Economic studies Journal
ISSN 2602-7925
https://www.asjp.cerist.dz/en/PresentationRevue/417

Volume: 20/ N°: 01 (2026), p 155-170

Human Capital and Hospital Efficiency: An Empirical Assessment of Algerian Public Hospitals Using Data Envelopment Analysis

Siradj Zighem
University Center of Illizi-ALGERIA
siradj.zighem@cuillizi.dz

Bebba Imane
University Center of Illizi-ALGERIA
imane.bebba@cuillizi.dz

Abstract

This study explores the effect of human capital deployment on hospital efficiency within the public healthcare system. An input-oriented Data Envelopment Analysis (DEA) approach was applied to assess the performance of Algerian public hospitals over the period 2020–2024. The analysis treated nurses and physicians as labor inputs, while inpatient admissions constituted the output. The empirical findings reveal notable disparities in efficiency levels across hospitals and across time. Observed inefficiencies were primarily attributable to managerial practices and scale imbalances rather than to insufficient staffing levels. Overall, the results suggest that optimizing the allocation of human resources is more decisive for enhancing hospital performance than merely increasing workforce numbers.

Article info

Received 15/02/2026
Accepted 04/04/2026

Keywords:
- ✓ Efficiency
- ✓ Human Capital
- ✓ Healthcare Systems

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

1. *Introduction*

Measuring the efficiency of hospital performance has become a critical issue for healthcare systems worldwide, particularly in the context of
rising costs, limited resources, and increasing demand for high-quality medical services. Public hospitals, which rely heavily on human resources such as nurses and physicians, face persistent pressure to optimize the use of available inputs while maintaining or improving service outcomes. Traditional performance indicators often fail to capture the multidimensional nature of hospital production processes, as healthcare delivery involves multiple inputs and outputs that interact simultaneously. In this context, Data Envelopment Analysis (DEA) has emerged as a powerful non-parametric methodology for evaluating relative efficiency among hospitals by comparing their ability to transform resources into healthcare outputs. DEA allows for the simultaneous consideration of multiple inputs and outputs without imposing restrictive functional assumptions, making it particularly suitable for the hospital sector. By constructing an efficiency frontier based on best-performing units, DEA identifies performance gaps, benchmark institutions, and sources of inefficiency related to both managerial practices and scale of operation. Consequently, DEA has been widely adopted in health economics and hospital management research as a robust tool for assessing technical and scale efficiency. This study applies DEA to Algerian public hospitals in order to provide empirical evidence on performance efficiency and to highlight the role of human capital utilization in shaping hospital efficiency outcomes.

1.1. *Main Research Problem* :

Despite the increasing allocation of human resources to public hospitals, significant disparities in performance efficiency persist across institutions and over time. This raises critical questions regarding the extent to which human capital is effectively transformed into healthcare outputs. While nurses and physicians constitute the core productive asset of hospitals, their quantitative expansion does not necessarily translate into higher efficiency levels. Moreover, inefficiencies may stem not only from managerial shortcomings but also from scale-related mismatches and suboptimal deployment of human capital. Consequently, there remains a lack of empirical evidence explaining how human capital utilization influences technical and scale efficiency in public hospitals, particularly in developing healthcare systems.

Accordingly, the main research problem of this study can be formulated as follows:

To what extent does human capital utilization influence the technical and scale efficiency of public hospitals, as measured by Data Envelopment Analysis, and how can observed inefficiencies be explained in terms of managerial practices and scale effects?

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

1.2. Research Hypotheses :

Hypothesis 1 (H1): Human Capital and Technical Efficiency

Hospitals that exhibit more effective utilization of human capital—measured through the efficient deployment of nurses and physicians—tend to achieve higher levels of technical efficiency.

This hypothesis assumes that efficiency is not driven by workforce size alone, but by how human capital is organized, coordinated, and translated into healthcare services.

Hypothesis 2 (H2): Human Capital and Scale Efficiency

Inefficiencies in hospital performance are partially attributable to scale inefficiency arising from a mismatch between human capital levels and service demand.

This hypothesis posits that hospitals operating below or above their optimal scale experience performance losses, even when managerial efficiency is relatively high.

Hypothesis 3 (H3): Human Capital, Organizational Learning, and Benchmarking

Hospitals that benefit from accumulated human capital experience and organizational learning are more likely to approach the efficiency frontier and serve as benchmarks for less efficient hospitals.

This hypothesis emphasizes the dynamic dimension of human capital, suggesting that learning-by-doing and experience accumulation contribute to sustained efficiency improvements over time.

2 Theoretical background :

2.1 Conceptual Foundations of Human Capital in Healthcare :

Human capital theory posits that investments in education, training, and employee development yield measurable returns in terms of enhanced individual and organizational performance (Mutua & al, 2024, pp. 54-57) . Within healthcare, this translates into improved clinical outcomes, reduced medical errors, greater adaptability to technological change, and higher levels of patient satisfaction. Unlike physical or financial capital, human capital is inherently dynamic, embedded within individuals, and difficult to replicate, making it a potential source of sustained competitive advantage (Roziq & Reawaroe, 2021, pp. 01-13). In hospitals, where service delivery depends heavily on skilled interactions between professionals and patients, the quality and deployment of human capital directly affect both technical efficiency (maximizing output per input) and allocative efficiency (optimally distributing resources across functions). The multidimensionality of human capital includes components such as professional qualifications, experiential learning, emotional intelligence, teamwork capabilities, and intrinsic motivation—all of which contribute uniquely to organizational outcomes (Lewaherilla & Hiariej, 2023, pp. 289-304).

2.1.1 Empirical Evidence on Human Capital and Organizational Performance :

A growing body of international research supports a strong positive correlation between human capital indicators and hospital performance metrics. A study conducted in North-Kivu Hospitals in the Democratic Republic of Congo found that human capital significantly predicted organizational performance, with measurement instruments demonstrating high

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

reliability (Cronbach's alpha = 0.864) (Lufungula & Borromeo, 2019, pp. 182-193). Similarly, an investigation at Dr. Haulussy Ambon General Hospital in Indonesia revealed that both human capital and organizational citizenship behavior had statistically significant effects on the service performance of medical personnel, underscoring the interplay between individual capability and prosocial workplace conduct . In South Sulawesi Province, another study confirmed that human capital components—including competence, product knowledge, and motivation—positively influenced nurse performance at Haji Hospital, thereby enhancing overall service quality (Ramadhan & al, 2022, pp. 49-56).

These findings are reinforced by cross-national analyses. For instance, research at Kenyatta National Hospital in Kenya demonstrated that structured HRM practices—such as recruitment, training, performance appraisal, and compensation—were positively associated with employee performance, particularly when aligned with sociotechnical systems and motivational theories like Herzberg's Two-Factor Theory (Kobia & Gitonga, 2025, pp. 50-66) .In Malaysia, transformational leadership was shown to facilitate stages of intellectual capital development, which in turn enhanced hospital performance through better application of knowledge and intangible assets (Hassan & al, 2015, pp. 12-26) .These studies collectively indicate that human capital does not operate in isolation; rather, its impact is mediated and moderated by organizational structures, leadership styles, and systemic support mechanisms.

2.1.2 Mediating and Moderating Mechanisms :

While direct links between human capital and performance exist, their strength is often shaped by mediating and moderating variables. Intellectual capital—the combination of human, structural, and relational capital—acts as a key mediator, transforming individual competencies into institutional knowledge assets that enhance decision-making and process optimization (Abulsaoud Ahmed Younis, 2018, pp. 559-586).Transformational leadership serves as a powerful moderator, amplifying the impact of human capital by fostering innovation, trust, and commitment . Furthermore, organizational culture, job satisfaction, and perceived organizational support play crucial roles in determining whether human capital potential is fully realized (Aktif Budiono, 2021, pp. 627-638).

For example, a study in Pakistan highlighted that job security, organizational support, and job satisfaction were significant predictors of physician performance, reinforcing the idea that even highly skilled professionals underperform in unsupportive environments (Umrani & al, 2019, p. e 12169). Conversely, supportive HRM practices—such as career development opportunities, fair compensation, and participatory management—enhance motivation and retention, leading to long-term gains in productivity and service quality (Van den Broek, 2023, p. 2812)

2.1.3 Global Contextual Variations and Technological Integration :

International comparisons reveal important nuances in how human capital impacts efficiency across different healthcare systems. In Albania, public organizations leveraging human capital strategically reported higher administrative effectiveness and responsiveness. In Australia, board gender diversity was found to positively correlate with human capital efficiency, especially in financially distressed firms, indicating that inclusive leadership

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

enhances resource utilization and adaptive capacity (Miglani & Obeng, 2023, p. 343). Meanwhile, the adoption of digital technologies such as Hospital Information Systems (HIS) and artificial intelligence (AI) reshapes human capital requirements. HIS implementation improves service efficiency but depends critically on staff proficiency and change management capabilities (Andwika & al, 2024, pp. 890-894). AI adoption in U.S. hospitals is more prevalent among institutions with larger market shares and shorter average lengths of stay—both indicators of underlying strengths in human capital readiness and operational agility (Pham & al, 2024, p. 114402).

2.1.4 Efficiency of Healthcare Performance: Understanding and Optimizing Key Metrics :

Healthcare efficiency draws significant attention as healthcare systems face growing demands, resource constraints, and an increasing need for high-quality patient outcomes. Efficiency in healthcare performance signifies the optimal use of inputs—such as financial resources, staffing, medical infrastructure—and their transformation into favorable outputs, including improved patient health outcomes, reduced morbidity and mortality rates, patient satisfaction, and cost efficiency. This paper examines the theoretical underpinnings, challenges, and practical strategies for improving healthcare efficiency, using evidence-based research to outline actionable insights.

2.1.5 Recommendations for Healthcare Institutions :

Based on DEA findings, hospitals can take specific measures to improve efficiency:

1. **Benchmarking Best Practices:** Identify top-performing facilities and emulate their operational strategies.
2. **Resource Optimization:** Reevaluate staffing levels, equipment usage, and budget allocation to address inefficiencies.
3. **Investing in Technology:** Implement technologies such as electronic health records (EHRs) and telemedicine to streamline processes (Ng & al, 2023, pp. 01-09)
4. **Policy Interventions:** Allocate additional funding to underperforming hospitals or rural healthcare facilities.

2.1.6 Defining Efficiency in Healthcare :

Efficiency in healthcare is typically divided into three core components:

1. **Technical Efficiency**: Refers to the ability of healthcare providers to deliver maximum outputs using the least amount of input. Hospitals or systems that achieve technical efficiency operate on the "efficiency frontier," which represents best practices in resource utilization (Nayar & Ozcan, 2008, pp. 345-362).
2. **Allocative Efficiency**: This segment reflects the appropriateness of resource allocation based on the needs of the patient population. A healthcare system achieves allocative efficiency if resources are directed to the most beneficial interventions, aligning with the health needs of the community (Cavalieri & Ferrante, 2020, pp. 183-191).

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

3. **Dynamic Efficiency**: It addresses the system's ability to adapt and introduce innovations to improve outputs over time, such as the adoption of advanced health technologies (Flaumenhaft & Ben-Assuli, 2018, pp. 815-826). These components are interrelated and require comprehensive evaluation to identify inefficiencies within healthcare systems.

2.2 Challenges in Measuring Healthcare Efficiency :

Measuring healthcare efficiency requires a nuanced understanding of the interplay between resources and outcomes. The following are critical challenges:

1. **Multifactorial Complexity**: The healthcare sector involves multiple, interdependent factors, making it challenging to establish straightforward relationships between inputs (e.g., staff, budgets, infrastructure) and outputs (e.g., health outcomes).
2. **Geographic and Contextual Variability**: Socioeconomic and geographic factors significantly influence healthcare delivery. For instance, hospitals in rural areas face unique challenges such as limited access to skilled labor and medical supplies, which can distort efficiency measurements when compared to urban counterparts (Coutinho & al, 2021, p. 48) (Leitch & al, 2024, pp. 1091-1099).
3. **Data Limitations**: Reliable and comprehensive data on healthcare inputs and outcomes are often unavailable, particularly in resource-limited settings, impeding the generation of accurate efficiency scores (Park & al, 2016, pp. 01-08).

2.2.1 Methodological Approaches to Measuring Efficiency :

Evaluating the influence of human capital on hospital efficiency requires robust analytical tools capable of capturing complex input-output relationships. Data Envelopment Analysis (DEA) has been widely adopted as a non-parametric method for assessing the relative efficiency of decision-making units (DMUs), such as hospitals or clinics.Applied in Yola North, Nigeria, DEA revealed variations in technical efficiency among healthcare centers, attributable in part to differences in staffing qualifications and continuing education opportunities (Raphael, 2025, pp. 202-214) In Iran, an integrated DEA and econometric approach identified significant associations between hospital size, catchment population, and technical efficiency, suggesting that human resource planning must be context-sensitive to optimize performance (Yousefi Nayer & al, 2022, pp. 08-22)

More advanced models have further refined these assessments. A novel common-weights DEA model incorporating uncertainty theory—Uncertain Common-Weights DEA (UCWDEA)—was developed to address data imprecision in real-world healthcare environments, enabling more reliable benchmarking and sensitivity analysis (Peykani & Pishvaee, 2024, p. 611). Additionally, three-stage DEA models combined with fuzzy-set qualitative comparative analysis (fsQCA) have been used to identify multiple pathways to sustainable efficiency in Chinese public hospitals, highlighting configurations involving skilled workforce deployment, effective governance, and digital integration (Li). These methodological innovations underscore the importance of using sophisticated, context-

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

aware techniques to isolate the specific contributions of human capital to efficiency outcomes

2.2.2 Advantages and Limitations of DEA :

Advantages:

- Simultaneous consideration of multiple inputs and outputs.
- Flexibility: No need for predefined weightings or assumptions about input-output relationships.
- Benchmarking: Identification of best practices from top-performing DMUs.

Limitations:

- Sensitivity to data quality and sample size.
- Difficulty in identifying causal factors for inefficiency.
- Inability to account for stochastic variations or random noise.

To overcome these challenges, researcherss often integrate DEA with complementary methods such as stochastic frontier analysis (SFA) or regression-based techniques (Chitnis & Mishra, 2019, pp. 152-167).

3. Methodology:Applied DEA Analysis of Technical and Scale Efficiency in Public Hospitals (2020–2024) :

3.1 Assessment of Data Suitability for Data Envelopment Analysis (DEA) :

Public hospitals rely predominantly on human capital, particularly nurses and physicians, to deliver healthcare services. Under increasing fiscal pressure and rising demand, improving the efficiency with which this human capital is utilized has become a strategic priority. Traditional performance indicators often fail to capture multidimensional efficiency, making DEA a suitable alternative.

This study aims to:

- Measure technical and scale efficiency of public hospitals,
- Identify best-practice benchmark units,
- Quantify excess labor inputs and output shortfalls,
- Examine the relationship between human capital utilization and hospital efficiency.

3.2 Descriptive Overview of the Dataset :

The empirical analysis draws upon a comprehensive panel dataset encompassing 15 Decision Making Units (DMUs) from three Algerian public hospital institutions—OUARGLA (large-scale), GHARDAIA (medium-scale), and ILLIZI (small-scale)—covering the period 2020-2024. This longitudinal dataset systematically captures human capital inputs comprising number of nurses (ranging 149-734; mean=387) and number of doctors (general practitioners and specialists; ranging 63-151; mean=107), benchmarked against total inpatient admissions as the primary output measure (ranging 2,173-15,721; mean=6,138).

The dataset's analytical value stems from its robust statistical properties—positive values throughout, substantial variation (Std: nurses=243, inpatients=4,403), and strong input-

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

output correlations (r[nurses-inpatients]=0.943; r[doctors-inpatients]=0.817)—rendering it ideally suited for Data Envelopment Analysis (DEA) application. This configuration enables precise technical efficiency benchmarking, input slack identification, and scale economy assessment across diverse hospital operational contexts, ultimately informing evidence-based resource optimization strategies critical for sustainable healthcare management in resource-constrained public systems

Table No (01) : Values of input and output variables for the study sample for the period from 2020 to 2024

*Output 01	*Input02	*Input01	Decision making unit DMU	YEAR
10004	120	695	OUARGLA 2020	2020
10422	125	702	OUARGLA 2021	2021
10840	134	710	OUARGLA 2022	2022
11418	144	722	OUARGLA 2023	2023
15721	151	734	OUARGLA 2024	2024
6128	105	246	GHARDAIA 2020	2020
5887	110	277	GHARDAIA 2021	2021
3314	111	269	GHARDAIA 2022	2022
3072	124	294	GHARDAIA 2023	2023
3568	122	302	GHARDAIA 2024	2024
2389	63	149	ILLIZI 2020	2020
2220	70	163	ILLIZI 2021	2021
2173	72	171	ILLIZI 2022	2022
2282	79	176	ILLIZI 2023	2023
2633	77	193	ILLIZI 2024	2024

***Output 01:Total number of inpatients**

***Input 02 :Number of doctors (general practitioners and specialists**

***Input 01:Number of nurses**

Prepared by the researcherss based on the studied hospitals

The dataset comprises three Algerian public hospitals—Ouargla, Ghardaïa, and IllIZI—observed over the period 2020–2024, resulting in a balanced panel of 15 decision-making units.

Two labor-related inputs (nurses and physicians) and one output (total number of inpatients) were selected to represent hospital production. Ouargla Hospital operates at a relatively large scale and exhibits a steady increase in both staffing levels and inpatient admissions. Ghardaïa Hospital shows notable fluctuations in output despite staff growth, suggesting potential inefficiencies. IllIZI Hospital operates at a smaller scale, reflecting structural and demographic constraints.

Overall, the dataset demonstrates sufficient consistency, variability, and theoretical coherence to support a robust application of Data Envelopment Analysis.

The dataset meets all methodological and statistical prerequisites for DEA implementation. The observed positive correlations between human resource inputs and hospital output confirm the appropriateness of the chosen variables and provide a solid empirical basis for subsequent efficiency analysis.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

All units included in the dataset represent **public hospitals operating within the same national health system** and providing comparable inpatient services. Although differences exist in size and annual activity levels, such variations are acceptable within the DEA framework, as the method is designed to evaluate relative efficiency among units performing similar functions.

Therefore, the homogeneity condition is satisfied.

3.3 Addressing the reliability of study data :

For the results to be reliable and dependable, the data must be credible**.**

3.3.1 Input–Output Relationship :

The selected variables clearly reflect the hospital production process:

- **Inputs :**
  - Number of nurses
  - Number of physicians (general practitioners and specialists)
- **Output :**
  - Total number of inpatients

Human resources constitute the primary productive factor in hospital service delivery, while inpatient admissions represent a core healthcare output. The causal relationship between inputs and output is well defined and theoretically sound.

This condition is fully met.

3.3.2 Non-Negativity of Data :

All input and output variables take strictly positive values across all DMUs and years, which complies with the basic mathematical requirements of DEA models.

Thus, the non-negativity condition is fulfilled.

3.3.3 Adequacy of Sample Size :

According to commonly accepted DEA rules of thumb:

Number of DMUs$\geq \max\{m \times s, 3(m+s)\}$

where:

- m= 2 inputs
- s= 1 output

This yields a minimum requirement of 9 DMUs.

The dataset includes **15 DMUs**, which exceeds this threshold and ensures sufficient discriminatory power.

Hence, the sample size is adequate for DEA application.

3.3.4 Correlation Between Inputs and Output :

DEA assumes the existence of a logical and positive relationship between inputs and outputs. To verify this assumption, Pearson correlation coefficients were examined.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

Table (02) Pearson Correlation Matrix

Variables	Number of Nurses	Number of Doctors	Total Inpatients
Number of Nurses	1.00	0.96	0.89
Number of Doctors	0.96	1.00	0.87
Total Inpatients	0.89	0.87	1.00

Prepared by the researchers based on SPSS outputs

The results indicate **strong and positive correlations** between:

- The number of nurses and total inpatients,
- The number of doctors and total inpatients.

These findings confirm that higher levels of human resources are associated with greater inpatient service capacity. No negative or weak correlations were observed, which supports the validity of the selected variables for DEA modeling.

Accordingly, the correlation condition required for DEA is satisfied.

3.4 Results :

After processing the data using the Data Envelopment Analysis Program, the following results were obtained**.**

3.4.1 DEA Efficiency Results :

Table (03) CCR and BCC Efficiency Scores

DMU	CCR	BCC
OUARGLA 2020	0.801	0.944
OUARGLA 2021	0.801	0.928
OUARGLA 2022	0.777	0.886
OUARGLA 2023	0.762	0.851
OUARGLA 2024	1.000	1.000
GHARDAIA 2020	1.000	1.000
GHARDAIA 2021	0.870	0.905
GHARDAIA 2022	0.499	0.654
GHARDAIA 2023	0.421	0.569
GHARDAIA 2024	0.481	0.613
ILLIZI 2020	0.645	1.000
ILLIZI 2021	0.547	0.914
ILLIZI 2022	0.512	0.875
ILIIIZI 2023	0.520	0.847
ILLIZI 2024	0.558	0.839

Prepared by the researchers based on DEA outputs

Only **OUARGLA 2024** and **GHARDAIA 2020** achieve full technical efficiency. The gap between CCR and BCC scores for most DMUs indicates that inefficiency is driven by both **managerial factors** and **scale effects**.

3.4.2 Scale Efficiency Analysis :

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

Table (04) Scale Efficiency Scores

DMU	Scale Efficiency
OUARGLA 2020	0.848
OUARGLA 2021	0.863
OUARGLA 2022	0.877
OUARGLA 2023	0.895
OUARGLA 2024	1.000
GHARDAIA 2020	1.000
GHARDAIA 2021	0.961
GHARDAIA 2022	0.763
GHARDAIA 2023	0.740
GHARDAIA 2024	0.785
ILLIZI 2020	0.645
ILLIZI 2021	0.598
ILLIZI 2022	0.585
ILLIZI 2023	0.615
ILLIZI 2024	0.664

Prepared by the researchers based on DEA outputs

- OUARGLA shows a **learning and adjustment trajectory**, reaching optimal scale in 2024.
- GHARDAIA experiences severe scale inefficiency after 2021, reflecting resource–demand mismatch.
- ILLIZI hospitals operate persistently **below optimal scale**, despite relatively good managerial efficiency.

3.4.3 Reference Sets (λ Values)

Table (05) Benchmark Reference Units

Inefficient DMU	Reference DMUs
OUARGLA 2020–2023	OUARGLA 2024
GHARDAIA 2021–2024	GHARDAIA 2020; OUARGLA 2024
ILLIZI 2021–2024	ILLIZI 2020; OUARGLA 2024

Prepared by the researchers based on DEA outputs

- **OUARGLA 2024** is the dominant benchmark, representing optimal human capital utilization at scale.
- **GHARDAIA 2020** serves as an internal benchmark, implying that later inefficiency is managerial rather than structural.
- **ILLIZI 2020** reflects best practice under constrained scale conditions.

3.4.4 Slack Analysis: Human Capital Inefficiencies

Table (06) Selected Input and Output Slacks

DMU	Excess Nurses	Excess Doctors	Output Shortfall (Inpatients)
GHARDAIA 2023	+38	+17	−1,420
GHARDAIA 2024	+31	+14	−1,100
ILLIZI 2022	+19	+8	−460
OUARGLA 2022	+24	+11	0

Prepared by the researchers based on DEA outputs

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

Positive input slacks indicate **underutilized human capital**, while output shortfalls reflect missed service capacity. Inefficiency is therefore linked to **organizational deployment of staff**, not numerical shortages.

04.Integrated Discussion, Human Capital and Hospital Efficiency:

By analyzing the study results, the following can be concluded.

4.1 .Quantity versus Quality of Human Capital :

The results show that increasing the number of nurses and doctors does not automatically improve efficiency. Hospitals with stable, experienced staff and better task allocation achieve higher productivity per worker.

4.2 .Organizational Learning and Human Capital Accumulation :

OUARGLA's gradual improvement illustrates **learning-by-doing effects**, where accumulated experience and coordination enhance efficiency over time.

4.3 Policy Implications :

- Workforce planning should emphasize **skill mix and deployment**, not staff expansion.
- Inefficient hospitals should emulate DEA-identified benchmarks.
- Continuous training and organizational learning are essential for sustainable efficiency gains.

4.4 Interpretation of Scale Efficiency :

The scale efficiency results reveal three distinct patterns:

4.4.1 Hospitals Operating at Optimal Scale

- **OU24** achieved full scale efficiency (SE = 1), indicating that the hospital operated at its **most productive scale size**.
- This reflects an optimal alignment between human resources and service demand.

4.4.2 Hospitals with Scale Inefficiency Due to Under-Utilization :

- Most **IL (IllIZI)** DMUs exhibit increasing returns to scale, suggesting that these hospitals operate **below optimal size**.
- Expanding service capacity or better utilization of existing staff could improve efficiency.

4.4.3 Hospitals with Structural Imbalances :

- **GH (Ghardaïa)** hospitals show significant scale inefficiency after 2021.
- The decline indicates that increases in staff were not matched by proportional increases in inpatient admissions.

4.4.4 Policy and Managerial Implications :

- Hospitals with **increasing returns to scale** should consider expanding service delivery or improving patient inflow mechanisms.
- Hospitals with **decreasing returns to scale** require restructuring and better internal coordination.
- Strategic investment in training and inter-hospital cooperation can enhance both technical and scale efficiency.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

The comparative DEA results reveal heterogeneous efficiency patterns across the three public hospitals, underscoring the differentiated role of human capital in shaping hospital performance. Although all institutions operate under similar regulatory and institutional frameworks, variations in efficiency scores over time reflect differences in how human resources are deployed, absorbed, and aligned with service demand.

Ouargla Hospital demonstrates a relatively favorable efficiency trajectory throughout the study period. The expansion of nursing and medical staff was accompanied by a pronounced increase in inpatient admissions, particularly in the later years. DEA findings suggest that this hospital was able to translate additional human capital into higher output without generating substantial input redundancy. From an efficiency standpoint, this indicates effective human capital utilization and a capacity to exploit scale expansion. The results imply that organizational arrangements and managerial practices at Ouargla Hospital may have facilitated the productive integration of an expanding workforce, allowing the institution to approach or remain close to the efficiency frontier.

In contrast, Ghardaïa Hospital exhibits persistent efficiency shortfalls despite an increase in human capital inputs. The observed decline in inpatient output during several years, combined with rising staffing levels, is reflected in lower DEA efficiency scores. This pattern suggests that additional nurses and physicians were not fully converted into service output, pointing to technical inefficiency and potential scale misalignment. Within a human capital framework, these findings indicate that workforce accumulation alone is insufficient to enhance performance in the absence of effective coordination, demand alignment, and organizational capacity. The results are consistent with prior evidence showing that inefficiencies in public hospitals often stem from managerial and structural constraints rather than resource scarcity.

ILLIZI Hospital displays a distinct efficiency profile shaped primarily by scale-related factors. Operating at a smaller size, the hospital shows moderate efficiency levels with limited variation over time. While human capital inputs increased gradually, output growth remained constrained, reflecting demographic and geographic limitations. DEA results suggest that inefficiency in this case is less attributable to poor human capital utilization and more to the hospital's inability to achieve an optimal production scale. Consequently, further increases in staffing may yield diminishing efficiency gains unless accompanied by broader regional integration or service reorganization.

Taken together, the comparative analysis indicates that the impact of human capital on hospital efficiency is highly context-dependent. Hospitals that successfully align workforce expansion with service demand and organizational capacity tend to achieve superior efficiency outcomes, whereas misalignment between human capital inputs and production

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

conditions leads to efficiency losses. These findings reinforce the importance of complementing investments in human resources with effective management practices and scale optimization strategies to enhance hospital performance.

Conclusion :

This study applied Data Envelopment Analysis to evaluate the efficiency of public hospitals by examining how human capital inputs are transformed into healthcare outputs. The findings reveal significant variations in both technical and scale efficiency across hospitals, indicating that inefficiency is primarily driven by suboptimal utilization and organization of human resources rather than by their absolute availability. Hospitals that aligned workforce deployment with service demand and organizational capacity achieved superior efficiency outcomes, while others experienced performance losses despite increased staffing levels. Overall, the results highlight the central role of effective human capital management and scale optimization in improving hospital performance, offering valuable insights for policymakers and hospital managers seeking to enhance efficiency in public healthcare systems.

***Bibliography List* :**

Abulsaoud Ahmed Younis, R. (2018). Human Resource Management Practices and the Perceived Hospital Performance: The Mediating Role of Intellectual Capital. *Scientific Journal of Economics and Commerce, 48*(03), pp. 559-586.

Aktif Budiono, N. (2021). THE INFLUENCES OF ORGANIZATIONAL CULTURE, QUALITY OF WORK LIFE AND ORGANIZATIONAL COMMITMENT ON EMPLOYEE PERFORMANCE AT RSPAD GATOT SOEBROTO HOSPITAL. *Dinasti International Journal of Management Science, 02*(04), pp. 627-638.

Andwika, I. B., & al. (2024). Hospital Management Information System in Increasing Efficiency. *IC-ITECHS, 05*(01), pp. 890-894.

Cavalieri, M. F. (2020). Convergence, decentralization and spatial effects: An analysis of Italian regional health outcomes. *Health Policy, 124*, pp. 183-191.

Cavalieri, M., & Ferrante, L. (2020). Convergence, decentralization and spatial effects: An analysis of Italian regional health outcomes. *Health Policy, 124*(02), pp. 183-191.

Chitnis, A., & Mishra, D. K. (2019). Performance efficiency of Indian private hospitals using data envelopment analysis and super-efficiency DEA. *Journal of Health Management, 21*(02), pp. 152-167.

Coutinho, R. M., & al. (2021). Model-based estimation of transmissibility and reinfection of SARS-CoV-2 P. 1 variant. *Communications Medicine, 01*(01), p. 48.

Flaumenhaft, Y., & Ben-Assuli, O. (2018). Personal health records, global policy and regulation review. *Health policy, 122*(08), pp. 815-826.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

Hassan, H., & al. (2015). Transformational leadership and development of intellectual capital management stages towards hospital performance. *In Esteem Academic Journal, 11*(02), pp. 12-26.

Kobia, C., & Gitonga, E. (2025). Human resource management practices on employee performance at Kenyatta National Hospital, Nairobi City County, Kenya. *International Journal of Business Management, Entrepreneurship and Innovation, 07*(02), pp. 50-66.

Leitch, A. R., & al. (2024). The rise of baobab trees in Madagascar. *Nature, 629*(8014), pp. 1091-1099.

Lewaherilla, N. C., & Hiariej, H. (2023). Analysis of the Influence of Human Capital and Organizational Citizenship Behavior on the Service Performance of Medical Personnel at Dr. Haulussy Ambon Public Hospital. *Jurnal Manajemen Pelayanan Publik, 07*(01), pp. 289-304.

Li, J. a. (s.d.). *Sustainable efficiency and operational pathways in public hospitals: An efficiency evaluation using three-stage DEA and fsQCA.* Frontiers in Health Services.

Lufungula, A. R., & Borromeo, R. A. (2019). The correlates of human capital and organizational performance: Empirical Evidence from North-Kivu Hospitals in DR Congo. *International Journal of Academic Research in Business and Social Sciences, 12*(09), pp. 182-193.

Miglani, S., & Obeng, V. (2023). Gender Diversity and Human Capital Efficiency in Australian Institutions: The Moderating Role of Workforce Environment Quality. *Journal of Risk and Financial Management, 16*(07), p. 343.

Mutua, J., & al. (2024). Jemmy Mutua, Ruth Kiman Human Capital Investment and Organizational Performance: A Theoretical Review. *Jemmy Mutua, Ruth Kimanthi, & Dr. Jacinta Kinyili. (2024). Human Capital Investment and OrganizaThe International Journal of Humanities & Social Studies., 12*(03), pp. 54-57.

Nayar, P., & Ozcan, Y. A. (2008). Comparison of hospital efficiency and quality using DEA. *Journal of Medical Systems, 32*(04), pp. 345-362.

Ng, F. Y., & al. (2023). Artificial intelligence for healthcare optimization: Challenges and future directions. *Cell Reports Medicine, 10*(01), pp. 01-09.

Park, N. G., & al. (2016). Towards stable and commercially available perovskite solar cells. *Nature Energy, 01*(11), pp. 01-08.

Peykani, P., & Pishvaee, M. S. (2024). Performance Evaluation of Hospitals under Data Uncertainty: An Uncertain Common-Weights Data Envelopment Analysis. *Healthcare, 12*(06), p. 611.

Pham, P., & al. (2024). Determinants and performance outcomes of artificial intelligence adoption: Evidence from U.S. Hospitals. *Journal of Business Research, 172*, p. 114402.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)

Ramadhan, S. W., & al. (2022). Analysis of the Effect of Human Capital on Nurse Performance in Haji Hospital South Sulawesi Province. *Journal of Business and Management Studies, 04*(01), pp. 49-56.

Raphael, A. O. (2025). Evaluating Technical Efficiency of Selected Healthcare Centres in Yola North using Data Envelopment Analysis. *International Journal of Development Mathematics (IJDM), 02*(02), pp. 202-214.

Roziq, M., & Reawaroe, H. P. (2021). Investment Perspectives in Human Resources Management and Its Contribution on Organizational Performance and Competitive Advantages. *journal of Management and Leadership, 04*(01), pp. 01-13.

Umrani, W. A., & al. (2019). Addressing the issue of job performance among hospital physicians in Pakistan: The role of job security, organizational support, and job satisfaction. *Journal of Applied Biobehavioral Research, 24*(03), p. e 12169.

Van den Broek, A. (2023). Human resource management (HRM) and performance: Balancing between optimization of organizational performance and well-being of (healthcare) employees. *Journal of Infrastructure, Policy and Development, 08*(01), p. 2812.

Yousefi Nayer, M., & al. (2022). Hospital efficiency measurement in the west of Iran: data envelopment analysis and econometric approach. *Cost Effectiveness and Resource Allocation, 20*(01), pp. 08-22.

Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International (CC BY-NC-ND 4.0)