Eduvest – Journal of Universal Studies
Volume 5 Number 9, September, 2025
p- ISSN 2775-3735- e-ISSN 2775-3727

Comparative Analysis of Specifications for the Construction of Robotic and Non-Robotic Operating Rooms in Hospitals in Jakarta

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ABSTRACT

Technological developments in the health sector, especially in surgery, have encouraged hospitals to adopt robotic-based operating systems. The use of robotic surgery provides clinical benefits such as increased precision, 3D visualization, and faster patient recovery. However, the adoption of this technology requires support from significantly different operating room infrastructure compared to conventional operating rooms. This research aims to conduct a systematic review of the literature that compares the specifications of robotic and non-robotic operating room construction, focusing on design aspects, mechanical-electrical systems, and construction costs. The method used is Systematic Literature Review (SLR) based on the PRISMA protocol, with data sources from Scopus, ScienceDirect, PubMed, and Google Scholar databases. A total of 25 scientific articles that met the inclusion criteria were analyzed qualitatively. The results of the research showed that robotic operating rooms require a larger area (≥60 m²), Laminar Air Flow (LAF) ventilation systems, additional radiation protection, as well as more complex electrical systems such as HMI and UPS. In addition, the cost of building a robotic operating room is reportedly much higher compared to a non-robotic room. The research also identifies the limitations of the literature in Indonesia that discusses the technical planning of robotic operating rooms, thus providing opportunities for further research in the field of health facility design. The results of this research are expected to be a reference for hospitals, construction planners, and policymakers in developing advanced technology-based operating room infrastructure.

KEYWORDS *Hospital, Operating Room, Robotic Surgery, Systematic Literature Review, Technical Specifications*

INTRODUCTION

The development of medical technology in the last two decades has brought significant changes in surgical practice. One of the biggest innovations is robotic surgery, which combines robotic technology and advanced imaging systems to support high-precision surgical procedures, 3D visualization, and a lower risk of complications (Lanfranco et al., 2004; Camarillo et al., 2004). Robotic surgery has also been shown to reduce incision size, accelerate patient recovery time, and improve hospital efficiency (Jayne et al., 2017; Shabir et al., 2021).

However, the adoption of this technology depends not only on the robotic surgical system itself but also on the readiness of the operating room infrastructure capable of supporting the robot's operation. Operating rooms for robotic surgery procedures require a specialized design that includes ergonomic layouts, complex installations of electrical and medical gas systems, and integrated ventilation and lighting (Bharathan et al., 2012; Marti et al., 2018). This distinguishes them from non-robotic operating rooms, which have standard infrastructure requirements and are architecturally and mechanically simpler (Delgado-Lopez et al., 2018; Ministry of Health of the Republic of Indonesia, 2022).

In Indonesia, the use of robotic surgery has begun to be introduced by several hospitals such as RSU Bunda Jakarta and Harapan Kita Heart Hospital, which are pioneers in the use of the Da Vinci Surgical System (Asia, 2025; Harapan Kita National Heart Centre, 2025). However, the penetration of this technology remains very limited compared to developed countries. One of the main challenges is the high investment cost, especially related to the construction of operating rooms that comply with international standards for robotic surgery (Khorgami et al., 2018; BDO USA, 2025).

Without clear standards regarding the design and specifications of robotic operating rooms, hospitals in Indonesia risk facing inefficient investments, patient safety issues, and delays in adopting global technology. Recognizing the urgency and relevance of this issue, a comprehensive understanding of the differences in robotic and non-robotic operating room specifications is needed. Previous research has generally focused on the clinical or financial aspects of robotic technology, but systematic studies reviewing the specification aspects of operating room development are still very limited, especially in the context of Indonesian hospitals. This research not only compares theories but also provides a systematic and contextual analysis in Indonesia that is rarely found in the literature.

This research aims to analyze the differences between robotic and non-robotic operating room specifications and assess their relevance to the context of hospitals in Indonesia. The benefits of this research are: (1) providing scientific references for hospital management in planning robotic operating room infrastructure; (2) assisting construction planners in understanding the technical specifications required; and (3) contributing to the development of national standards for advanced surgical facilities in Indonesia.

METHOD

This research uses the *Systematic Literature Review* (SLR) to collect, evaluate, and synthesize relevant scientific literature related to the comparison of specifications for the construction of robotic and non-robotic operating rooms in hospitals. The SLR approach allows for the systematic and transparent identification of trends, consistent findings, and research gaps from previous studies (Kitchenham et al., 2009; Moher et al., 2009).

The SLR process in this research follows the guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) which provides a transparent and accountable reporting structure (Page et al., 2021). The PRISMA flowchart is used to illustrate the stages of article search, selection, and exclusion.

The literature was obtained through a search of the following scientific databases:

a. Scopus
b. ScienceDirect
c. PubMed
d. Google Scholar

Keywords used in the search (with the AND/OR operator boolean technique) include:
“operating room” AND (“robotic surgery” OR “non-robotic surgery”) AND (“hospital design” OR “construction” OR “facility planning” OR “infrastructure”) AND (“Indonesia” OR “developing country”)

A search was conducted for publication in the period 2004 to 2024, to capture the evolution of *robotic surgery systems* and their influence on the design of operating room facilities.

Criteria included:

a. Studies that contain specifications for the design, construction, or planning of robotic and/or non-robotic operating room facilities.

b. Studies published in reputable scientific journals or international conferences.
c. Research in English or Indonesian.
d. Studies that list the context of hospitals, especially in developing countries or Southeast Asia.

Exclusion criteria:

a. Studies that only address clinical procedures without including infrastructure elements.
b. Editorials, comments, and opinion articles.
c. Duplication of results or non-scientific project reports.

The selection process is carried out in three stages:

a. Identification: the initial search yields a total number of articles based on keywords.
b. Screening: screening of titles and abstracts to evaluate initial relevance.
c. Eligibility: full-text evaluation to ensure the article fits the focus of the research.
d. Inclusion: articles that meet the criteria are included in the final analysis.

The PRISMA diagram will be used to illustrate the number of articles at each stage of selection (Moher et al., 2009), which can be seen in Figure 1.

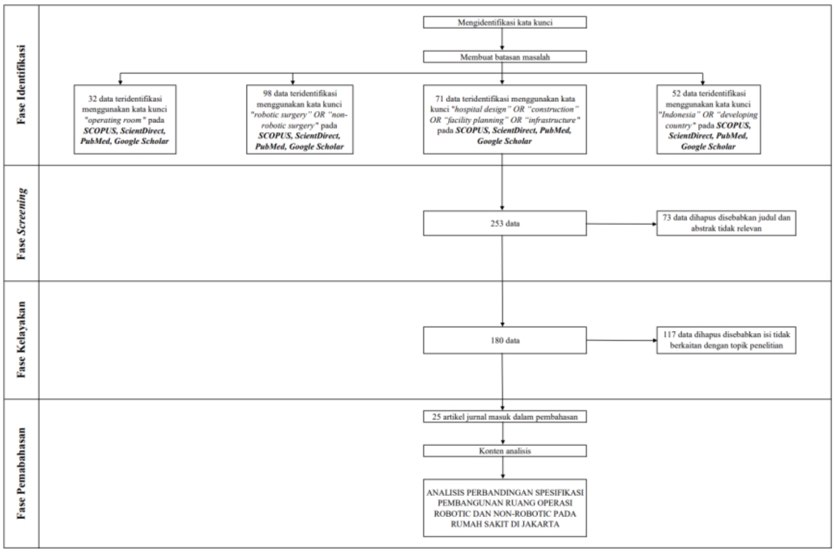

Figure 1. Research PRISM diagram

Data from selected studies were analyzed using a narrative synthesis approach. The information collected includes:

a. Year and location of research
b. Type of operating room discussed (robotic/non-robotic)
c. Technical specifications (HVAC, protective materials, layout, electrical system)
d. Cost or complexity of implementation
e. Design and technology recommendations

The data is then presented in the form of a comparison table to facilitate the identification of patterns, gaps, and potential contributions to academic literature and field practice.

RESULT AND DISCUSSION

Characteristics of the reviewed studies

From the results of searching and filtering literature on Scopus, PubMed, ScienceDirect, and Google Scholar databases, as many as 25 scientific articles were selected for review. The studies came from various countries including the United States, the United Kingdom, India, China, and some from Indonesia and Southeast Asia. Most studies have focused on comparisons between robotic and non-robotic operating rooms from aspects of physical design, HVAC systems, supporting technologies, and construction costs (Lanfranco et al., 2004; Camarillo et al., 2004; Marti et al., 2018; Bharathan et al., 2013; Delgado-Lopez et al., 2018; Jayne et al., 2017). The Da Vinci robotic system can be seen in Figure 2.

Gambar 2. Da Vinci robotic system (Camarillo et al., 2004)

Comparison of robotic and non-robotic operating room specifications

Dimensions and layout of the space

Robotic operating rooms require larger dimensions than non-robotic due to the existence of robotic systems and surgical consoles. A research by Bharathan et al. (2013) states that a robotic space should ideally be ≥ 60 m², while non-robotic spaces are generally between 36–50 m² (Ministry of Health of the Republic of Indonesia, 2022). The layout of the robotic space also considers the cable paths, connectivity between devices, and the clearance of the robotic arm's movements (Chabot et al., 2024). A reference to the design of the operating room that has followed the regulations can be seen in Figure 3. The location of the case research of the operating room to be built is marked in red, as shown in Figure 4.

Figure 3. Operating room design reference (Machtron mastevi, 2025)

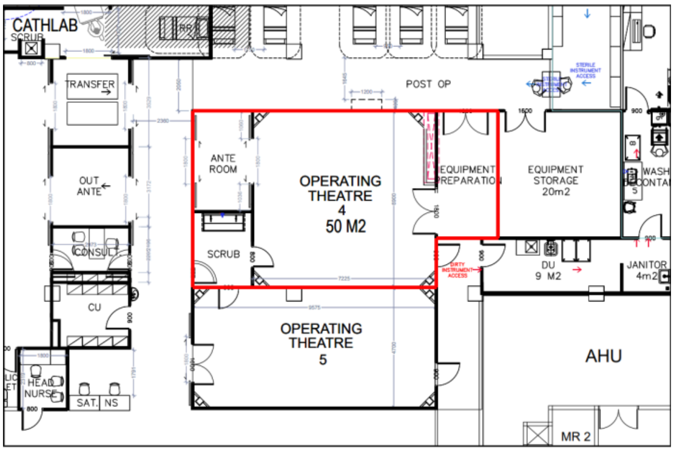

Figure 4. The location of a case research of the construction of a robotic operating room in a hospital in Jakarta

Air conditioning and ventilation systems

A research by Sadrizadeh et al. (2021) shows that Laminar Air Flow (LAF) systems are more commonly used in robotic spaces because airflow stability is crucial when high-precision procedures are performed. Displacement Ventilation (DV) systems are still found in non-robotic operating rooms in some developing countries, but they have a risk of "lock-up" on pollutants (Friberg et al., 1996). There are several air distribution systems in the operating room that have been developed, all of which are summarized in Table 1. The airflow scheme of the LAF distribution system can be seen in Figure 5.

Table 1. Air distribution system in the operating room

System Name	Information	Source
Mixing	Clean air is supplied through a diffuser in the ceiling or wall and extracted at floor level.	(Kuivjõgi et al., 2021)
	Relying on dilution methods to remove contaminants.	
	The effectiveness of this system is influenced by the location of the air supply and exhaust, the characteristics of the diffuser, and the indoor heat distribution.	
Laminar Airflow (LAF)	Air is flowed vertically from the ceiling to the floor at a low speed (0.2–0.3 m/s).	(Agirman et al., 2019) (Melhado et al., 2006)
	Capable of "sweeping" airborne pathogens from the operating area to the ventilation outlet.	
	LAF is superior in reducing contamination over turbulent	

	ventilation, but its effectiveness is still debated.	
Displacement (DV)	Clean cold air is flowed from the floor and pushes the polluted air upwards towards the exhaust vents. However, DV can cause the phenomenon of "lock-up", where pollutants are trapped at a certain height and not disposed of properly.	(Friberg et al., 1996) (Erichsen Andersson et al., 2014)
Hybrid	Combining two or more distribution systems to improve efficiency. An example is temperature-controlled airflow (TcAF) which combines LAF and turbulent with cooler air temperatures to maintain air quality.	(Wang et al., 2018)

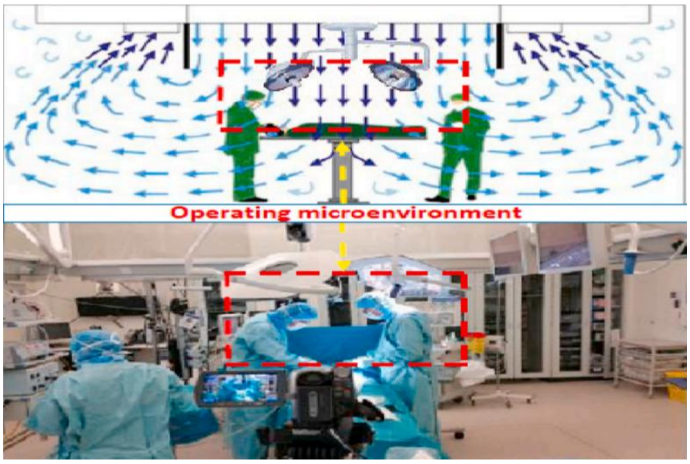

Figure 5. Airflow scheme of the LAF distribution system (Sadrizadeh et al., 2021)

Protective materials and radiation

For robotic chambers that use fluoroscopy or procedures with high radiation (such as robotic urology), protection using lead (Pb) or barite concrete is important (Delgado-Lopez et al., 2018). Standard non-robotic spaces do not necessarily require radiation shielding, depending on the clinical procedure performed. A sketch of an operating room equipped with a lead layer can be seen in Figure 6, while a visualization of the wallplan of a case research of the construction of a robotic operating room in a hospital in Jakarta can be seen in Figure 7.

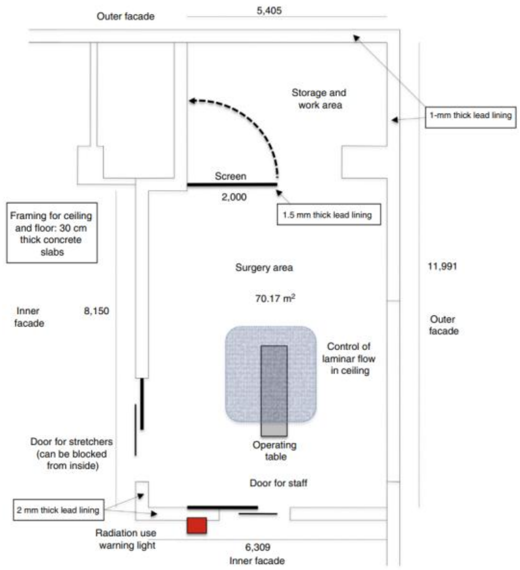

Figure 6. Sketch of a lead-equipped operating room (Delgado-Lopez, 2018)

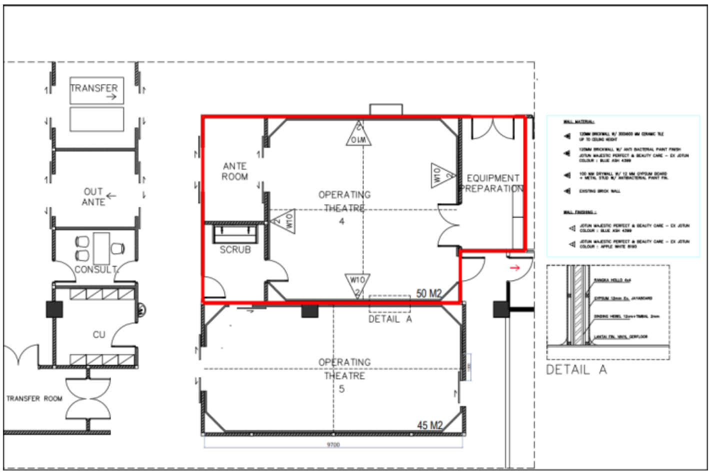

Figure 7. Wall plan Research of robotic operating rooms in hospitals in Jakarta

Electrical and information systems

The robotic operating room is equipped with a Human-Machine Interface (HMI), PLC (Programmable Logic Controller), and a more complex UPS power backup system. This is explained in the research by Marti et al. (2018) and also exemplified in hospital project data in Jakarta. Non-robotic spaces generally do not require complex internal communication networks and are more economical in power distribution systems. The schematic of the HVAC case research of the construction of a robotic operating room in a hospital in Jakarta can be seen in Figure 8.

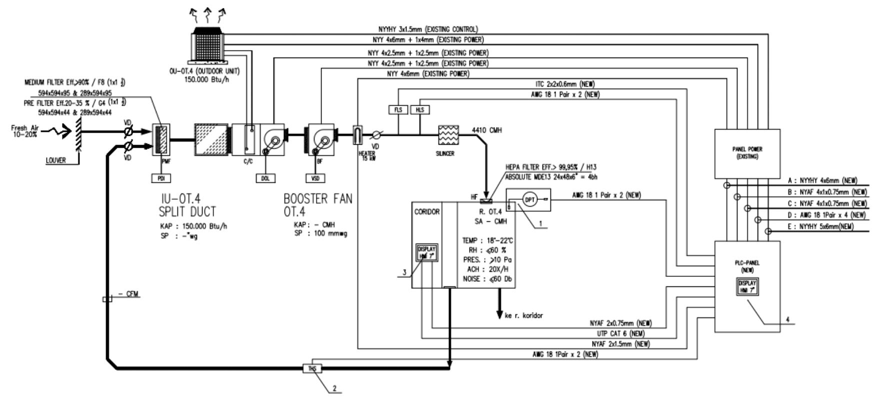

Figure 8. Schematic plan case research of robotic operating rooms in hospitals in Jakarta

Cost and complexity of the building

Based on cost data in the Jakarta case research, the construction of a robotic room costs up to Rp 44 billion, while a non-robotic room is around Rp 4.1 billion. This difference comes from the procurement of robotic systems, additional protective materials, specialized HVAC devices, and automated control systems. A research by Khorgami et al. (2018) also shows that the cost of procuring a robotic system can be 8–12 times higher than that of a conventional operating room, but it can be compensated by increased utilization and efficiency of procedures in the long run. Cost plan (RAB) data on the case research of the construction of robotic and non-robotic operating rooms in hospitals in Jakarta, as shown in Table 2.

Table 2. Draft budget for the cost of a case research of operating rooms in hospitals in Jakarta.

No	Job Items	Operating Room	
		Non-Robotic (Rp.)	***Robotic*** (Rp.)
I	**Preparatory and supporting work**		
1	Project management	10,350,000	10,350,000
2	Drawings of work and execution	13,800,000	13,800,000
3	Cleanliness and neatness	2,500,000	2,500,000
4	Mobilization and demobilization	3,500,000	3,500,000
5	Temporary offices and warehouses	8,600,000	8,600,000
6	Work safety equipment	8,480,000	8,480,000
7	Electricity and working water	9,300,000	9,300,000
8	Work equipment and supplies	1,800,000	1,800,000
Total preparation and support work		58,330,000	58,330,000
II	**Architectural work**		
1	Demolition work	9,802,500	9,802,500
2	Wall work	49,627,590	364,404,690
3	Flooring work	19,761,920	19,761,920
4	Ceiling work	14,720,000	14,720,000
5	Wall *finishing* work	11,841,690	11,841,690
6	Door and window work	82,078,000	143,500,000
7	Sanitary jobs	43,146,250	43,146,250
Total architectural work		230,977,950	607,177,050

No	Job Items	Operating Room	
		Non-Robotic (Rp.)	***Robotic*** (Rp.)
III	**Mechanical, electrical, plumbing (MEP) jobs**		
1	Mechanical work	745,463,400	972,463,400
2	Electrical work	162,537,208	176,463,208
3	Plumbing jobs	14,417,250	14,417,250
4	Electronic work	27,044,500	27,044,500
5	Firefighter work	39,823,000	39,823,000
6	Medical gas jobs	80,250,000	80,250,000
7	Nursecall jobs	13,245,573	13,245,573
Total MEP work		1,082,780,931	1,323,706,931
IV	**Medical Devices**		
1	Medical device procurement	2,793,000,000	38,000,000,000
	Sub total	4,165,088,881	39,989,213,981
	VAT 11%	458,159,777	4,398,813,538
	Final total	4,623,248,568	44,388,027,519

Synthesis of operating room specification comparison table

Table 3. Comparison of operating room specifications

Aspects	Non-Robotic Operating Room	Robotic Operating Room	Source
Space Dimensions	36–50 m²	≥60 m²	Bharathan et al., 2013; Project case research data
Ventilated & HVAC	Mixing/DV system, LAF optional	LAF mandatory, with HEPA + UV-C filter	Sadrizadeh et al., 2021
Radiation Shields	Generally none	There are (Pb, barite concrete) depending on the type of operation	Delgado-López et al., 2018
Electrical System	Standard system, basic outlet	Higher power, UPS, HMI & PLC, more outlet points	Marti et al., 2018; Project case research data
Construction Costs	± IDR 4.1 billion	± IDR 44 billion	Project case research data; Khorgami et al., 2018
Supporting Technology	Standard manual & digital equipment	Da Vinci system, 3D camera, digital integration system	Camarillo et al., 2004; Lanfranco et al., 2004

There have not been many systematic studies in Indonesia that compare the physical specifications of robotic vs non-robotic operating rooms technically and cost.

a. The majority of studies focus on clinical benefits, not building design or MEP (Mechanical, Electrical, Plumbing) systems.
b. The need for national/international design standards for robotic spaces in developing countries is still a further research opportunity.

The findings of this literature research show that the differences in robotic and non-robotic operating room specifications are striking, both in terms of architecture, electrical mechanical, and cost. Robotic operating rooms require a larger space size, HVAC systems with high levels of sterility (LAF and HEPA), and technological infrastructure that supports robotics in real-time (Marti et al., 2018; Camarillo et al., 2004). This not only adds to the complexity of planning, but also significantly increases the total development investment.

Nonetheless, the findings also suggest that long-term operational efficiencies and the potential for improving the quality of patient services may be the main justification for such investments, particularly in hospitals with high volumes of procedures (Khorgami et al., 2018; Jayne et al., 2017). However, hospitals in developing countries such as Indonesia must consider sustainability and system readiness factors, including HR training and equipment integration.

In this research, only a few publications from Indonesia discussed the operating room in terms of technical design, and most of the research is still focused on the clinical aspect. This indicates that there is a research gap in the development of modern operating room design at the policy or hospital management level.

CONCLUSION

A systematic review of 25 studies on operating room construction in Jakarta hospitals highlights significant design and technological differences between robotic and non-robotic operating rooms. Robotic operating rooms are substantially larger (≥60 m²) to accommodate complex equipment, require advanced HVAC systems with HEPA filters, incorporate specialized radiation shielding such as lead or barite concrete, and depend on sophisticated electrical infrastructure including HMIs, UPS, and PLCs—features absent in conventional rooms. These enhanced specifications lead to markedly higher construction costs, approximately IDR 44 billion compared to IDR 4.1 billion for non-robotic rooms. The review also exposes a notable gap in Indonesia-specific research, with most existing literature originating internationally, underscoring the need for greater national focus on policy development, infrastructure readiness, and standardization. It is therefore recommended that hospitals engage in comprehensive planning addressing technical requirements, costs, and operational sustainability, while regulators—such as the Ministry of Health—develop specific national standards for robotic operating rooms. Future research should investigate lifecycle costs, practical challenges of implementation in Indonesia, and advance technology-driven design models like Building Information Modeling (BIM) to support more efficient and standardized development of these sophisticated surgical facilities.

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