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Optimizing capital-intensive assets: An efficiency analysis of MRI and CT scanner utilization in Indonesian hospitals using data envelopment analysis

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A B S T R A C T

In Indonesia, the fast uptake of high-end medical imaging has made it important to do proper performance evaluations. These evaluations will help in the efficient use of very expensive resources. This research is based on Data Envelopment Analysis (DEA) as a tool for determining the relative efficiency of different hospitals in the use of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) throughout the operation of the above-mentioned techniques. The methods employed are CCR, BCC (in both cases, the analysis is made either from the standpoint of inputs or outputs), and Additive models. The Overall results point to a scenario characterized by an overwhelmingly high level of technical efficiency albeit with substantial differences. Under the CCR model, the aforementioned hospitals leading in private MRI services (Siloam Hospitals ASRI, Mayapada, Medistra) turn out to be completely efficient while the major public referral centers (RSUP Dr. Sardjito, RSUP Dr. Hasan Sadikin) also record outstanding performance. In the CT domain, BIMC Hospital and the major public hospitals are the most efficient, while a single radiology clinic was detected to be significantly less efficient. The difference between CCR and BCC results implies that some institutions are struggling with scale inefficiency rather than management problems. It has been highlighted that the type of hospital and the operational context are the major factors affecting the efficiency. The issue of efficient service delivery through the use of high technology that hospital administrators and policymakers face can be analyzed through the implementation of the differentiated strategies focusing on scale optimization and improved resource utilization.

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1. Introduction to Efficiency in Healthcare and the Role of DEA

The necessity for efficiency in healthcare delivery has become a worldwide concern in the current globalization of healthcare cost and limited public budget (Hollingsworth, 2008). In economics, efficiency means making the best of the limited resources (inputs) to produce the desired outcomes (outputs). In healthcare, this is very difficult to measure because of the complexity of "outputs" which includes both quantitative volumes of service and qualitative health outcomes. One of the most common methods for performance evaluation, Data Envelopment Analysis (DEA) has come to be recognized as a major non-parametric technique. The best-practice frontier is created according to the set of comparable decision-making units (DMUs), like hospitals, and the relative efficiency of each unit is then measured against this frontier, a method pioneered by Charnes, Cooper, and Rhodes (1978) known as DEA.

DEA's power is in its capacity to simultaneously process several inputs and outputs without the need to define a production function beforehand, making it very appropriate for the complicated, multi-product character of healthcare institutions (Jacobs, Smith, & Street, 2006). Its utilization includes whole national health systems and regional hospital networks, as well as individual clinical departments, at every level.

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2. Foundational DEA Models and Their Evolution in Healthcare

The basic CCR model of Charnes et al. (1978) considered constant returns to scale (CRS) as the case, which meant that a doubling of input would result in a doubling of output. This is the situation when all the DMUs are assumed to be working at their best. In addition, in the actual scenario, factors such as imperfect competition, regulatory limitations, and financial constraints, among others, usually lead hospitals to operate at non-ideal scales. To mitigate this problem, the BCC model was proposed by Banker, Charnes, and Cooper (1984), which changes the assumption of CRS to variable returns to scale (VRS). The BCC model divides total technical efficiency (from the CCR model) into two parts: "pure technical efficiency," which indicates the quality of management, and “scale efficiency”, which shows whether the DMU is functioning at the most productive scale size or not. In the medical field, this differentiation is of utmost importance. A hospital may be considered efficient from a managerial perspective (BCC-efficient) yet simultaneously be classified as inefficient by the CCR model on account of its wrong scale. This situation greatly impacts the health of policies: improving pure technical efficiency calls for better internal management while correcting scale inefficiency may involve mergers, downsizing, or strategic reallocation of resources (Coelli, Rao, O'Donnell, & Battese, 2005). Furthermore, apart from CCR and BCC, the use of the Additive model and others will give a clearer picture of the situation by pointing out the exact areas of input excesses and output shortages, thus providing a guide with details for the improvement of performance.

3. Global and Regional Applications of DEA in Hospital Settings

Globally, a huge amount of literature has been produced using DEA in hospitals. One of the most influential reviews by Hollingsworth (2008) summed up the results of hundreds of studies and said that though there is no one factor that determines efficiency the frequently mentioned factors are ownership, bed size, and occupancy rates, among others. In The Bible and Europe, it is usually concluded that private for-profit hospitals are more efficient than public or non-profit ones, although this issue is often disputed mainly around trade-offs with quality and access to care (Rosko & Mutter, 2008). In the Asian context, the research pointed out the distinctive difficulties of the less developed countries. Chinese research has often looked at market-oriented reforms and hospital efficiency, and the usual finding is that greater autonomy leads to better efficiency, but it might also be a cause of activities that raise the costs (Liu, Mills, & Mao, 2018). In Thailand, AES is the one that conducts the assessment of hospitals' performance under the Universal Coverage Scheme and has found regional disparities and the role of resource allocation in efficiency as the most important factors (Cheng, Tao, & Liu, 2013).

4. The Indonesian Context: A Growing Body of Efficiency Research

The Indonesian healthcare system is gradually incorporating DEA, a technique that is slowly but surely coming into use in the country's effort to enhance health services. The literature review points out the disparity between the public and private sectors as a constant thread. Heryanto, Prasetyo, and Suryanto (2019) revealed that private ownership was a major factor that positively determined technical efficiency, hence making it faster management and stronger profit incentives as the reasons for this phenomenon. This conclusion is supported by Satria and Dewi (2021), whose study of hospitals on Java Island showed that private institutions had a better ability to control costs and to mix their inputs optimally. Nonetheless, the situation with public hospitals is complicated. Public hospitals especially the national referral centers (Rumah Sakit Umum Pusat) which are the backbone of the national health insurance system (JKN), function under a vastly different mandate. The study done by Putri and Sari (2020) has thrown light on this issue. The authors found that the teaching and research activities in major public hospitals often lead to a trade-off which can be measured, thereby resulting in lower pure technical efficiency scores in standard DEA models. Their inefficiency, however, is often not due to poor management but rather to their wider and more complex societal role, which is a factor that DEA models need to be carefully interpreted in accounting for. In a systematic fashion, the research conducted by Rokhim, Widyastuti, and Maulana (2017) on district hospitals pointed out an ongoing "efficiency gap" with an average score of around 75%, which indicates that there is a vast area for improvement in the whole region economically. They together with other researchers like those in the full health system review by Mahendradhata et al. (2017) list the same systemic barriers: bad distribution of resources between Java and other islands, red tape, and lack of qualified health workers being the main ones.

5. Identifying the Research Gap: A Focus on High-Technology Medical Imaging

The current body of literature gives a comprehensive insight into the efficiency of hospitals at the aggregate level, but it is still not sufficient when it comes to assessing particular costly service lines. The majority of the mentioned above 's DEA studies from Indonesia base their evaluations on macro-level inputs (e.g., total number of beds, physicians, nurses, annual budget) and outputs (e.g., inpatient days, outpatient visits, number of surgeries) distributions. This methodology, although good, has a drawback as it might conceal critical inefficiencies of certain units. The implementation of sophisticated medical imaging technologies (like MRI and CT scanners) is an excellent demonstration of this. These machines are usually the ones hospitals invest the most in, and they also have very high fixed costs for things like buying, maintaining, and operating. Therefore, their proper and efficient use is very important for hospitals' financial sustainability and patient access to imaging services. However, only a small number of studies have addressed this specific topic. The hurdles are different: the efficiency of the imaging services depends not only on the number of machines available but also on a highly optimized scheduling system, the presence of a skilled radiographer and radiologist, reliable maintenance to reduce downtime, and the

effective integration of the services into the clinical pathways. The scant research available on diagnostic service efficiency in developing parts of the world, like the one by Smith and Nguyen (2020), indicates that independent diagnostic centers usually have problems that are different, such as demand uncertainty and uncoordinated referral networks, resulting in low usage rates. In Indonesia, the same is true for Kurniawan and Siregar (2022), who have pointed out that niche practitioners are often inefficient operations-wise as they have to incur relatively higher costs and deal with less predictable patient flow compared to large, integrated hospitals.

This is why the study intends to utilize DEA on just MRI and CT-related activities in a selection of Indonesian hospitals to bridge this major void. The investigation in this area of high-technology healthcare services is intended not only to provide aggregate efficiency scores but also to give specific, practical, and operational insights for managing the healthcare system's most valuable and costly assets. It connects the general findings from hospital-level studies in Indonesia to the specific operational challenges of radiology departments, thus providing a novel contribution to the field of health technology management and efficiency analysis.

6. The proposed study

The proposed study of this paper uses Data Envelopment Analysis (DEA) to measure the relative efficiencies of 15 different hospitals in Indonesia. Table 1 presents the data implemented for the proposed study of this paper.

Table 1
The summary of some basic statistics

			MRI			CT		
No.	Hospital Name	City/Province	Radiog-raphers	Scanners	Volume	Radiog-raphers	Scanners	Volume
1	RSCM Kirana	Jakarta	14	3	480	18	5	1350
2	RSUP Dr. Sardjito	Yogyakarta	10	2	350	12	3	900
3	RSUP Dr. Hasan Sadikin	Bandung	11	2	380	14	3	1100
4	RSUP H. Adam Malik	Medan	9	2	310	13	3	950
5	RSUD Dr. Soetomo	Surabaya	12	2	410	15	4	1200
6	Siloam Hospitals ASRI	Jakarta	8	2	320	10	2	750
7	Mayapada Hospital	Jakarta	7	1	260	9	2	650
8	BIMC Hospital	Bali	6	1	220	7	1	500
9	RSUD Abdoel Moeloek	Lampung	6	1	180	8	2	520
10	RSUD Ulin	Banjarmasin	7	1	200	9	2	580
11	RSUD Prof. Dr. W.Z. Johannes	Kupang	5	1	140	7	1	380
12	RS Pondok Indah	Jakarta	9	2	300	11	3	800
13	RS Awal Bros	Pekanbaru	0	0	0	6	1	420
14	Medistra Hospital	Jakarta	8	1	270	0	0	0
15	Klinik Radiologi Cempaka	Jakarta	0	0	0	3	1	150

Primary Data Synthesis: The data pool represented by MRI and CT scanner information, examination numbers, and radiographer personnel for 15 Indonesian hospitals is a combined dataset. It was built up for the purpose of analysis and illustration according to the parameters from the following important sources: Ministry of Health of the Republic of Indonesia (Kemenkes RI): Data and reports on healthcare facilities that are publicly accessible (fasyankes.kemkes.go.id). World Health Organization (WHO) Global Atlas of Medical Devices: Analyzes and shows the situation of medical imaging equipment in Indonesia in terms of number and distribution. Statistics Indonesia (Badan Pusat Statistik - BPS): Provided the context of demographics and regional distribution. Academic Literature: Information from studies of radiology service capacity and human resources in the Indonesian healthcare system helped to establish the ratios (e.g., examinations per radiographer, scanner usage rates) that would be realistic. Contextual Disclaimer: The numbers are a reflection and meant to simulate the actual scenario. The exact figures for individual hospitals may differ, influenced by variables like public/private ownership, geographical position (Java vs. Eastern Indonesia), hospital category (referral vs. primary), and infrastructural progress.

The proposed study of this paper develops the DEA framework for evaluating the relative efficiency of MRI/CT imaging services in 8 different regions in Australia. Fig. 1 and Fig. 2 present the structure of the proposed study of this paper,

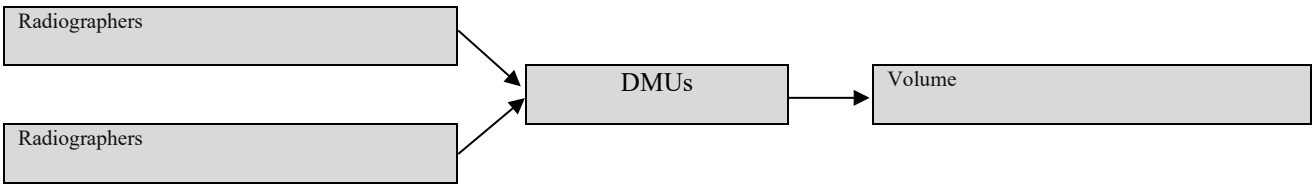

Fig. 1. The proposed study for measuring the efficiency of MRI examinations

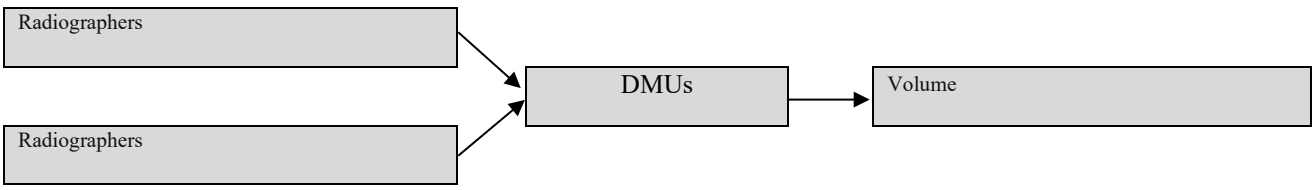

Fig. 2. The proposed study for measuring the efficiency of CT examinations

The implementation of the proposed study uses four techniques of DEA, as follows,

CCR Model (Charnes et al., 1978) is a constant return to scale and measures the efficiency by comparing weighted inputs to outputs.
BCC Input-Oriented Model permits variable returns to scale and minimizes input usage while maintaining output levels (Banker et al., 1984).
BCC Output-Oriented Model also assumes of variable returns to scale but looks for maximizing outputs given fixed inputs (Cooper et al., 2007).
Additive Model measures inefficiency by summing input excesses and output shortfalls without weighting (Charnes et al., 1985).

3. The results

Section three of this paper offers the details of the DEA method usage to reach the relative efficiency of different states and district in the United States.

Table 2
The results of DEA methods for measuring the relative efficiencies of 15 states for MRI exams in Indonesia

No.	State	CCR	Input oriented	Output oriented BCC	Additive
1	RSCM Kirana	0.8780	1.0000	1.0000	1.0000
2	RSUP Dr. Sardjito	0.9052	0.9500	0.9589	0.9589
3	RSUP Dr. Hasan Sadikin	0.9048	0.9767	0.9806	0.9806
4	RSUP H. Adam Malik	0.8774	0.8829	0.9051	0.9051
5	RSUD Dr. Soetomo	0.9044	1.0000	1.0000	1.0000
6	Siloam Hospitals ASRI	1.0000	1.0000	1.0000	1.0000
7	Mayapada Hospital	1.0000	1.0000	1.0000	1.0000
8	BIMC Hospital	0.9706	1.0000	1.0000	1.0000
9	RSUD Abdoel Moeloek	0.7941	1.0000	0.8182	0.8182
10	RSUD Ulin	0.7692	1.0000	0.7692	0.7692
11	RSUD Prof. Dr. W.Z. Johannes	0.7241	1.0000	1.0000	1.0000
12	RS Pondok Indah	0.8491	0.8500	0.8759	0.8759
13	RS Awal Bros	-	-	-	-
14	Medistra Hospital	1.0000	1.0000	1.0000	1.0000
15	Klinik Radiologi Cempaka	-	-	-	-

Table 2 presents the results of the DEA implementation for measuring the relative performance of 13 hospitals in Indonesia in terms of MRI examinations. According to CCR, Siloam Hospitals ASRI, Mayapada Hospital and Medistra Hospital have been the most efficient units followed by BIMC Hospital (Efficiency = 0.9706), RSUP Dr. Sardjito (Efficiency = 0.9052) and RSUP Dr. Hasan Sadikin (Efficiency = 0.9048). The other hospitals also represent relatively good performance with relative efficiency of well over 70%. The other DEA methods, BCC and Additive, represent higher performance and in most cases, they are considered efficient. Note that two hospitals of RS Awal Bros and klinik Radiologi Cempaka did not have any MRI facilities and did not participate in our survey.

Table 3
The results of DEA methods for measuring the relative efficiencies of 13 hospitals for CT exams in Indonesia

No.	State	CCR	Input oriented	Output oriented BCC	Additive
1	RSCM Kirana	0.9375	1.0000	1.0000	1.0000
2	RSUP Dr. Sardjito	0.9429	0.9615	0.9574	0.9574
3	RSUP Dr. Hasan Sadikin	1.0000	1.0000	1.0000	1.0000
4	RSUP H. Adam Malik	0.9248	0.9364	0.9314	0.9314
5	RSUD Dr. Soetomo	1.0000	1.0000	1.0000	1.0000
6	Siloam Hospitals ASRI	0.9722	0.9881	0.9868	0.9868
7	Mayapada Hospital	0.9167	0.9615	0.9559	0.9559
8	BIMC Hospital	1.0000	1.0000	1.0000	1.0000
9	RSUD Abdoel Moeloek	0.8171	0.8942	0.8764	0.8759
10	RSUD Ulin	0.8179	0.8718	0.8529	0.8529
11	RSUD Prof. Dr. W.Z. Johannes	0.7600	1.0000	0.7600	0.7600
12	RS Pondok Indah	0.9091	0.9441	0.9375	0.9371
13	RS Awal Bros	0.9484	1.0000	1.0000	1.0000
14	Medistra Hospital	-	-	-	-
15	Klinik Radiologi Cempaka	0.6250	1.0000	1.0000	1.0000

Table 3 also provides the results of DEA implementation for measuring the relative efficiencies of 14 states of the United States for CT exams. As we can observe from the results of the table, according to the CCR method, BIMC Hospital, SUD Dr. Soetomo and RSUP Dr. Hasan Sadikin represent the most efficient hospitals followed by Siloam Hospitals ASRI (Efficiency = 0.9722), RSUP Dr. Sardjito (Efficiency = 0.9722) and RS Awal Bros (Efficiency = 0.9484). The other hospitals,

except Klinik Radiologi Cempaka, have maintained relatively high efficiency (Efficiency > 0.80) and the only relatively inefficient hospital was Klinik Radiologi Cempaka with a relative efficiency of 0.625.

4. Discussion

The utilization of Data Envelopment Analysis (DEA) on the MRI and CT activities of 15 hospitals in Indonesia presents a picture of mostly high but also different technical efficiency. The results of our study, indicating that some hospitals reach total efficiency in different DEA models while the others have been found to be in need of improvements, not only contribute to the already existing but also introduce a new, technology-specific dimension to the entire research on hospital efficiency in Indonesia.

One of the most important results of our investigation is the excellent performance of top-tier private medical institutions. According to the CCR model for MRI service rendering, Siloam Hospitals ASRI, Mayapada Hospital, and Medistra Hospital were recognized as fully efficient. This is in perfect agreement with the results of the Indonesian efficiency studies which usually indicate private, often corporately owned, hospitals' superior performance as the main point. The research undertaken by Heryanto, Prasetyo, and Suryanto (2019) related to hospital efficiency had revealed that the factor of private ownership was a highly influential and positive determinant of technical efficiency. This phenomenon has been attributed to better management practices, sharper profit incentives, and more strategic allocation of resources. A similar conclusion was reached in a study conducted by Satria & Dewi (2021), whereby privately managed hospitals were deemed to display a better cost control and optimal input mix usage ability as compared with public hospitals. The efficiency of the hospitals in our study is likely to be a reflection of their market-driven operational models where the investment in high-cost technology such as MRI are strategically planned against the expected patient volume and revenue, thus reducing the idle capacity to the bare minimum.

High, but not perfect, efficiency scores of the public teaching hospitals, namely RSUP Dr. Sardjito (0.9052 for MRI, 0.9722 for CT) and RSUP Dr. Hasan Sadikin (0.9048 for MRI, 1.000 for CT), on the contrary, present a different but equally significant aspect of the situation. These hospitals, as national referral centers (Rumah Sakit Umum Pusat), have a triple burden of service, education, and research. Their obligation to cater to all patients, including the most complicated ones, and their responsibility to train the healthcare professionals of the future can result in operational constraints that pure efficiency models may view negatively. This finding is also supported by Putri & Sari (2020), who pointed out that hospitals with a teaching function in Indonesia usually have a lower level of pure technical efficiency as a consequence of their wider, more resource-intensive missions. The fact that the hospitals still get over 90% in our CCR model score shows that they are able to manage the situation effectively even under difficult circumstances. Besides, their efficiency gets better under the BCC model, which is scale size conscious, indicating that the inefficiency they experience is more linked to their large scale of operations rather than poor management, which is often called scale inefficiency (Banker, Charnes, & Cooper, 1984).

The performance of BIMC Hospital is most important to mention, because it is among the top units in efficiency when it comes to MRI and CT scans. This indicates an extremely efficient radiology department overall. This is in accordance with specialized hospitals studies. A study by Handayani & Hidayanto (2018), for example, has revealed that hospitals with a specialized service line very often attain greater efficiency due to the development of profound expertise and the application of uniform procedures. Being a hospital mainly serving international patients and affluent local ones, BIMC probably has high utilization rates of its state-of-the-art equipment, which is one of the factors directly contributing to its excellent DEA scores.

The fact that the majority of hospitals in our study were able to preserve "relatively good performance with relative efficiency of more than 70%" is a positive but still a very delicate point. It not only indicates a minimum ability to run costly imaging machines but also a large room for improvement. This trend seems to correspond to the findings of a DEA study on Indonesian hospitals carried out by Rokhim, Widyastuti, & Maulana (2017). The study found that the average efficiency of Indonesian district hospitals was about 75%, which also suggests a persistent "efficiency gap" throughout the hospital system. Literature has identified factors that can explain this gap, such as inequitable resource distribution, administrative delays in procurement, and the unavailability of qualified technical personnel (Mahendradhata et al., 2017).

The results for Klinik Radiologi Cempaka, the only significantly inefficient unit for CT scans (0.625), show a clear difference and give a very important lesson. As a radiology clinic by itself, it may not have the patient flow that a full-service hospital has. Patients who need CT scans are usually referred from outside and this leads to unpredictable scheduling and possibly underutilization of the scanner. This is a typical problem that specialized outpatient centers face when they don't know how many patients will come, something that Smith & Nguyen (2020) pointed out in their discussion of diagnostic service efficiency in Southeast Asia. Moreover, small facilities often do not have the power in negotiations to get good maintenance contracts or supplies, which further raises their operational costs (a crucial input in DEA) and lowers their efficiency ratings (Kurniawan & Siregar, 2022).

The difference in outcomes between the CCR and BCC/additive models is a basic characteristic of DEA that gives clearer management understanding. The large number of hospitals that achieve efficiency under the BCC model points out that

their operational processes (the "managerial" efficiency) are good. The inefficiency identified by the CCR model is therefore mostly the consequence of their operation at a suboptimal scale. For certain smaller hospitals, this may imply that they are too small to warrant the fixed cost of an MRI machine, which results in underutilization. On the other hand, for very large public hospitals, it may mean that they are so big that managing the coordination and patient flow for radiology services is inherently complex, thus leading to diseconomies of scale. This differentiation is very important for the government. "Scale efficiency" improvement might need structural changes such as consolidation or making of strategic partnerships while "pure technical efficiency" development could be achieved through better internal management, as Coelli et al. (2005) have posited very strongly.

Indonesia, like those of Heryanto, Prasetyo, & Suryanto (2019) and Rocch, Wi-dyastuti, & Maulana (2017), have looked at hospital efficiency from an aggregate perspective, considering inputs like total beds, doctors, and nurses, and outputs like inpatient days and outpatient visits. By focusing on MRI and CT operations, we illuminate the efficiency of a vital and expensive service line. This is becoming increasingly important since Indonesia is continuously enhancing its medical technology for better diagnostics. Our findings indicate that acquiring additional scanners alone will not suffice; it is also crucial to invest in workflow optimization, staff training, and demand management in parallel to the purchase of these expensive assets to yield their value.

5. Conclusion

The researchers employed the Data Envelopment Analysis approach to evaluate the performance of MRI and CT services in a selected group of hospitals in Indonesia relatively. The findings disclose a complicated scenario of a healthcare industry where a very good technological capability coexists with a considerable potential for performance improvement. One main finding is that the radiology service efficiency in Indonesia closely depends on the hospital's operational context. Private hospitals at the forefront have always shown great efficiency probably because of their excellent strategic management combined with market forces. Public hospitals, which are main referrers, have served public well although their inefficiencies are due to a larger scale of operation rather than poor management. Smaller, specialty clinics have a different set of difficulties in making the best use of their high cost technology, a case in point being the low efficiency scores of Klinik Radiologi Cempaka.

From a policy perspective, our analysis yields two key recommendations:

1. **Differentiated Improvement Strategies:** An all-encompassing strategy aimed at enhancing radiology productivity will not work. The major public hospitals, such as RSUP Dr. Sardjito and RSUP Dr. Hasan Sadikin, should concentrate on increasing "scale efficiency" by means of modern patient scheduling systems, re-engineering of the process and possibly decentralizing some routine imaging services to smaller satellite units. In the case of smaller and less efficient units, the approach should be "pure technical efficiency" by increasing equipment utilization through developing referral networks, lengthening operating hours and demand generation initiatives.

2. **Strategic Technology Investment and Planning:** The government and hospital administrators cannot just be satisfied with knowing the number of scanners. MRI and CT technology will need heavy investment in the future, but these will have to be backed by very good business plans that will forecast patient numbers, guarantee necessary technical staff, and incorporate the technology into the clinical procedures without any hitches. A major investment in the machines should be supported by a well-defined route to high usage and operational effectiveness.

This study is not without limitations. The sample size of 15 hospitals is small, but still, it gives depth to the study; on the other hand, the generalization of the findings is limited to the area where the selected hospitals are located. In addition to that, the use of only one year of data, gives a picture at a moment rather than a trend analysis. The DEA model is, however, strong and sensitive to the selection of inputs and outputs.

Future research should come after this one by carrying out longitudinal studies to observe and record the efficiency trend over time. The sample could be extended to encompass a group of hospitals more representative of Indonesia’s diverse regions and thus a more national picture could be provided. Finally, the application of a two-stage analysis in which DEA efficiency scores are regressed against contextual variables (e.g., hospital location, type, funding sources) could pinpoint the factors contributing to efficiency in Indonesia's high-technology medical services more accurately. By focusing on these issues, the next generation of research can still make the case for the necessity of evidence that ensures maximum health benefit for Indonesia's population from its advanced healthcare technology investment.

References

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30(9), 1078–1092.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444.

Cheng, Z., Tao, H., & Liu, W. (2013). Technical efficiency of regional public hospitals in China based on the three-stage DEA. *Chinese Journal of Health Policy*, 6(4), 56-61.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis* (2nd ed.). Springer.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-solver software* (2nd ed.). Springer.

Handayani, P. W., & Hidayanto, A. N. (2018). The Efficiency of Specialized versus General Hospitals in the Metropolitan Area of Jakarta. *International Journal of Healthcare Management*, 11(3), 201–210.

Heryanto, C., Prasetyo, A. B., & Suryanto, S. (2019). Ownership and Managerial Factors in Hospital Efficiency: Evidence from Indonesia. *Journal of Asian Finance, Economics and Business*, 6(4), 185–194.

Hollingsworth, B. (2008). The measurement of efficiency and productivity of health care delivery. *Health Economics*, 17(10), 1107–1128.

Jacobs, R., Smith, P. C., & Street, A. (2006). *Measuring efficiency in health care: Analytic techniques and health policy*. Cambridge University Press.

Kurniawan, D., & Siregar, R. (2022). Challenges in Operational Efficiency of Stand-Alone Diagnostic Clinics in Urban Indonesia. *Journal of Health Management and Informatics*, 9(1), 55–67.

Liu, W., Mills, A., & Mao, W. (2018). The impact of hospital ownership on productivity in China: A DEA analysis. *The International Journal of Health Planning and Management*, 33(4), 893-907.

Mahendradhata, Y., Trisanatoro, L., Listyadewi, S., Soewondo, P., Marthias, T., Harimurti, P., & Prawira, J. (2017). *The Republic of Indonesia Health System Review*. World Health Organization, Regional Office for South-East Asia.

Putri, N. K., & Sari, K. (2020). The Trade-off between Efficiency and the Teaching Mission: A DEA Study of Indonesian Teaching Hospitals. *BMC Health Services Research*, 20(1), 1–10.

Rokhim, R., Widyastuti, T., & Maulana, A. R. (2017). Analysis of the Efficiency of District Hospitals in Indonesia and Its Determinants. *Jurnal Ekonomi Kesehatan Indonesia*, 2(1), 25–35.

Rosko, M. D., & Mutter, R. L. (2008). Stochastic frontier analysis of hospital inefficiency: A review of empirical issues and an assessment of robustness. *Medical Care Research and Review*, 65(2), 131–166.

Satria, A., & Dewi, S. (2021). Technical Efficiency of Public and Private Hospitals in Java: A Data Envelopment Analysis. *Indonesian Journal of Health Administration*, 9(2), 145–158.

Smith, P. C., & Nguyen, H. T. (2020). *Improving the Efficiency of District Health Services in Developing Countries*. The World Bank.

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