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Short Communication

Data envelopment analysis: a pioneering approach to benchmarking healthcare resource utilization and clinical outcomes

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ABSTRACT

In India, the nursing profession faces significant challenges due to manpower shortages, making the optimal use of nursing staff crucial for patient safety and care quality. This study aims to identify high-performing nursing units that demonstrate optimal staffing and better clinical outcomes using benchmarking. By adopting data envelopment analysis (DEA), a proven tool in management and technical sectors but relatively new to healthcare, the study introduces a novel method for evaluating nursing efficiency. DEA was used to assess the relative efficiency of nine nursing units across medical and surgical specialties. The analysis considered one input (number of bedside nurses) and two outputs (number of patients served and clinical performance). The DEA software calculated efficiency scores, identifying benchmark units and highlighting areas for improvement. The Obstetrics and Gynecology Ward, Ortho 1 Ward, and Surgery Male General Unit were found to be 100% efficient, serving as benchmarks for optimal clinical performance and manpower utilization. Conversely, units such as plastic surgery, extended ortho, ortho female, urology, surgery female, and medical general demonstrated the need for improvements. The findings encourage healthcare administrators to adopt best practices from efficient units, improve workflows, revise staffing models, and reallocate resources based on patient volume and acuity. This study showcases DEA as a powerful multi-criteria decision-making tool, offering a comprehensive alternative to traditional single-criterion benchmarking methods. DEA not only identifies performance gaps but also fosters a culture of continuous quality improvement in nursing and healthcare systems.

Keywords: Data envelopment analysis, Bench marking, Man power optimization, Clinical efficiency, Health care quality

INTRODUCTION

Nurses play a vital role in healthcare who are essential in providing high-quality, and safe care to patients.[1] However, the Indian healthcare sector is currently grappling with a significant issue of nursing attrition and a widespread shortage.[2] This is largely attributed to factors such as low pay, poor working conditions, and limited opportunities for professional growth.[2] According to the World Health Organization (WHO) 2022, an additional 7.6 million nurses are needed globally by 2030.[3]

Studies suggest inadequate staffing results in missed nursing care, which in turn is linked to mortality rates, extended hospital stays, and poorer patient outcomes.[4,5] It also contributes to staff dissatisfaction, increased

turnover, and decreased work efficiency. Consequently, insufficient staffing increases the likelihood of medical errors, contributes to the unsafe delivery of patient care, and negatively impacts the quality of care. These challenges, in turn, can harm the organization's reputation.[6]

Missed nursing care is considered as an outcome linked to the organizational quality, influenced by factors in the nursing work environment. It can be mitigated by ensuring effective manpower utilization, developing the skills of nurse managers, fostering effective leadership as well as a strong safety culture within units.[7] Effective utilization of manpower reflects how efficiently an organization can utilize its nursing resources to achieve optimal outcomes. It is especially important for nurse managers to optimize staffing levels to address the challenge of nurse shortages while also enhancing patient safety.[8]

Many organizations use internal benchmarking as a key tool to improve performance and optimize the manpower.[9] Benchmarking helps to enhance competitive advantage, evaluate techniques for better performance, by comparing and implementing the best practices. The adoption of benchmarking in healthcare, particularly in manpower utilization, can serve as a valuable learning opportunity for healthcare systems to drive further improvements.[9]

The study identifies optimal nursing units with efficient manpower and strong clinical performance, offering insights for administrators to adjust staffing based on patient acuity. It emphasizes evaluating safety compliance, monitoring errors, and optimizing workforce allocation to enhance patient safety, clinical performance, and overall outcomes.

METHODS

The methodology employed in this study is data envelopment analysis (DEA) which is multi-criteria decision-making approach.[10] DEA is a robust technique for analysing DMUs by comparing their efficiency against an optimal frontier. It evaluates multiple inputs and outputs, aiming to minimize inputs and maximize outputs, producing a comprehensive performance index.[10,11] Thus, it analyses the relative efficiency of units under study.

The DEA principle is based on relative efficiency (θ), calculated using the formula:[12]

θ = Output / Input

This formula measures DMU efficiency by comparing its output to input in a single scenario. DEA is widely applied in fields like finance, healthcare, education, manufacturing, and supply chain management.[12] Thus the technique has opened opportunities to solve cases which are resistant to other techniques due to their complex relationships between multiple inputs and outputs.[12]

DEA uses variable input vi and output ur weights which can be derived from the data objectively for n DMUs. Sum of inputs (X) and outputs (Y) of a DMU can be depicted in the following equation:[13]

$$\sum_{r=1}^{n} urY \quad / \sum_{i=1}^{n} viX$$

To address degrees of freedom in DEA, the number of DMUs (n) must be ≥max (ms) or 3 (m+s), where m is inputs and s is outputs.[14] In this study, the researcher uses one input and two output for nine DMUs.

$$n \geq \max. \{(m*s), (3*(m+s))\}$$

DEA can be input-oriented, minimizing input usage with constant outputs, or output-oriented, maximizing output production while keeping input levels fixed for each DMU.[12] The method used in this study is output oriented DEA.

This study assesses the relative efficiencies of nine nursing units as Decision-Making Units (DMUs): Obstetrics and Gynaecology Ward, Ortho 1 Ward, Surgery Male Ward, Plastic surgery ward, Ortho II Ward, Ortho Female Ward, Urology Ward, Surgery Female Ward, and Medical General Ward. For DEA analysis, each DMU is evaluated using one input and two outputs. The input is the number of bedside nurses (staff nurses) allocated to each unit. The first output is the average number of patients served, while the second output is Clinical Performance, evaluated based on compliance with five key patient care processes: Patient Identification, Medication Management, Hand Hygiene Practices, Care of Tubes/Lines, and Patient Reported Experience Measures. These processes are audited by the organization's quality team to ensure adherence to NABH standards and Nursing Excellence Accreditation. Clinical Performance is a cumulative measure reflecting each unit's overall performance in these areas. Output-based DEA software is used to analyse the input-output relationship and determine how efficiently each unit utilizes its nursing staff.

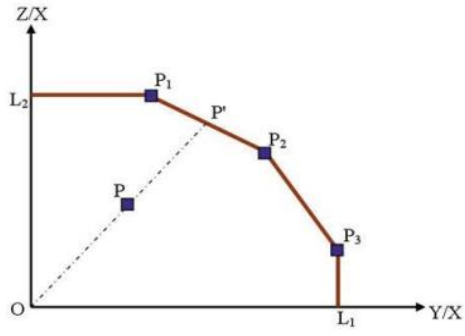

Figure 1: An output-oriented DEA with two outputs and one put.

Output-oriented DEA problem has two outputs (Y, Z) and one input (X). The technical efficient frontier (L1L2) includes efficient DMUs (P1, P2, P3). A DMU's technical inefficiency is the distance PP0, indicating the proportional increase in outputs without increasing input, expressed as OP/OP0.[12]

Thus, in this study DEA was used to assess the relative efficiency of nine nursing units, identifying the benchmark units in terms of clinical performance and optimal manpower utilization. The analysis also highlights the areas where each unit needs improvement to enhance their efficiency.

RESULTS

DEA methods in benchmarking units enhance patient safety and quality care by identifying efficient manpower utilization, effective strategies, and strong leadership. The analysis highlights top-performing units and areas for improvement, enabling resource optimization and superior outcomes in patient care.

Results are interpreted under three headings:

Bench marking

The Obstetrics and Gynaecology, Ortho-1, and Surgery Male General Wards achieved 100% clinical performance with optimal manpower, serving as benchmarks for clinical care and efficient resource utilization. Their success demonstrates how leveraging skilled manpower and streamlined workflows creates a competitive advantage. The synergy of strategies, leadership, and operational frameworks drives improved outcomes. In contrast, the plastic surgery, ortho-2, ortho female, urology, surgery female, and medical general wards show areas for improvement. By adopting strategies from high-performing units, these wards can enhance clinical care, improve patient accommodation, and optimize nursing manpower. This approach enables nurse managers and administrators to effectively deploy staff, ultimately ensuring safe, high-quality patient care.

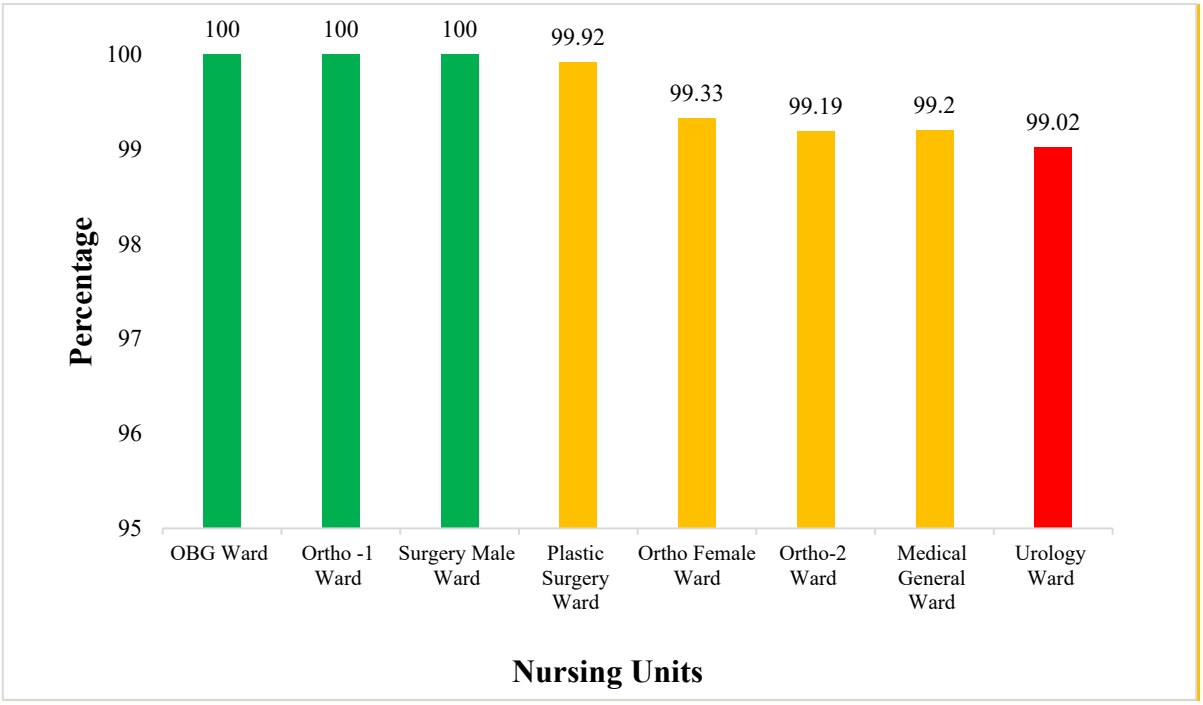

Figure 2: Efficiency of nursing units in terms of clinical performance with optimal man power utilization.

Table 1: Representation of potential improvement in output parameters of patient served and clinical performance for nursing units.

Unit	Potential Improvement-Patient Served	Potential Improvement - Clinical Performance
Plastic surgery ward	0.08	0.08
Ortho female ward	1.7	1.7
Ortho II ward	4.4	0.82
Medical general ward	0.81	0.81
Urology ward	0.99	0.99
Surgery female ward	12.05	4.88

Direction of improvement

The study outlined specific directions for improvement across six nursing units, focusing on the percentage improvement in clinical performance and the increased capacity to serve patients. By identifying these areas of growth, the research study provides a clear direction for each unit to enhance both the quality of care and operational efficiency.

Incremental opportunities for improvement

The plastic surgery ward (0.08%) and medical general ward (0.81%) have minimal gaps, suggesting small adjustments can improve performance. Comparing the medical general ward and surgery male ward, both with the same staff count, the surgery male ward performs better. This presents an opportunity for the medical general ward to adopt effective practices from the surgery male ward for improvement. Meanwhile, the plastic surgery ward serves more patients with the same staff as the surgery male ward, indicating significant potential for enhancing its clinical performance and efficiency.

Significant improvement needed for underperforming units

The surgery female ward has the highest improvement potential, serving only 11 patients compared to 14 in the ortho female and 13 in the extended ortho wards. Despite having the same staff, these wards show better performance, suggesting that by increasing patient management capacity by 12.05%, the surgery female ward could improve its performance by 4.88%.

Moderate improvement areas

The ortho female (1.7%) and urology (0.99%) wards have moderate gaps, indicating a need for strategy adoption from benchmark units. The ortho female ward, with 8 staff members serving 14 patients, operates at 99.3% efficiency, lower than ortho 1. the urology ward, with 12 staff, serves 4 less patients than plastic surgery ward, with lower efficiency (99.02%). Both wards could improve performance and optimize manpower utilization by adopting successful strategies from better-performing units.

Disparities between patient served and clinical performance

The extended ortho ward, with 8 staff and 99.19% efficiency, serves fewer patients compared to ortho 1 ward, highlighting the need for process optimization. With a 4.40% potential improvement in patients served but only 0.82% in clinical performance, tailored strategies are crucial. Adopting best practices across units can optimize manpower, enhance patient safety, and drive organizational excellence. In contrast, improper staff utilization can lead to resource wastage, reduced efficiency, and safety risks, emphasizing the importance of strategic workforce management.

Learning from the peer group

The improvement strategy focuses on adopting practices from top-performing units to enhance clinical performance and optimize manpower utilization.

Plastic surgery ward

The plastic surgery ward achieved a clinical performance of 99.92% and aims to improve by 0.08%, allowing it to serve more patients by enhancing its performance. To achieve this, the ward can adopt strategies from top-performing units—53.89% from Obstetrics and Gynaecology, 34.80% from surgery male ward, and 11.31% from ortho 1 ward for clinical performance, while for optimal manpower utilization, it can integrate 63.04% of strategies from Obstetrics and Gynaecology, 31.58% from surgery male ward, and 5.38% from ortho 1 ward. Key strategies from peer groups, such as optimizing operational functions, improving manpower utilization, and providing better training, can be implemented alongside regular performance evaluations and feedback mechanisms to drive continuous improvement. Encouraging staff involvement in decision-making, recognizing achievements, and promoting engagement will enhance efficiency and ensure consistency in patient care.

Male general ward

The male general ward, with a clinical performance of 99.20%, aims to improve by 0.81%, enabling it to serve more patients. To achieve this, it can adopt 4.26% of strategies from ortho 1 ward and 95.47% from surgery male ward for clinical performance enhancement. For manpower utilization, it can integrate 97.72% of practices from surgery male ward and 2.28% from ortho 1 ward. Key strategies include efficient resource allocation, fostering interdepartmental collaboration, increasing staff involvement, flexible staffing models, and strong leadership. These approaches will optimize resources, enhance teamwork, ensure skill balance, and drive overall performance improvement.

Ortho 2 ward

Ortho 2 ward, with a clinical performance of 99.19%, aims to improve by 0.82%, enabling it to serve 4.40% more patients. To achieve this, it can adopt strategies from ortho 1 ward to enhance clinical performance and manpower utilization. Optimizing patient scheduling and discharge planning will reduce delays, streamline processes, and improve bed utilization. Effective staffing, cross-department collaboration, and leadership development will strengthen team management, conflict

resolution, and decision-making, ultimately enhancing overall performance and efficiency

Urology ward

The urology ward achieved a 99.02% clinical performance. A 0.99% improvement will enable it to serve 1% more patients. To enhance performance, 86.36% of strategies should be adopted from the surgery male ward and 13.64% from ortho 1. For optimal manpower utilization, 92.35% of strategies should come from surgery male and 7.65% from ortho 1. Key steps include adopting care pathways from surgery male, integrating ortho 1's efficient workflows, and implementing cross-training initiatives to enhance workforce flexibility and efficiency, ensuring high-quality patient care.

Ortho female ward

The ortho female ward had a 98.33% clinical performance. A 1.70% improvement enables serving 1.70% more patients. To achieve this, 89.51% of strategies should be adopted from ortho 1 and 10.49% from surgery male. For manpower utilization, 83.24% should be adapted from ortho 1 and 16.76% from surgery male. Key initiatives include adopting ortho 1's clinical protocols and patient tracking for better care and early complication detection, enhancing multidisciplinary coordination, and integrating surgery male's patient education programs to improve outcomes and reduce complications.

Surgery general ward female

The surgery general female ward had a 95.35% clinical performance. A 4.88% improvement enables serving 12.05% more patients. To achieve this, the unit should adopt strategies from ortho 1, known for efficiency and better outcomes. Key initiatives include implementing flexible staffing models to adjust for patient acuity and volume, cross-training staff for greater workforce flexibility, and integrating performance monitoring tools to track and enhance clinical efficiency. These measures will improve both care quality and manpower utilization, optimizing overall ward performance.

Peer learning drives continuous improvement. Senior managers should evaluate and implement effective manpower and operational strategies, enhancing efficiency, staff utilization, and patient safety while reducing errors in nursing units.

DISCUSSION

The study introduces a unique and innovative benchmarking tool specifically tailored for healthcare and nursing sectors. This tool builds upon foundational frameworks developed by Kumar et al and Kumar et al who previously proposed models for evaluating and improving performance across hotel and technical industries.[10] However, this study advances those frameworks by integrating healthcare-specific variables such as patient outcomes, care efficiency, nurse-to-patient ratios, and resource utilization patterns. This makes the tool not only more relevant but also highly adaptable across a variety of healthcare settings, including hospitals, long-term care facilities, outpatient clinics, and community health programs.

A key feature of this tool is its use of the multi-criteria decision-making (MCDM) approach, which moves beyond traditional single-metric benchmarking. MCDM allows decision-makers to consider multiple factors simultaneously, helping them to prioritize improvements based on the unique needs and challenges of each healthcare or nursing unit. This multi-dimensional perspective is particularly valuable in complex healthcare environments where performance is influenced by a variety of interrelated factors. Furthermore, the application of data envelopment analysis (DEA) within this model aligns with the principles of the NABH (National Accreditation Board for Hospitals) 5th edition standards. It supports a structured and data-driven approach to continuous quality improvement (CQI), encouraging collaboration, knowledge sharing, and cross-functional learning among nursing units and healthcare teams. By leveraging DEA as part of this peerless methodology, organizations can create a culture of accountability and excellence, driving consistent improvements in care quality, operational efficiency, and patient satisfaction.

CONCLUSION

Data Envelopment Analysis (DEA) assessed nine nursing wards, highlighting efficiency and improvement areas. Obstetrics & Gynaecology, Ortho 1, and Surgery Male Wards achieved 100% efficiency, excelling in manpower utilization and clinical performance. Surgery Female Ward had the lowest efficiency at 95.35%, facing workload, care process, and leadership challenges. Plastic Surgery, Ortho 2, Ortho Female, Urology, and Medical General Wards ranged from 98.33% to 99.92%, with inefficiencies in workload balance, workflows, and leadership. Lower-performing units should adopt best practices from benchmarked wards, optimizing manpower and enhancing patient care outcomes for improved efficiency and effectiveness. The study highlights how benchmarking drives excellence, with high-performing units demonstrating 100% efficiency through optimized manpower and effective strategies. Identifying benchmarked units helps set standards for resource utilization and healthcare quality. Gaps in clinical practices and manpower use must be addressed to enhance patient care and efficiency. Strong leadership, clear communication, and teamwork are crucial for performance, as leadership challenges lead to underperformance. Peer mentoring and knowledge-sharing bridge performance gaps. Resource optimization

improves patient care and outcomes while ensuring efficiency. DEA offers actionable insights, supporting data-driven decisions to enhance operational effectiveness, clinical care quality, and shared best practices. Administrators can now implement successful practices across units by adopting approaches from benchmarked units. This promotes continuous improvement and a culture of efficiency and high-quality care, based on comparisons within nine medical and surgical nursing units.

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