure 3, Several districts attained an SBM efficiency score of 1, positioning them on the efficiency frontier. These districts, including Angul, Balangir, Bargarh, Bhadrak, Cuttack, Ganjam, Jharsuguda, Kalahandi, Kendujhar, Khordha, Koraput, Mayurbhanj, Puri, Sambalpur, and Sundargarh, demonstrated optimal performance in managing health sector inputs and achieving satisfactory health outcomes relative to their peers.

Conversely, some districts exhibited lower SBM efficiency scores, indicating potential for improvement. For instance, Malkangiri, with an efficiency score of 0.3977, ranked among the least efficient districts, signaling the need for focused policy attention and resource allocation. Other underperforming districts included Nabarangpur (0.2596) and Rayagada (0.2381), suggesting inefficiencies in service delivery and underutilization of available health infrastructure.

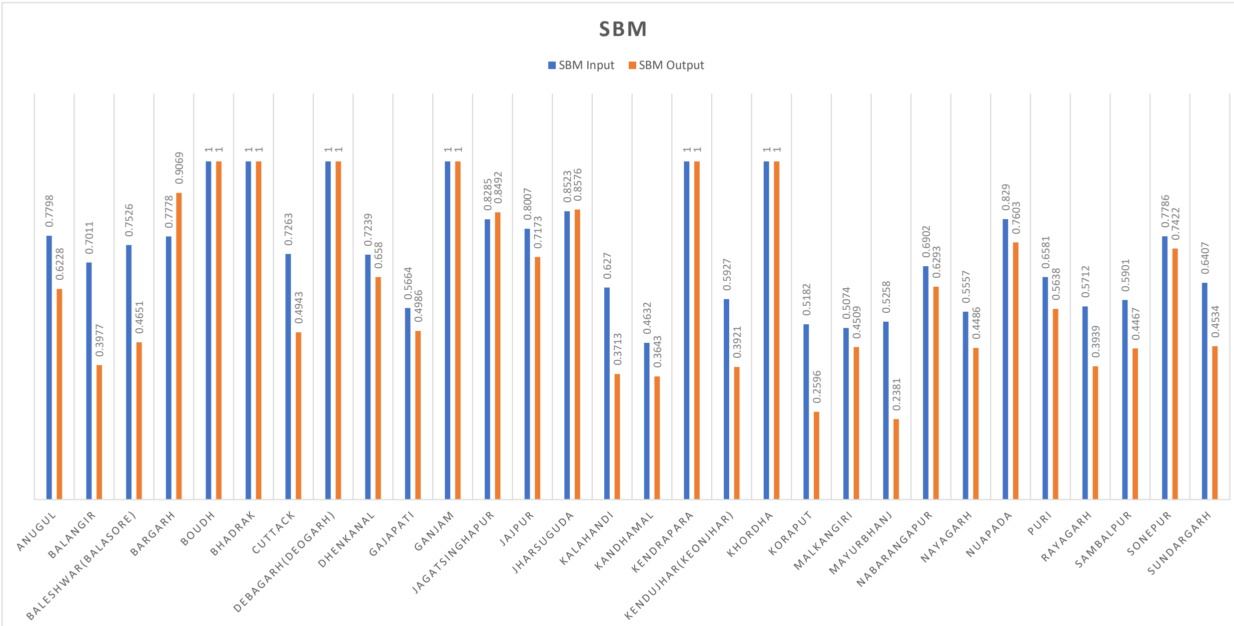


Figure 3. Efficiency score of the districts in SBM model.

The findings point to a considerable variation in healthcare efficiency across Odisha. High-performing districts can serve as benchmarks, while lower-performing ones highlight the areas where interventions—such as capacity building, infrastructure strengthening, or better resource management—are critically needed. These insights can guide state health authorities in designing targeted programs to enhance equity and overall efficiency in the health sector.

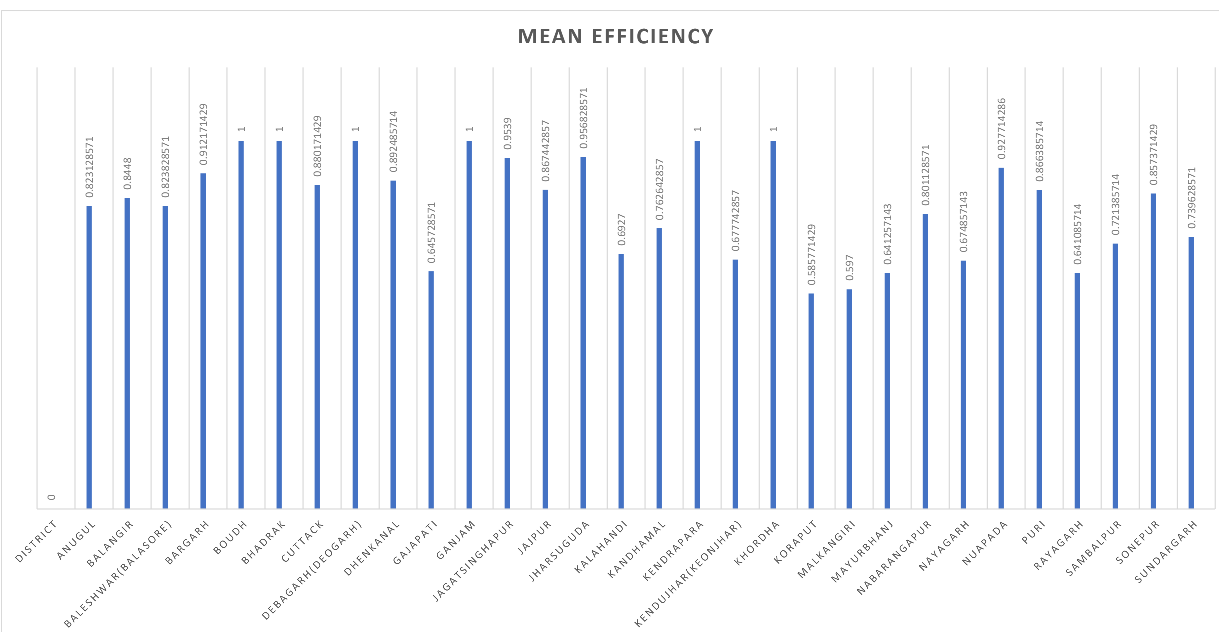


Figure 4. Mean efficiency score of the districts of Odisha.

The analysis of mean efficiency scores, as derived from the DEA models, provides key insights into the performance of Odisha's health sector across various districts. These scores reflect how well health service providers utilize available resources to deliver optimal outcomes, serving as a diagnostic tool to identify both strengths and gaps in the system.

In Figure 4, Several districts demonstrated high mean efficiency scores, with values clustering between 0.80 and 0.95. This indicates that a significant portion of districts are managing their healthcare inputs effectively and are close to the efficiency frontier. High-efficiency scores suggest robust healthcare management practices and effective service delivery mechanisms.

However, some districts registered considerably lower efficiency scores, with a few falling below 0.70. These scores point to notable inefficiencies—either in the overuse of inputs or in failing to maximize outputs—highlighting the need for strategic interventions. For example, districts scoring around 0.58 to 0.65 reflect suboptimal resource utilization, possibly due to infrastructural gaps, limited workforce capacity, or challenges in service accessibility.

The variation in mean efficiency underscores disparities in healthcare delivery performance across the state. High-performing districts can act as models of best practice, while underperforming regions demand focused policy measures, such as targeted resource allocation, capacity building, and monitoring mechanisms. These findings can support data-driven decision-making aimed at improving the equity and effectiveness of Odisha's health system.

**Analysis of Super Efficiency DEA Results for Odisha's Health Sector**

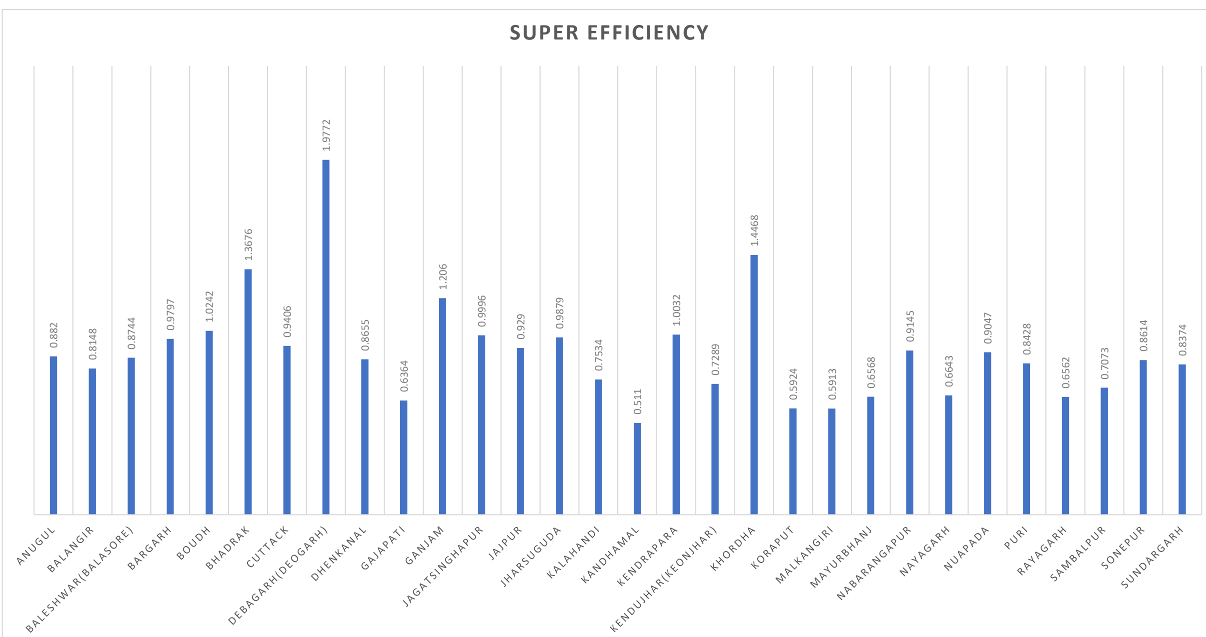


Figure **5.** Super efficiency score of the districts of Odisha

The Super Efficiency model was utilized to evaluate the relative performance of various districts in Odisha's health sector. Unlike the standard DEA models, the super-efficiency approach allows for a finer distinction among efficient units by assigning efficiency scores greater than one to those that outperform the efficient frontier.

In Figure 5, The analysis revealed a broad spectrum of efficiency across districts. Several districts attained super-efficiency scores greater than 1.0, signifying their exceptional performance in utilizing health sector inputs to achieve superior outcomes. Notable among these are districts with scores like 1.36, 1.44, and even as high as 1.97—indicating highly effective health service delivery relative to their counterparts. Conversely, some districts registered efficiency scores well below 1.0, highlighting inefficiencies in their health service operations. Scores such as 0.51, 0.59, and 0.63 suggest considerable scope for improvement, either by optimizing resource utilization or by enhancing service outputs. These disparities point to structural or operational bottlenecks in certain regions that need to be addressed.

The findings emphasize the importance of identifying best-performing districts as benchmarks, while also drawing attention to the need for targeted policy interventions in underperforming areas. Strengthening managerial practices, reallocating resources, and improving infrastructure could be critical steps toward improving overall health sector efficiency in Odisha. We identify the efficient and inefficient districts with their efficiency score; If the efficiency score is 1, then it is efficient; otherwise, it is inefficient. The efficient districts are Bhadrak, Cuttack, Ganjam, Jagatsinghpur, Khordha, Puri, Kendrapara, Sambalpur, and Sundargarh.

These regions consistently demonstrate effective conversion of inputs—like manpower, funding, and infrastructure—into health outcomes. They represent best practices in Odisha's public health landscape.

In contrast, inefficient districts with the lowest scores across models included Rayagada (CCR: 0.511, SBM VRS Output: 0.2381), Nabarangpur (SBM VRS Output: 0.2596), Malkangiri (BCC Output: 0.593, SBM Input: 0.3977), and Kandhamal (CCR: 0.592).

These results highlight systemic issues such as poor resource allocation, insufficient infrastructure, or ineffective healthcare delivery mechanisms.

The superefficiency analysis further differentiates among efficient districts: Deogarh (1.9772), Jagatsinghpur (1.3676), and Koraput (1.206) emerged as super-efficient, meaning they outperform the basic efficiency frontier and serve as ideal targets for performance improvement. These peer relationships can guide strategic planning and policymaking. Underperforming districts can model their operations on efficient peers to enhance service quality and resource utilization.

# 6 | Conclusion

This study employed multiple DEA models—including BCC, CCR, SBM (VRS), and Super Efficiency models—to evaluate the relative efficiency of health service delivery across districts in Odisha. The results revealed substantial variation in performance across the state. Several districts consistently achieved full efficiency (score = 1) under different DEA models, indicating optimal utilization of resources. For instance, districts like Cuttack, Bhadrak, Khordha, and Puri frequently appeared on the efficiency frontier across multiple models, suggesting strong healthcare management and service delivery mechanisms. Conversely, several districts such as Rayagada, Nabarangpur, and Malkangiri exhibited notably low efficiency scores in both traditional and slack-based models. The lowest efficiency scores were recorded as 0.2381 (SBM), 0.2596 (SBM), and 0.511 (CCR), revealing significant inefficiencies in resource utilization and healthcare output generation. The Super Efficiency model highlighted standout performers with scores exceeding 1.0 (up to 1.97), further enabling differentiation among already efficient districts. These districts can serve as benchmarks for best practices. The mean efficiency analysis reinforced these disparities, with a majority of districts scoring between 0.80–0.95, while some fell below 0.70, emphasizing the need for targeted policy responses. While the findings offer valuable insights, the study is not without limitations: The analysis relied on the availability and reliability of secondary data. Inaccuracies or gaps in district-level health data could affect the robustness of efficiency scores. DEA models assume that all districts are operating under comparable conditions, which may not fully account for contextual variations such as geography, socio-economic factors, or disease burden. The study presents a cross-sectional view of health efficiency without incorporating temporal dynamics or trends over time. The study focused on selected output indicators. Broader health outcomes (e.g., maternal mortality, disease prevalence) were not included due to data limitations.

Future research can build on the current work by addressing its limitations and expanding the analytical scope: Incorporating time-series or panel data would allow for a dynamic assessment of health efficiency and the tracking of performance changes over time. Future studies can integrate quality-of-care measures (e.g., patient satisfaction, treatment outcomes) alongside quantitative outputs to provide a more holistic view of efficiency.

Introducing exogenous variables such as literacy, poverty rates, and urbanization into a second-stage analysis (e.g., Tobit regression) could help explain efficiency differences.

Mapping efficiency scores spatially could help visualize regional disparities and identify clusters of low or high efficiency for geographically targeted interventions. Conducting comparative analyses between Odisha and other Indian states can benchmark performance at a broader level and derive region-specific policy lessons. By embracing these avenues, future research can provide deeper, more actionable insights into optimizing health resource allocation and improving equity in healthcare access across regions.

# Author Contribution

S. Rana & V. Chaubey: methodology, software, and editing. K. K. Mohanta: conceptualization, writing and editing. All authors have read and agreed to the published version of the manuscript.

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# Data Availability

All data supporting the reported findings in this research paper are provided within the manuscript.

# Conflicts of Interest

The authors declare that there is no conflict of interest concerning the reported research findings.

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