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**Research Article**

# Achieving Efficient Frontiers In Hospital Supply Chains Through Moderation Of Supplier Relationship And Evaluation Criteria Using Data Envelopment Analysis

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**ABSTRACT**

This paper aims to empirically evaluate all hospital suppliers and identify the benchmarked practices to have an efficient frontier. The paper studies the hospital categories that follow a strategic method of Supplier Relationship Management (SRM) and the Supplier Evaluation Criteria (SEC) with their suppliers to help Hospital Policymakers and Hospital Administrators understand healthcare functioning. The study aimed to understand the relationships between healthcare providers and their suppliers, and also to increase the quality of performance by strengthening supplier evaluations.

The study contributes to the novel idea of benchmarking the SRM and SEC parameters of various industries and imbibing them into the healthcare sector with Data Envelopment Analysis to ensure an efficient frontier to healthcare. It also contributes to exploring the level of SRM and SEC practices and their impact. Thereby allowing us to identify the target hospitals to scale up the performance by adopting the practices. The novelty of the study contributes to its ability to address the performance rating of hospitals by supplier selection and evaluations. The findings revealed the DEA identifies and suggests efficient hospital performance by examining the level of practice and impact of SRM and SEC in healthcare. Helping the hospital administrators understand the health governance in India. The proposed analysis acts as a good guideline to improve hospital performance.

**Keywords:** Data Envelopment Analysis, Benchmarking, Healthcare Supplier Relationship, Supplier Evaluations.

## Introduction

The most general concern of the nation has been in delivering quality healthcare, thereby affecting the country's plan for sustainable economic development (Habib and Shahwan, 2020). The importance of sourcing in hospitals/healthcare organizations is becoming more complex resulting in the drastic need for adopting concepts of Supply Chain Management (SCM) and various efficiency measures to enhance hospital performance (Liu, Ding, and Lall, 2000; Li, Seo, and Ha, 2021). Hospitals need to make the best use of the resources available to identify and address the deficiencies and challenges faced by them.

Data Envelopment Analysis (DEA) is one of the preferred tools for analyzing hospital performance (Abdulsalam et al., 2018). The DEA model uses Decision-Making Units (DMUs) to determine the efficient frontier that envelopes the inefficient DMUs. It assigns an efficiency value to every DMU by measuring the distance from the input to the frontier. The DEA model helps to estimate the efficiency score, allowing the researcher to imply the allocation of the right resources and utilize them to reach the efficient frontier, leading to improved hospital performance(Kohl et al., 2019). DEA allows multiple inputs and multiple outputs to be considered at the same given time.

The research work contributes to how each of the hospital categories can attain the efficient frontier by identifying the key performance indices (KPIs). It reveals the level of practices of supplier relationship management and the impact of how these practices influence hospital performance.
The study is one of the best attempts to assess the relative efficiency of Indian hospitals on the level of SRM practices and Supplier Evaluations while selecting new suppliers or assessing the present suppliers. The research attracts hospital administrators, policymakers, and supply chain decision-makers in India to decide upon the parameters to improve the overall performance of the hospitals. The study aims to test the listed Objectives.
O1: To analyze and arrive at the modeling parameters of supplier relationship management for hospital Supply Chains for their operational implementation
O2: Development of a HSRM model that enhances the effectiveness of hospital supply chains
O3: To propose progressive supplier evaluation criteria by analyzing the operational performance of existing suppliers and prepare a roadmap to be on the efficient frontier

## Literature Review

In a competitive environment that concerns decisions and financial terms, the selection of suppliers is a multi-criterion problem (Soukup, 1987). In an interrelated firm such as healthcare, effective supplier selection is a core aspect of success. Dickson, (1966) suggested supplier selection criteria along with evaluating the suppliers of their organization. Hospitals focusing on their Strategic goals by making purchasing decisions can achieve desired objectives (Anthony and Buffa, 1977; Browning et al., 1991; Sharma et al., 1989; Weber et al. 1991). There was a need for hospital administrators to evaluate the performance of their suppliers by evaluation criteria (Liu, Ding, and Lall, 2000). A benchmarked idea of partnership with the supplier, reducing the hospital costs, and processes evaluation of suppliers to increase the overall hospital performance was identified. This was achievable through evaluating the suppliers helping to aggregate the performance of the current suppliers (Liu, Ding, and Lall, 2000).
Hospital performance has become an essential part of the survival of the healthcare sectors, hence hospital supply chain practitioners, hospital administrators, and healthcare policymakers are motivated to relook at the Supplier Relationships and Supplier Evaluations for the hospital suppliers. Hospital efficiency in terms of patient, financial, internal business, innovation and learning perspective is among the key contributing factors for demonstrating the best-benchmarked practices, strategies and policies that ensure efficient hospital performance (Liu, Ding and Lall, 2000; Chen, Chen and Peng, 2008; Kohl *et al.*, 2019; Habib and Shahwan, 2020; Wang, et al., 2016)

## Methodology

The research work investigated the efficiency of 60 hospitals covering the Central Govt., State government, private, corporate, and teaching hospitals employing DEA. The work excluded hospitals that ceased to exist 10 years before the data collection. The samples were further purged to eliminate responses from hospital administrators having less than 5 years of experience. The final sample of the study consisted of 60 responses covering all the hospital categories from the Indian perspective. The hospital categories were bifurcated from the number of beds, geographical location, services offered, and critical areas of expertise.

| Category | No. of Beds | Geographical Location | Services provided | Critical areas | Laboratory/ Radiology Service |
|---|---|---|---|---|---|
| **State Govt. hospitals** | 100-200 | Taluk, District, Semi-urban | Day – Care Specialty services | OT | Limited Services |
| **Central Govt. Hospitals** | 50-100 | Taluk, District, Semi-urban | Super Specialty | OT | Limited Services |
| **Private Hospitals** | 200-300 | Urban and Semi-Urban | Pediatric/ Ortho/ Cancer/Cardio/Neuro | ICU and OT | Limited Services |
| **Primary health centers** | 50 – 100 | Taluk District | OP services And Daycare | × | × |
| **Secondary Hospitals** | 200-300 | Semi-Urban Urban | Super Specialty | ICU and OT | Limited Services |
| **Tertiary Hospitals** | 300-400 | Semi-Urban Urban | Pediatric, Ortho, Cancer, Cardio | ICU, OT, and NICU | ✓ |
| ✓**Corporate** | ✓300-500 | ✓Urban | ✓Super Specialty | ✓Emergency with or without ICU | ✓ |

### The Model Development Strategy: Defining the SEM Model To Enhance Hospital Supply Chains

The paper aims to evaluate the efficiency of the various hospital categories using the multicriteria Data Envelopment Analysis (DEA) methodology. DEA opens possibilities in cases for evaluating the performances having multiple inputs and outputs. It supplies new insights through benchmarked practices, identifying sources of inefficiency in the management Charnes et al. (1978). DEA extends a new horizon on data exploitation. DEA has Decision-Making Units (DMUs) that attain the efficiency score of the hospital

performances. DEA measures the inputs to get the desired outputs, by identifying the benchmarked input practices and suggesting the best practice frontier. It reveals the best practices of SRM and SEC in hospitals indicating the most efficient hospitals and the inefficient ones. It clearly distinguishes efficient hospitals by indicating the magnitude of their inefficiencies.

DEA works on the key derivatives of efficiency assessment by application of the BCC models, identifying the targets. The model moderates as the strength of the relationship between the SRM and SEC are dependent on the hospital performance. Our third variable hospital performance (W), interacts with the SRM (X) in predicting (Y), while the regression weights of SEC(Y) on SRM (X) varies as a function of hospital Performance (W). Moderation is assessed with the regression equation:

$Y= a_0 + a_1X+ a_2W+ a_3XW+ r$

W is the moderator in our case it is SEC. So, the equation can be represented as

$Y= ( a_0+a_2W) + ( a_1+ a_3W) X + r$

The regression equation reveals how the slope of SEC (Y) regressed on SRM (X), then the function ( $a_1+ a_3W$) is SEC that acts as a moderator.

The constructs of Top management commitment, Selection, and hospital Performance Variables are represented by bold rectangles. The measured variables of sourcing strategies and Trading Partner Participation are dotted rectangles. The moderating effects are shown with pointed arrows. The structural relationships are specified in the model. Two kinds of relationships are observed among the constructs-dependence relationships and correlational relationships.

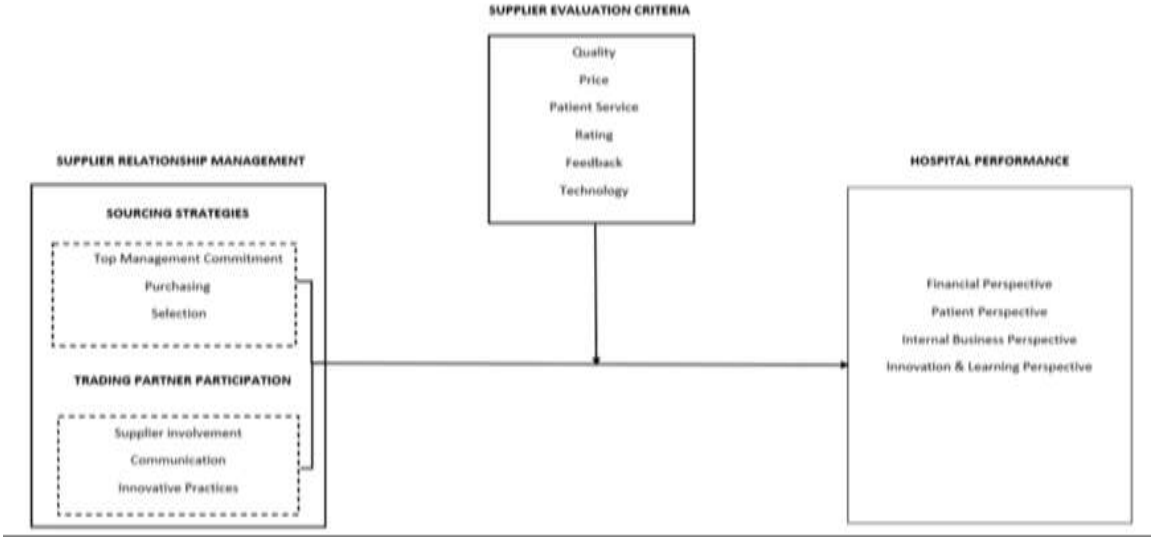


**Fig. 1** SEM model to enhance hospital supply chains

| Sl. No. | Constructs | Factors | Factor Loadings | Cronbach's Alpha | Composite Reliability | Average Variance Extracted (AVE) |
|---|---|---|---|---|---|---|
| 1. | Sourcing Strategies | Purchasing | 0.969 | 0.972 | 0.981 | 0.946 |
| 2 | | Selection | 0.985 | | | |
| 3. | | TMC | 0.964 | | | |
| 4. | Trading Partner Participation | Communication | 0.988 | 0.971 | 0.979 | 0.921 |
| 5. | | Innovative Practices | 0.985 | | | |
| 6. | | Supplier Involvement | 0.896 | | | |
| 7. | | Technology | 0.967 | | | |
| 8. | Hospital Performance | Patient Perspective | 0.837 | 0.826 | 0.883 | 0.654 |
| 9. | | Financial Perspective | 0.745 | | | |
| 10. | | Innovation and Learning Perspective | 0.821 | | | |
| 11. | | Internal Business Perspective | 0.828 | | | |

The model is identified as a distinct case where the former model exists where all the paths of a simple mediation model are moderated by the SEC(W). This is a conditional indirect effect on operational moderation at multilevel. The paths between SRM(X) and SEC (Y) have cross-level interactions. The conditional indirect effect is quantified as

$$f\left(\frac{\emptyset}{W}\right) = (\ a + \ a_3\mathrm{W})\ (b_1 + b_2\mathrm{W})$$

The indirect effect probes the conditional level of the moderator.

### 4.9.1 Formative Measurement Model Evaluation:

The bootstrapping multicollinearity criterion was used for evaluating the indicator weights. The analysis evaluated (a) convergent validity check by redundancy analysis (b) Indicator multicollinearity (c) indicators relative and absolute contribution to the hospital constructed.

The scarcity of empirical studies on healthcare SRM, SEC, and Hospital performance and a dearth of understanding of the Healthcare Supply Chains concept led to this maiden attempt to provide a comprehensive understanding of the model enhancing the hospital supply chains. Healthcare supply chains at a strategic level were unknown to the Indian Healthcare Sectors. SRM and SEC have a positive and significant impact on hospital performance. Lack of technology awareness limited the adoption of SRM and SEC in hospitals. The developed model shows how the SRM and SEC significantly improve hospital performance if adapted to healthcare. Thus helping the healthcare policymakers and the hospital supply chain administrators to make decisions concerning their suppliers.

### Achieving Efficient Frontiers Through DEA in Hospitals:

The research work contributes to evaluating the efficiency of various hospital categories using the multicriteria Data Envelopment Analysis (DEA) methodology. DEA opens possibilities in cases for evaluating the performances having multiple inputs and multiple outputs. It supplies new insights through benchmarked practices, identifying sources of inefficiency in the management Charnes *et al.* (1978). DEA extends a new horizon on data exploitation. The relative efficiency of the DEA in comparison to the other DMUs is measured in the DEA. An efficiency score is then calculated which is the weighted sum of the outputs divided by the weighted sum of the inputs, and the weights are assigned to each of the healthcare DMUs. DMUs, attain the efficiency score of the hospital performances. The DEA assigns an efficiency score of 1 or less to avoid potential difficulty. DEA measures the inputs to get the desired outputs, by identifying the benchmarked input practices and suggesting the best practice frontier. It reveals the best practices of SRM and SEC in hospitals indicating the most efficient hospitals and the inefficient ones. It clearly distinguishes efficient hospitals by indicating the magnitude of their inefficiencies.

Hospital performance improvises by supplier evaluations (Dickson, 1966). A DEA model is developed to achieve an efficient frontier in the healthcare supply chains with a strategic orientation towards SRM and SEC. To calculate an aggregate value of the hospital performance the

$$\boldsymbol{maximise}\ h_0 = \frac{\sum_{r=1}^{t} u_r\, y_{rjo}}{\sum_{i-1}^{m} v_i\ x_{iju}}$$

Subject to,

$$\frac{\sum_{r=1}^{t} u_r\, y_{rjo}}{\sum_{i-1}^{m} v_i\ x_{iju}} \leq 1, j = 1, \ldots . n$$
$$u_r \leq €, r = 1, \ldots \ldots t$$
$$v_i \leq €, i = 1, \ldots \ldots m$$

Where,

$u_r$ = weights for the output (r)
$v_i$ =weights for the input (i)
$y_{rjo}$ = amount of output (r) for DMU j
$x_{iju}$ = amount of input (i) for DMU j
t= total outputs
m= total inputs
n= total DMUs
€= negligible positive number

The defined linear programming function aims to maximize the efficiency score of the DMUs by identifying a set of weights for all the hospital inputs and the hospital outputs. The function looks to attain the maximum efficiency score of the hospital DMU $J_0$ by selecting the input and the output weights. In the first set, the weights

chosen are the efficiency scores ranging no more than 1. In the second set, the weights are ensured not to be 0 for considering the inputs and the outputs for DEA for improving hospital performance. The DMU $J_0$ attains an efficient frontier if the objective function P1 results in an efficiency score of 1, if not it is considered inefficient. For an inefficient DMU, to achieve efficiency we make adjustments to the hospital inputs to improve the performance. The linear programming equation renders the relative efficient DMUs $J_0$, $\lambda_i$>0.

By interchanging the denominator and setting the function to 1, we arrive at the linear programming equation Maximize $h_0 = \sum_{r=1}^{t} u_r\, y_{rj_0}$

$$\sum_{i=0}^{t} v_i\, x_{ij_0} = 1$$

$$= \sum_{r=1}^{t} u_r\, y_{rj} \; - \sum_{i=1}^{m} v_i\, x_{ij} \le 0,\; j = 1,..,n,$$
$$u_r \le \varepsilon,\; r = 1,\dots,t,$$
$$v_i \le \varepsilon,\; i = 1,\dots,m$$

The equation can be written as:

Maximize $z_0 = \varepsilon[\sum_{i=1}^{m} s_i^+ + \sum_{r=1}^{t} s_r^-]$

Subject to:

$$z_0 x_{ij_0} - \sum_{j=1}^{n} x_{ij}\,\lambda - s_i^- = 0,\; i = 1,\dots,m,$$
$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = y_{rj_0},\; r = 1,\dots,t,$$
$$\lambda_{j,} s_i^-,\; s_r^+ \ge= 0$$

Where $z_0$, $\lambda$, $s_i^-$, $s_i^+$a re the variables.
The asterisk denotes an optimal solution. When the case is true both the optimal objective function and the corresponding primal problem has an hospital efficiency score of 1. For the inefficient Hospital DMUs appropriate adjustments can be done to improve the hospital performance. The following linear equation achieves the condition.

$$x'_{ij_0} = z_0^* x_{ij_0} - \; s_i^{-*},\ \text{i= 1 ,....,m}$$
$$y'_{rj_0} = y_{ij_0} - \; s_r^{+*},\ \text{r= 1 ,....,t}$$

It is noted from the linear programming equation that those inefficient DMUs that are less than 1 need to be adjusted to attain efficiency. The DMUs that fall into the equation are all put into a set of the peer group. It is defined as a set of inefficient DMUs that require adjustments to attain the efficiency score of 1. The target inputs for improvement are called input-oriented to emphasize the reduction of the inputs to reach the efficient frontier.

$$\sum_{i=1}^{n} \lambda_{j=1}$$

(P4) Maximize $z_0 - \varepsilon\left[\sum_{i\epsilon 1_D} s_i^- \; + \sum_{r0_D} s_r^+\right]$
Subject to:

$$z_0 x_{ij_0} - \sum_{j=1}^{n} x_{ij}\;\lambda - s_i^- \;=\; 0,\; i \in I_D$$
$$x_{ij_0} - \sum_{j=1}^{n} x_{ij}\;\lambda_j - s_i^- \;=\; 0,\; i \in I_F$$

$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = y_{rj_0}\,,\ r \in O_D \cup O_F$

$$z_0, \lambda_j, s_i^-,\ s_r^+ \geq 0$$

Where:
$I_D$ = The input index
$I_f$ = Fixed inputs index
$O_D$ = Outputs index
$O_F$ = Fixed outputs index
(P1) Maximize $h_o = \frac{\sum_{r=1}^{t} u_r\, y_{rj_0}}{\sum_{i=1}^{m} v_i\, x_{ij_0}}$
Subject to:

$$\frac{\sum_{r=1}^{t} u_r\ y_r}{\sum_{i=1}^{m} v_i\ x_i} \leq 1,\ j = 1, \dots, n$$
$$u_r \leq \varepsilon,\ r = 1, \dots, t$$
$$v_i \leq \varepsilon,\ i = 1, \dots, m$$

The DEA model was constructed after evaluating the suppliers and checking on the SRM and SEC practices of the hospital. The hospital resources were considered as inputs and performance measures as outputs. The study considers seven input parameters TMC, communication, innovative practices, technology, quality, patient service, and feedback. Four output parameters financial perspective, patient perspective, innovative and learning perspective, and internal business perspective.
A brief description of inputs and outputs selected for hospital performance evaluation can be elucidated as follows:

**Table 1.** Input and Output Parameters of Hospital Performance

| Category | Factor | DMU | Variables |
|---|---|---|---|
| Input Parameters | Supplier Relationship Management | Top Management Commitment (TMC) | Resources, Organizational Structure, Continual Improvement |
| | | Communication | Sharing Proprotery Data, Interaction, Information Sharing |
| | | Innovative Practices | New Services, Risk and Rewards, Collaboration |
| | | Technology | Electronically Linked, Service Requirements, Accessibility, Data Analysis, Inventory Monitoring |
| | Supplier Evaluation Criteria | Quality | Supplier Performance Criteria, Goods and Services, Proper Packaging Guidelines, Validity Instructions |
| | | Patient Service | Acknowledgment of Purchase orders |
| | | Feedback | Supply Quality, Information Sharing, Delivery Time, Packing Improvement, Employee Training |
| Output Parameters | | Financial Perspective | Improvement in Profitability, Return on Investment, Increase in Productivity, Decrease in Inventory |
| | | Patient Perspective | On-Time Project Releases, Error Reduction, Handling Patient Complaints, Post Release Services, Maintenance and Association |
| | | Innovative And Learning Perspective | Collaborative Problem Solving, Continuous Improvement, New Product Development |
| | | Internal Business Perspective | Capacity Utilization, Quality of Work, Self-motivation and Efficiency, Reduction in Stress and Working Environment, Reduced Absenteeism, Employee Turnover |

### Input Parameter 1: TMC
The complete process of gathering, implementing, measuring, and achieving the goals of the hospital is considered to be the role of the top management commitment. The process in hospitals where individuals realize the quality needs of healthcare services and serve with strategic hospital management techniques.

### Input Parameter 2: Communication
Integrating effective communication techniques among the hospital administrators and their suppliers helps develop strong SRM by promoting, long-term supplier relationship goals, information sharing among the hospital suppliers, advanced risk management, and building trust. An active communication channel, that embraces authenticity, acts as the central role in building a trustworthy relationship, that ultimately leads to commitment.

### Input Parameter 3: Innovative Practices
The development and implementation of methodologies and tools by the hospitals and the suppliers of the hospital. The main aim of the innovative practice is to maintain quality, cost, and on-time supplies of hospital needs.

### Input Parameter 4: Technology
The management of hospital information, patient databases, research and development, and supply chain operations management are the functional activities that encompass the hospital's technological goals. These activities must be aligned with its hospital system. Strategically achieving the competitive demands of hospital technology depends on the proper management of hospital technology. Hence, the process of the hospital's ability to develop, acquire, share, and manage technology effectively and appropriately is the key issue to be addressed.

### Input Parameter 5: Quality
Concerning suppliers means engaging the suppliers and involving them so that they take ownership and serve the hospitals with affordable, safe, and effective supplies. It is a collaborative effort that involves healthcare experts, suppliers, doctors, and the community as a whole.

### Input Parameter 6: Patient Service
Customer service is enhanced and appreciated with the patient centric-approach, where the patients are treated humanely. The sole purpose of healthcare is to provide great customer service rather than generate revenue. The main focus should be on improving the quality of care provided to patients. Working either directly or in supporting roles to patient-centric goals.

### Input Parameter 7: Feedback
To understand the services rendered it is important to capture the feedback. The feedback can be used to enhance the quality of care leading to patient satisfaction. Further, the feedback can be used to implement changes for supplier evaluations ensuring patient safety.

### Output Parameter 1: Financial Perspective
The financial perspective are objectives that are linked directly to measurements of productivity, inventory, and return on investment in the hospitals. By linking the objectives from the model, it can identify where to define plans and make an investment.

### Output Parameter 2: Patient Perspective
The patient perspective parameter is linked to the suppliers of the hospital where the performance of the hospital results in patient satisfaction by the services provided. This can be achieved by looking from the patient's perspective taking a step outside of the hospital. To achieve this the supplier needs to be seen as the hospital's business partners.

### Output Parameter 3: Innovation and Learning Perspective
The measurement parameters of innovation and learning perspective are the supplier skills, training materials of hospitals, leadership management strategies, hospital culture towards their suppliers, and healthcare expert's knowledge base. This section is where most of the investment takes place for corporate and private hospitals.

### Output Parameter 4: Internal Business Perspective
The internal business perspective measures and determine how the hospital are run. Whether the products and services provided by the healthcare experts conform to what is required by the patients. This happens by streamlining the internal process. Also, the best era to focus on new and creative ideas.

**Table 2.** Fit Indices of the DEA Model to Attain the Efficient Frontier of Hospital Performance

| Sl. No. | Constructs | Factors | Factor Loadings | Cronbach's Alpha | Composite Reliability | Average Variance Extracted (AVE) |
|---|---|---|---|---|---|---|
| 1. | Sourcing Strategies | Purchasing | 0.969 | 0.972 | 0.981 | 0.946 |
| 2 | | Selection | 0.985 | | | |
| 3. | | TMC | 0.964 | | | |
| 4. | Trading Partner Participation | Communication | 0.988 | 0.971 | 0.979 | 0.921 |
| 5. | | Innovative Practices | 0.985 | | | |
| 6. | | Supplier Involvement | 0.896 | | | |
| 7. | | Technology | 0.967 | | | |

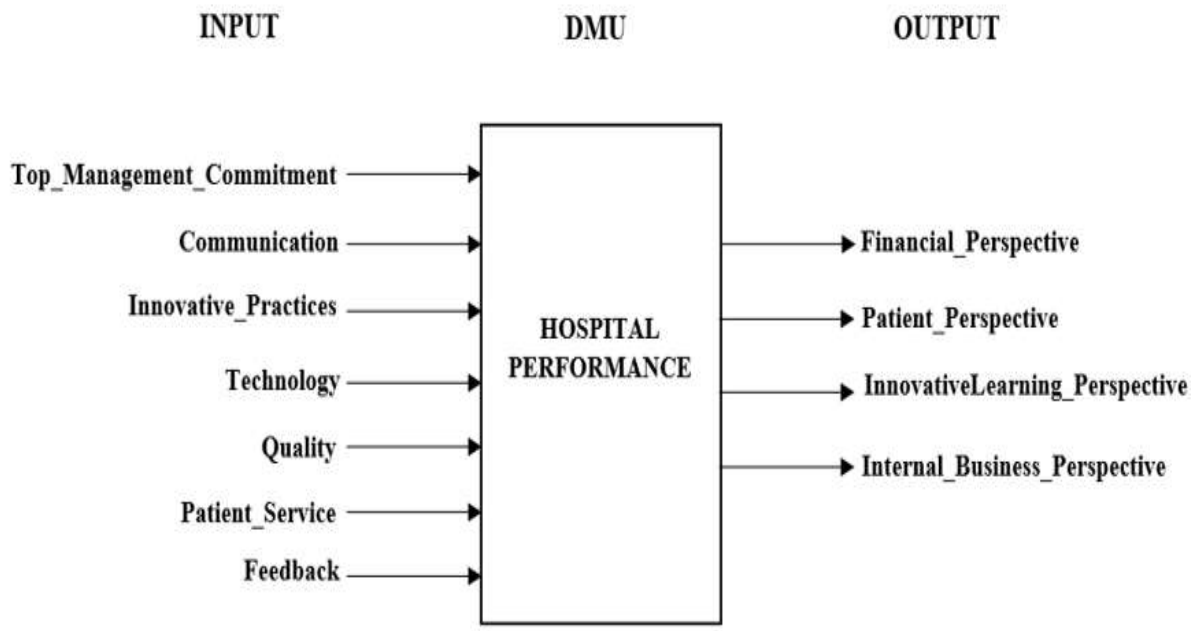


**Fig. 2** The DEA Model to Attain the Efficient Frontier of Hospital Performance

The DEA for the hospitals was analyzed based on the hospital's technical efficiency CCR and the BCC model to understand the pure technical efficiency of the hospital performance. Considering 60 DMUs (n 1,2,3, . . .. . ., 60) using r inputs to produce s outputs. The Hospital performances were studied for the 60 hospitals, 12 each for the five hospital categories. The input DMUs were the SRM and SEC practices starting from the State Government hospital, Central Government hospitals, Private, Teaching and Coprporate hospitals. In the analysis from figures 2-6, the hospital efficiency scores are identified and corresponding data sets to improve their efficiency scores are suggested to reach the efficient frontier.

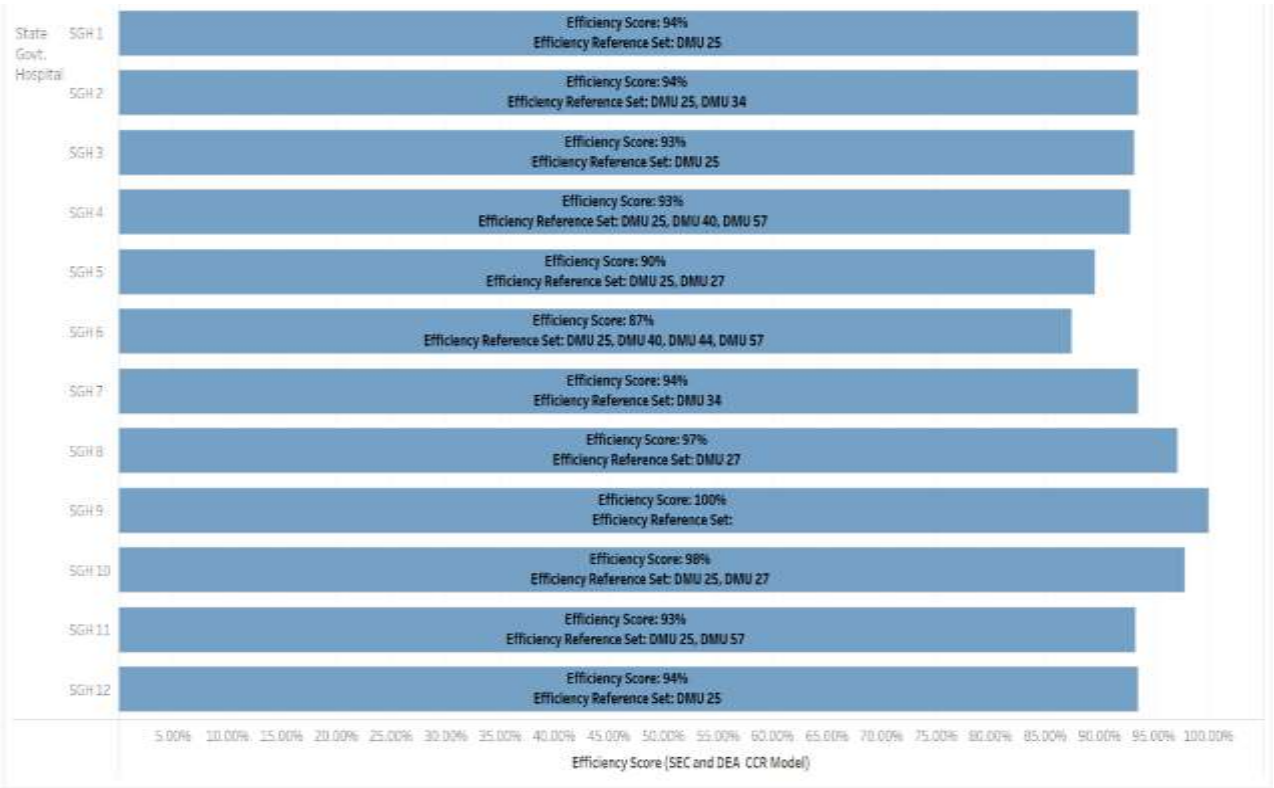


**Fig. 3** Efficiency Score of State Government Hospitals

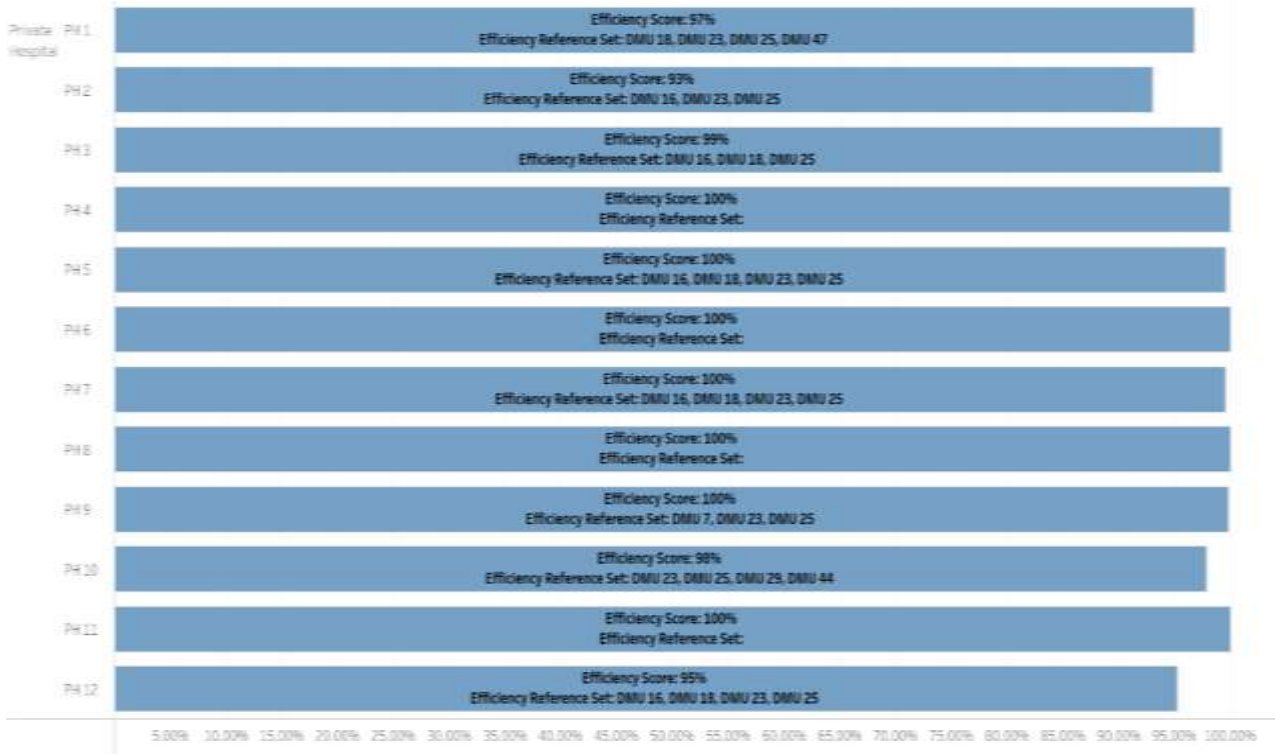


**Fig. 4** Efficiency Score of Private Hospitals

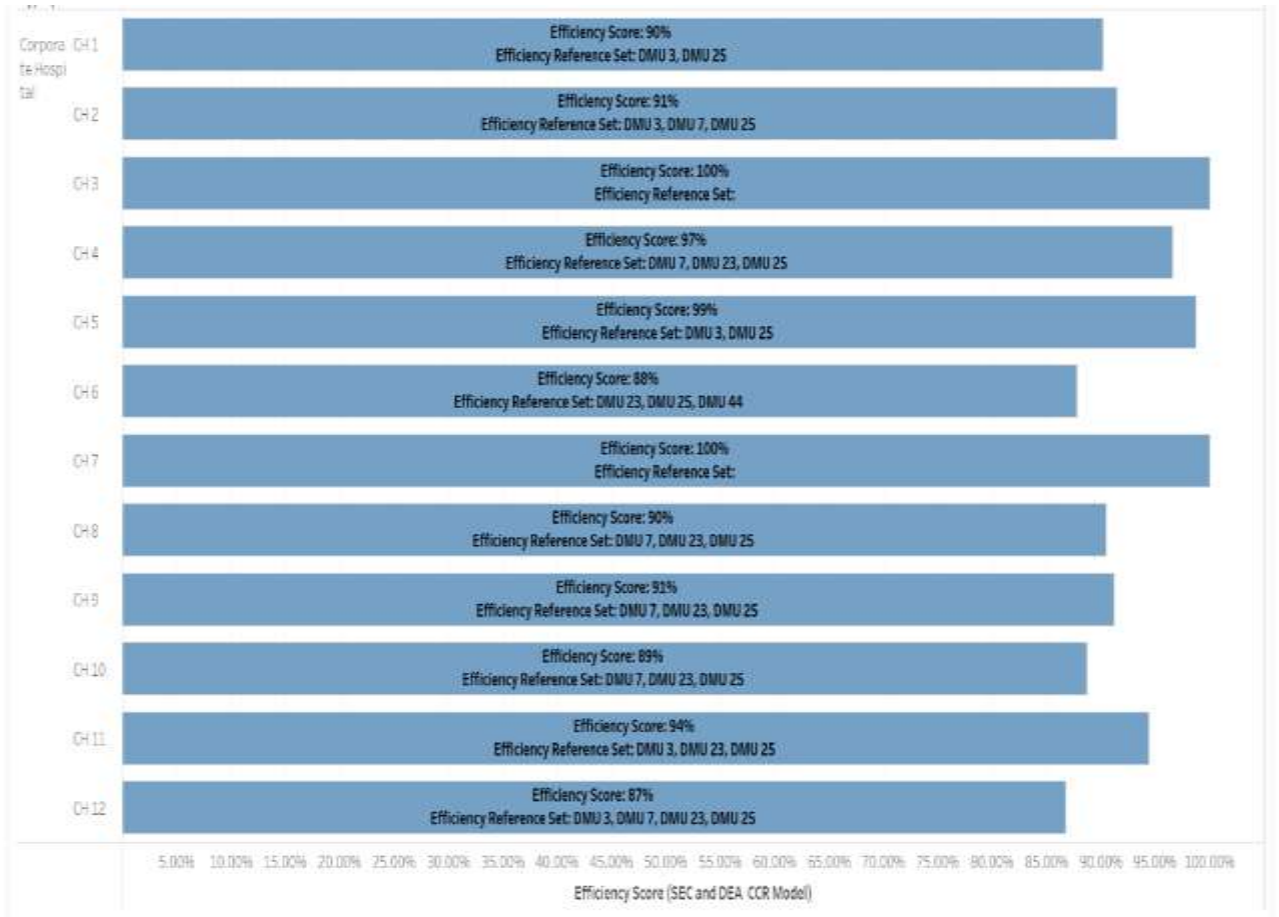


**Fig. 5** Efficiency Score of Corporate Hospital

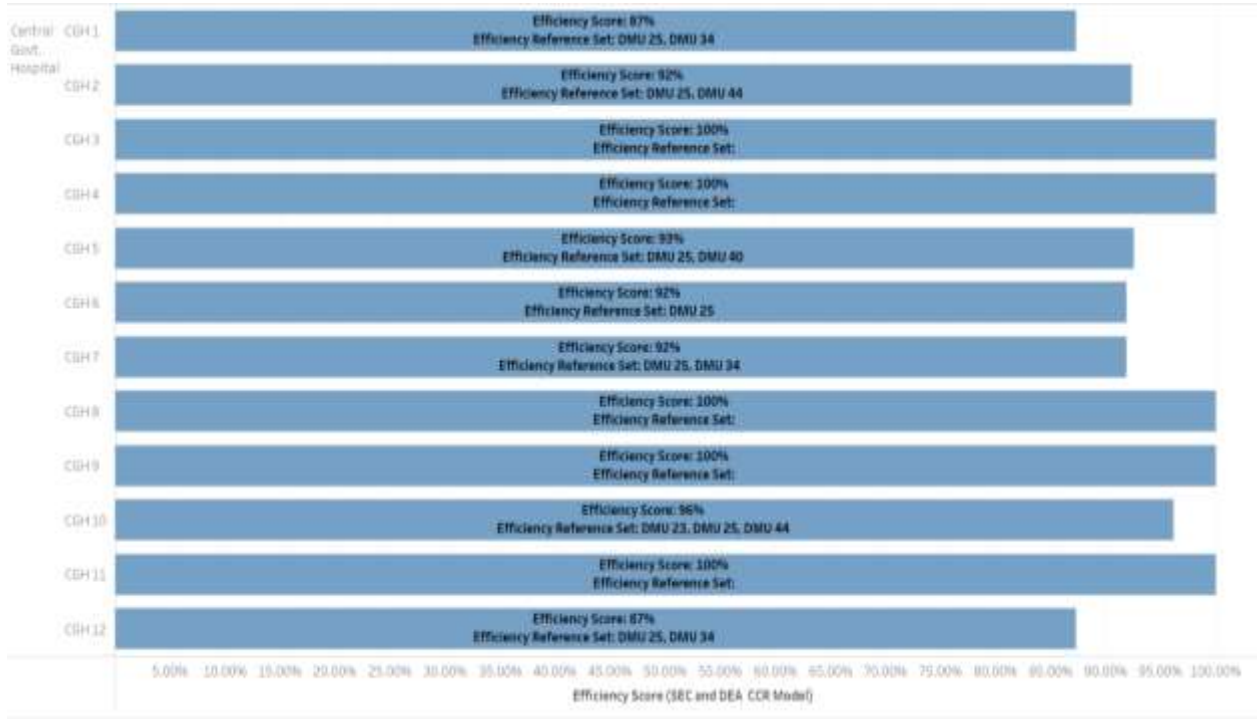


**Fig. 6** Efficiency Score of Central Government Hospitals

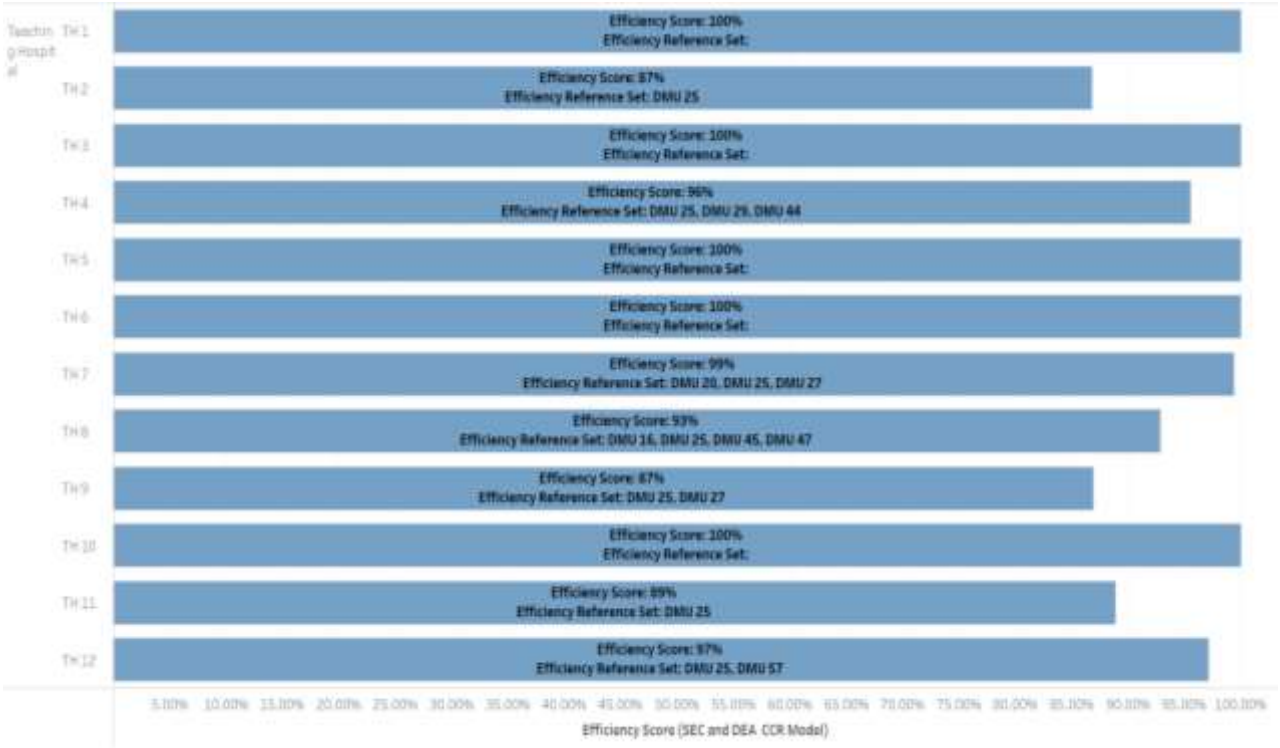


**Fig. 7** Efficiency Score of Teaching Hospitals

## Empirical Analysis and Results

The research utilized DEA hospital model under the assumptions of CCR and BCC to analyse the overall efficiency of the DMUs for hospital performance. An empirical investigation was performed by the DEA solver software to study the hospital categories. The input and the output models are used for scaling up the hospital performances. The hospital dataset comprises 60 responses equally distributed between state government, central government, private, corporate, teaching, and regional hospitals. The findings of the study evaluate the technical, pure technical, and scale efficiency scores of the hospitals. An in-depth level of hospital sector analysis has been carried out to investigate the performance of hospitals concerning SRM and SEC practices.

DEA computed the relative efficiencies of the SRM and SEC for improving the hospital performances. Low efficiency scores indicate lowered performances in the hospital. The input parameters from the targeted peer group can be provided to the hospital administrators and Supply Chain decision makers to improve the hospital performance. The suppliers can also be negotiated to make use of the benchmarked results. The individual hospital level indicated that the corporate sector hospitals are the most efficient ones followed by the central government and the private hospitals, the least efficient hospital categories in practicing SRM and SEC are State government and teaching hospitals. However, the overall hospital analysis reports there is a need to adapt following SRM and SEC practices to scale up the overall hospital performance.

The findings contribute to the understanding of the hospital performance of practicing SRM and SEC and how these influence the overall hospital performance. Further, it indicates the possibilities of improvement factors that each of the hospitals has to focus upon to reach the efficient frontier. Lastly, the evidence highlights that the State Government and the teaching hospitals need to adapt to SRM and SEC practices to efficiently deliver quality healthcare.

The findings of the research have suggestions for supply chain managers, hospital administrators, and healthcare supply chain analysts to assess the feasibility of the hospitals. Firstly, regardless of the hospital categories sectors it was noticed that the hospitals lagged in the efficiency score, reporting the lack of SRM and SEC practices. The DEA has identified the factors of improvement for each of the hospital categories to increase their performance and attain efficiency. Thirdly the hospitals should consider supplier selections based on technology, quality, service, feedback, and rating before signing up for long-term contracts. These hospitals can take the efficient frontier hospitals for improving managerial efficiency, handling efficient supplier evaluations, and supplier selections. Nonetheless, the conclusions of the study are interpreted in light of the hospital categories in India. The results may vary with hospitals functioning outside the country.

## Results and Discussions

The input-oriented efficiency scores from BCC and CCR models are studied. The input efficiency measures reveal the level of the input DMU magnitudes to be reduced equivalently without modifying the outputs. The analysis revealed the overall magnitude of technical inefficiency (OTIE). The results showed that the Indian hospitals have asymmetrical hospital performance concerning supplier relations as regards their overall technical efficiency in percentages ranging between 70 to 100. The average efficiency score turned out to be 85. From the observations, producing hospital efficiency on the efficient frontier would need 85% of the inputs to be used Hospitals with an Overall Technical Efficiency score equal to 1 are reflected to be the most competent among the hospitals involved in the analysis. The hospitals with an OTE of less than 1 are considered inefficient. Of the 60 hospitals, 28 hospitals were found to be technically efficient since they had an OTE score of 1. These hospitals together define the best practices and the efficient frontier, forming the reference set for inefficient hospitals. The hospitals with an OTE score of 1 reveal that the hospitals are utilizing their resources and production process in the best possible manner. Also, showing that the hospitals are not categorizing any waste of inputs. In DEA, these efficient hospitals are termed as peers and set an example of good operational practices for inefficient hospitals to emulate. The efficient hospitals practicing SRM and SEC are mostly corporate, private, and central government hospitals. The remaining 32 hospitals have their OTEs less than 1 and are marked as technically inefficient. The results thus indicate, the marked deviations of the hospitals from the best frontier.

These inefficient hospitals can improve their efficiency by looking at their reference sets. The OTE from inefficient hospitals ranges from 70% to 98% in Indian Healthcare sectors. The findings imply that the state government hospitals and the teaching hospitals can potentially reduce their input levels by 30% leaving the output levels unchanged. The interpretation can be observed for the other corresponding hospitals, looking into the reference sets and increasing the efficiencies.

## Summary and Conclusions

The research endeavors to evaluate the extent of technical, pure technical, and scale efficiencies in the Indian hospital categories using cross-sectional data for 60 hospitals from the year 2020 to 2024. Besides, an attempt has been made to identify the impact of each of the input DMUs of supplier evaluations like quality service and feedback on the overall technical efficiency of hospital performance. To realize the objective of the research, a two-stage DEA framework was applied to estimate the technical, pure technical, and scale efficiencies of the individual hospitals obtained by BCC and CCR models. And finally, regression analysis to study the relationship between the overall technical efficiency in the second stage.

The study followed an intermediation approach to select the inputs and the outputs. The vector outputs contain financial perspective, Patient perspective, internal business perspective, innovation, and learning perspective. While the vector inputs contain TMS, communication, innovative practices, technology, quality, patient service,

and feedback. The results indicate the level of technical inefficiency to be 30%. Most of the corporate, private, and central government hospitals score unity and thus defined the efficient frontier. Based on frequency count and a reference set of inefficient hospitals, state government hospitals have been noticed as the lowest practices of SRM and SEC in the hospitals.

Interviews and studies of the hospital sources revealed that the overall technical inefficiency of the Indian hospitals is due to poor utilization of the technologies and the lack of SRM practices to operate on a production scale. However, in most hospitals, the overall technical efficiency is attributed to scale inefficiency. Hence, Indian hospitals are more successful in choosing optimal levels of output than adopting best practices. From the returns to scale analysis, it is studied that 70% of the hospitals operate in the zone of decreasing returns to scale and thus have to downsize their operations to reach efficiency gains.

The paper contributed by presenting a methodology to increase hospital performance by applying DEA. The operational, financial, innovative, and learning, the internal business of 60 hospitals in India were assessed for efficiency. The study aimed at utilizing DEA as an analytical tool to illustrate the efficiency of hospital performances. The objective of the paper was to apply a systematic analysis for decision-making to the hospital administrators, healthcare experts, and hospital supply chain analysts. The work focused on reaching an efficient frontier by revealing the target improvement DMUs. An improvement target of hospital variables was recommended to increase hospital performance. The findings of the study revealed that the hospitals legged in SRM and SEC practices.

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