



Evaluating Intensive Care Facilities Zoning and Circulation using Evidence-Based Design (EBD) in dr. Gondo Suwarno Ungaran Hospital

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Abstract

Intensive care facilities such as the Intensive Care Unit (ICU), Neonatal Intensive Care Unit (NICU), Pediatric Intensive Care Unit (PICU), Intensive Cardiology Care Unit (ICCU), and High Care Unit (HCU) require optimal zoning and circulation integration to ensure patient safety, medical efficiency, and infection control. However, existing spatial configurations are still not fully aligned with these principles, particularly in circulation flow and spatial relationships. This study evaluates the suitability of zoning and circulation systems in the intensive care units of dr. Gondo Suwarno Ungaran Regional Hospital based on Evidence-Based Design (EBD) principles. This study used a descriptive-evaluative method with a qualitative approach through floor plan observation, spatial relationship identification, and analysis of EBD indicators, including visibility, accessibility, and infection control. The results show that spatial functions have been administratively defined, but spatially they have not fully met the principle of separating clean and dirty circulation paths, potentially increasing the risk of cross-contamination. The findings highlight the need to strengthen spatial integration through circulation separation and improved inter-unit connectivity to support a safe and efficient healthcare environment.

Keywords: intensive care, zoning, circulation, Evidence-Based Design, hospital

Evaluasi Zonasi dan Sirkulasi Ruang Perawatan Intensif Berdasarkan Pendekatan Evidence-Based Design (EBD) di Rumah Sakit dr. Gondo Suwarno Ungaran

Abstrak

Ruang perawatan intensif seperti, Intensif Care Unit (ICU), Neonatal Intensif Care Unit (NICU), Pediatric Intensif Care Unit (PICU), Intensif Cardiology Care Unit (ICCU) dan High Care Unit (HCU) memerlukan integrasi zonasi dan sirkulasi yang optimal untuk menjamin keselamatan pasien, efisiensi tenaga medis, serta pengendalian infeksi. Namun, dalam praktiknya masih ditemukan konfigurasi ruang eksisting yang kurang sesuai dengan prinsip-prinsip tersebut, terutama dalam alur pergerakan dan hubungan antar fungsi ruang. Penelitian ini bertujuan mengevaluasi kesesuaian zonasi & sirkulasi ruang perawatan intensif di RSUD dr. Gondo Suwarno Ungaran berdasarkan prinsip Evidence-Based Design (EBD). Penelitian ini menggunakan metode deskriptif-evaluatif dengan pendekatan kualitatif melalui observasi denah ruang, identifikasi hubungan spasial, serta analisis indikator EBD yang meliputi visibilitas, aksesibilitas, dan pengendalian infeksi. Hasil penelitian menunjukkan bahwa pembagian fungsi ruang telah terdefinisi secara administratif, namun secara spasial belum maksimal memenuhi prinsip pemisahan jalur bersih dan kotor. Sehingga memungkinkan berpotensi meningkatkan risiko kontaminasi silang. Temuan menunjukkan perlunya penguatan integrasi hubungan spasial melalui pemisahan jalur dan peningkatan konektivitas antar unit, serta menjadi dasar konseptual dalam penerapan area steril dan alur pergerakan yang lebih terarah guna mendukung lingkungan perawatan yang aman dan efisien.

Kata-kunci: ruang intensif, zonasi, sirkulasi, Evidence-Based Design, rumah sakit

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Introduction

Hospitals as healthcare facilities possess a high level of complexity, particularly within critical care units. These spaces are designed to accommodate patients with life-threatening conditions requiring intensive monitoring and medical intervention, including the Intensive Care Unit (ICU), Neonatal Intensive Care Unit (NICU), Pediatric Intensive Care Unit (PICU), Intensive Cardiology Care Unit (ICCU), and High Care Unit (HCU). Although each unit has distinct service characteristics, all require integrated spatial planning, particularly in terms of zoning and circulation systems, to support patient safety, medical staff efficiency, and infection control [1], [2]. In addition, intensive care environments require flexible spatial configurations capable of supporting rapid medical response and continuity of critical care services [3], [4]. Hospital spatial layout is also an important determinant of operational efficiency, patient safety, and the quality of healthcare delivery because the configuration of rooms, circulation routes, and functional relationships influences how patients, staff, and resources move within the healthcare environment [5].

The quality of hospital physical environments has been proven to influence patient clinical outcomes and healthcare staff performance. The concept of Evidence-Based Design (EBD) emphasizes that healthcare facilities should be designed based on scientific evidence to improve patient safety, reduce the risk of nosocomial infections, and enhance operational efficiency and service quality [6], [7]. EBD also emphasizes the importance of integrating environmental, functional, and organizational aspects within healthcare facilities to improve healthcare outcomes and reduce operational risks [8], [9]. In intensive care environments, clear zoning and effective circulation management are essential because poor spatial planning may result in the intersection of clean and contaminated pathways, thereby increasing contamination risks and hindering medical response efficiency [1], [10]. These principles are also aligned with national healthcare facility regulations emphasizing the importance of separating clean, semi-sterile, and contaminated zones, as well as organizing circulation systems within hospital buildings to support infection prevention and control [11], [12]. Although these principles have been widely adopted in healthcare facility planning, numerous studies indicate that intensive care unit design still faces challenges related to spatial layout, room relationships, and inefficient circulation patterns. Such conditions may reduce healthcare staff mobility efficiency and increase the risk of delayed responses

to critically ill patients [13], [14]. Inefficient spatial layouts may also contribute to staff fatigue, increased workload, and reduced quality of healthcare delivery within intensive care settings [15]. Furthermore, spatial configurations that inadequately consider infection control principles may increase the risk of healthcare-associated infections (HAIs), particularly in highly vulnerable units such as ICUs [16], [17].

Recent studies demonstrate that intensive care design not only affects medical service efficiency but also directly influences infection prevention and patient safety. The COVID-19 pandemic further highlighted the need for hospital environments that can adapt to changing epidemiological conditions, particularly through flexible spatial organization, improved isolation capacity, and clearer separation of circulation pathways [18], [19]. Contemporary research highlights that hospital spatial configurations, particularly within intensive care units, should support the separation of infectious and non-infectious circulation pathways, flexible isolation spaces, and integrated medical service routes to reduce the risk of healthcare-associated infections (HAIs) [2], [18].

Spatial separation between infectious and non-infectious pathways is considered a critical strategy in minimizing cross-contamination and improving hospital safety performance [20], [17]. In addition, patient-centered ICU design emphasizes the importance of integrated spatial layouts, patient visibility, and healthcare staff accessibility in improving patient recovery quality and hospital operational efficiency [21], [4]. These findings indicate that spatial evaluation based on EBD principles has become increasingly important in supporting safe, efficient, and adaptive intensive care environments within modern healthcare facilities.

Previous studies generally focused on specific intensive care units, particularly ICU facilities, in a partial manner. Consequently, integrated studies examining intensive care environments encompassing ICU, NICU, PICU, and HCU units within a unified healthcare system remain limited. In addition, EBD studies in Indonesian healthcare facilities, especially regional public hospitals, are still relatively scarce, particularly those investigating the relationship between spatial zoning and circulation systems based on evidence-based indicators. In fact, national healthcare regulations have established technical requirements concerning hospital zoning and circulation systems to ensure patient and healthcare worker safety [11].

Although numerous studies have discussed ICU design and infection control within healthcare facilities, most of them remain focused on specific technical aspects such as isolation rooms, ventilation systems, or patient-centered care design in a partial manner. Studies specifically evaluating the relationship between zoning, circulation systems, patient safety, and infection control within an integrated intensive care system based on EBD, particularly in Indonesian regional hospitals, remain limited. Therefore, an evaluative study is needed to identify the level of conformity between intensive care spatial configurations and EBD principles as a basis for developing healthcare facility designs that are more responsive to patient safety and healthcare service efficiency.

Therefore, there is still a lack of comprehensive studies evaluating the relationship between zoning and circulation systems in integrated intensive care environments based on EBD indicators, particularly within the context of regional hospitals in Indonesia. This gap highlights the importance of evidence-based evaluations in ensuring the effectiveness of spatial configurations and circulation systems in supporting healthcare service quality.

RSUD dr. Gondo Suwarno Ungaran, as one of the regional referral hospitals, provides intensive care facilities consisting of several critical care units. However, the level of conformity between the existing zoning and circulation planning and EBD principles has not been clearly identified. Therefore, evaluating the existing spatial configuration is necessary to assess its alignment with evidence-based indicators and identify potential zoning and circulation issues that may affect service efficiency and infection control.

This study evaluates the suitability of zoning and circulation systems in the intensive care units of RSUD dr. Gondo Suwarno Ungaran using a descriptive-evaluative approach based on EBD indicators, including visibility, accessibility, infection control, patient safety, and staff efficiency. While previous studies have examined these aspects individually, limited attention has been given to their integrated evaluation within multi-unit intensive care environments, particularly in Indonesian regional hospitals. Therefore, this study integrates these factors into a single EBD-based spatial evaluation framework to identify potential spatial issues and support improvements in intensive care facility planning and design.

Methods

This study employed a descriptive-evaluative method with a qualitative approach to evaluate the suitability of zoning and circulation systems within intensive care units based on EBD principles. To ensure alignment between the research methods and objectives, the research stages were structured around three key evaluation aspects: zoning, circulation, and EBD. The objective of evaluating the zoning and circulation of intensive care units was pursued by identifying existing conditions, analyzing spatial relationships and circulation patterns, and comparing these conditions against EBD indicators and technical standards for hospital buildings. Zoning was analyzed based on the separation of clean, semi-sterile, and contaminated zones, while circulation was analyzed based on the pathways for patients, medical staff, logistics, and medical waste. Subsequently, these spatial conditions were evaluated using EBD indicators covering patient safety, infection control, and staff efficiency.

Thus, every stage of data collection and analysis was directly geared toward addressing the research objectives: identifying the level of conformity in the spatial configuration and circulation of intensive care units and pinpointing spatial aspects requiring improvement. This approach was used to systematically examine existing conditions through the identification of spatial relationships, circulation patterns, and their relationship to patient safety, infection control, and medical staff efficiency. The descriptive-evaluative approach was selected because the objective of the study was to determine the level of conformity between the existing spatial configuration of intensive care facilities and predefined EBD indicators.

The research therefore followed a sequence of existing-condition identification, spatial and circulation analysis, indicator-based assessment, scoring, and interpretation. This sequence directly connects the research objective with the evaluation procedure by translating observed spatial conditions into measurable levels of conformity. The object of this study was the intensive care facilities at RSUD dr. Gondo Suwarno Ungaran, which include several critical care units, namely the Intensive Care Unit (ICU), Neonatal Intensive Care Unit (NICU), Pediatric Intensive Care Unit (PICU), and High Care Unit (HCU). The intensive care units were selected as the study cases because they represent interconnected critical-care functions within the existing hospital building and share circulation, supporting facilities, and service pathways. The selection therefore enables an integrated evaluation of zoning and circulation across

multiple intensive care functions rather than assessing a single unit in isolation. The units were included based on their physical connection and relevance to the movement of patients, healthcare staff, logistics, and medical waste within the existing intensive care service system. The research focused on spatial zoning and circulation systems that support medical service activities. The units of analysis consisted of intensive care spatial configurations, inter-room relationships, circulation corridors, isolation rooms, nurse stations, and supporting medical service areas.

Data Collection Techniques.

Data collection was conducted using three complementary methods:

1. Direct observation, by analyzing intensive care floor plans to identify zoning distribution, inter-room relationships, and user circulation patterns within the healthcare service system.
2. Literature review, which included EBD principles and hospital planning standards based on national regulations, namely the Technical Guidelines for Hospital Buildings and the Regulation of the Minister of Health of the Republic of Indonesia Number 24 of 2020 concerning Technical Requirements for Hospital Buildings and Infrastructure [5], [6].
3. Supplementary supported by discussions with a member of the ICU staff, conducted to clarify observed circulation patterns, operational activities, and the movement of patients, healthcare staff, logistics, and medical waste. These discussions were used as supporting information to contextualize and clarify the observed spatial conditions. They were not conducted as structured interviews and were not treated as a separate qualitative dataset or subjected to independent qualitative analysis.

Research Variables and Indicators

The evaluation in this study was based on variables derived from EBD principles and hospital planning standards. The research variables included zoning, circulation systems, and EBD-based environmental performance. The Evidence-Based Design (EBD) variables were operationalized into three main aspects, namely patient safety, infection control, and staff efficiency, which are considered fundamental components in evidence-based healthcare environment evaluation [6], [7]. These aspects were used to assess the extent to which the spatial configuration supports patient safety, infection

prevention, and healthcare staff efficiency. The zoning indicators focused on the physical division of spaces based on sterility levels, namely clean zones, semi-sterile zones, and contaminated zones. Meanwhile, the infection control indicators emphasized the implications of zoning and circulation systems on the potential occurrence of cross-contamination. Thus, both aspects have different focuses, although they are interconnected in supporting the quality of healthcare environments.

Each indicator was further translated into observable parameters identified through floor plan analysis and existing spatial conditions. The assessment of these parameters was conducted based on the interpretation of spatial conditions, inter-room relationships, and circulation patterns within the intensive care service system.

1. Zoning Indicators

Table 1. Zoning indicators

No	Indicator	Parameter
1	Zone separation	The presence of clean zones, semi-sterile zones, and contaminated zones
2	Clarity of spatial function	No overlapping room functions
3	Isolation room	Available / not available
4	Spatial transition (airlock)	Available / not available
5	Standard-compliant zoning	Refers to applicable regulations

Source: Compiled by the author based on healthcare facility planning standards [11], [12].

2. Zoning Circulation

Table 2. Zoning circulation

No	Indicator	Parameter
1	Patient circulation pathway	Not intersecting with other circulation pathways
2	Medical staff circulation pathway	Efficient and rapid
3	Equipment/logistics circulation pathway	Separated from other pathways
4	Medical waste circulation pathway	Does not intersect with clean circulation pathways
5	Circulation conflict	Present / not present

Source: Compiled by the author based on healthcare facility planning standards [11], [12].

3. Evidence-Based Design (EBD)

a. Patient Safety

Table 3. Patient safety

No	Indicator	Parameter
1	Patient visibility from the nurse station	Patients can be directly observed without visual obstruction
2	Rapid access to patients	Distance and circulation pathways to patients are unobstructed
3	Clear evacuation routes	Evacuation routes are available, easily accessible, and unobstructed

Source: Compiled by the author based on Evidence-Based Design principles and hospital planning standards [6], [12], and

b. Infection Control

Table 4. Infection control

No	Indicator	Parameter
1	Separation of clean and contaminated pathways	Circulation pathways do not intersect
2	Risk of contamination	No intersection between clean pathways and medical waste circulation
3	Zoning supports sterility	Spatial zoning is organized according to cleanliness levels

Source: Compiled by the author based on Evidence-Based Design principles and hospital planning standards [6], [7], and [12].

c. Staff Efficiency

Table 5. Staff efficiency

No	Indicator	Parameter
1	Nursing travel distance	The distance between the nurse station and patients is relatively short
2	Strategic nurse station location	Located centrally and easily accessible to all patient areas
3	Accessibility of medical equipment	Medical equipment can be accessed easily without obstruction

Source: Compiled by the author based on Evidence-Based Design principles and hospital planning standards [6], [12], and [19].

Data Analysis Technique

Data analysis was conducted by comparing the Data analysis was conducted by comparing the existing spatial conditions of the intensive care units with the predefined architectural parameters derived from EBD principles and applicable hospital planning standards. The assessment focused on the conformity

of zoning, circulation, patient safety, infection control, and staff efficiency with the established spatial criteria.

A four-point Likert-type ordinal conformity scale was used to assess the degree of alignment between the existing architectural conditions and the predefined EBD criteria. The scale was applied as a criterion-referenced architectural assessment rather than as a conventional respondent-based perception survey. Therefore, the scores represent the degree of conformity of the observed spatial conditions with the defined architectural criteria. The four-point Likert-type scale was selected instead of a five-point scale because the assessment required a clear classification of the degree of architectural conformity without a neutral midpoint. This characteristic was considered appropriate for the present study because the objective was to determine the extent to which the existing spatial configuration conforms to predefined architectural criteria, rather than to measure respondents' preferences or attitudes. The four-point scale was interpreted as follows: Score 1 represents non-conformity with the defined architectural criterion; Score 2 represents partial conformity with significant spatial limitations; Score 3 represents general conformity with minor spatial limitations; and Score 4 represents full conformity with the predefined architectural criterion and corresponds to the reference or ideal architectural condition.

Table 6. Analysis technique

Score	Description	Operational Criteria
1	Not Suitable	Spatial parameters are not fulfilled, and zoning or circulation conflicts occur that may interfere with patient safety and infection control
2	Less Suitable	Only some parameters are fulfilled, and circulation conflicts, accessibility limitations, or pathway intersections that affect healthcare services are still present
3	Moderately Suitable	Most parameters are fulfilled; however, minor conflicts or spatial limitations still exist but do not significantly interfere with healthcare services
4	Suitable	All spatial parameters fulfill Evidence-Based Design principles and hospital technical standards without circulation conflicts or pathway intersections

Source: Developed by the author based on Evidence-Based Design principles [18], [19].

For example, for patient visibility, the reference condition represented by Score 4 is a clear visual relationship between the nurse station and patient treatment areas without significant visual obstruction. For rapid patient access, the reference condition is direct and unobstructed access between the nurse station and patient beds. For infection control, the reference condition involves appropriate separation between clean and contaminated circulation and spatial organization according to cleanliness requirements. These architectural reference conditions were used to assess the existing spatial configuration.

The assessment was conducted comparatively between the existing conditions and the applied standards, ensuring that the scoring results represented the level of conformity with the ideal conditions based on Evidence-Based Design principles. Although this study employed a qualitative approach, it also integrated a simple quantitative assessment through a scoring system to obtain measurable conformity results. The conformity level was calculated by converting the obtained scores into percentages using the following formula:

$$\text{Conformity Value (\%)} = \frac{\text{Total Obtained Score}}{\text{Maximum score}} \times 100\%$$

This conversion aimed to demonstrate the achievement level of the existing conditions relative to the ideal conditions and to facilitate the interpretation of results through conformity categories. To clarify the interpretation of the results, the following conformity classification was applied:

This classification was used to provide interpretative boundaries for the assessment results, thereby facilitating the identification of conformity levels and determining improvement priorities within the zoning and circulation systems of intensive care units.

To minimize subjectivity in the assessment process, the interpretation of existing conditions was conducted systematically based on spatial parameters established according to Evidence-Based Design (EBD) principles and hospital technical regulations. The evaluation was performed comparatively between the existing conditions and healthcare facility planning standards so that each score represented the level of conformity with the ideal conditions. The validation of interpretation results was carried out through cross-checking hospital Detail Engineering Design (DED) documents, spatial observations, and discussions with hospital management and intensive care medical personnel to

ensure consistency between spatial configurations and ongoing healthcare service systems. This spatial indicator-based evaluative approach is consistent with previous studies emphasizing the relationship between spatial layout, circulation systems, and infection control as essential components in modern healthcare facility design [18].

Table 7. Classification

Percentage	Category
0-25%	Not Suitable
26-50%	Less Suitable
51-75%	Moderately Suitable
76-100%	Suitable

Source: Developed by the author based on the Likert scale method.

Research Flow

The research was conducted through the following stages:

The research flow was structured to directly address the research objective of evaluating the suitability of zoning and circulation systems within intensive care units based on Evidence-Based Design (EBD) principles. The sequence of research activities links the identification of existing spatial conditions with zoning and circulation analysis, EBD-based evaluation, conformity scoring, validation, and formulation of recommendations. Therefore, each research stage contributes directly to identifying the level of conformity and the spatial aspects requiring improvement.

1. Identification of intensive care unit floor plans and existing spatial conditions. This stage involved collecting and reviewing floor plans, spatial configurations, and circulation systems within the intensive care units at RSUD dr. Gondo Suwarno Ungaran.
2. Analysis of spatial zoning based on sterility levels. The zoning analysis was conducted by identifying clean zones, semi-sterile zones, and contaminated zones based on healthcare facility planning standards and hospital technical regulations [11], [12].
3. Analysis of circulation patterns. Circulation analysis focused on patient pathways, medical staff circulation, logistics circulation, and medical waste circulation to identify potential circulation conflicts and cross-contamination risks.
4. Evaluation based on EBD indicators. The existing spatial conditions were evaluated

- using EBD indicators consisting of patient safety, infection control, and staff efficiency through a comparative scoring system.
5. Scoring and conformity assessment. Each parameter was assessed using a Likert scale to determine the conformity level between the existing conditions and ideal healthcare facility planning standards.
 6. Interpretation and validation of evaluation results. The evaluation results were interpreted descriptively and validated through cross-checking with hospital technical documents, spatial observations, and discussions with hospital management and intensive care medical personnel.
 7. Formulation of evaluation findings and recommendations. The final stage involved identifying zoning and circulation issues and formulating recommendations for improving intensive care spatial configurations based on Evidence-Based Design principles.

Results And Discussion

Location and Existing Condition Data

The research location is situated at Jl. Diponegoro No. 125, Ungaran, Genuk, West Ungaran District, Semarang Regency, Central Java, Indonesia. The study was conducted in the existing old hospital building (front building).

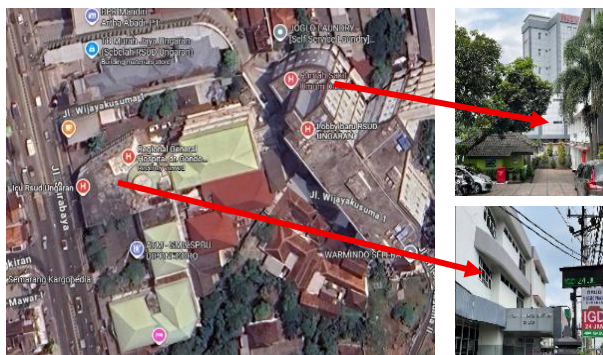


Figure 1a (left). Location of dr. Gondo Suwarno Hospital

Figure 1b (right top). View of the Building

Figure 1c (right bottom). View of the Building

The intensive care units are located on the third floor, where the ICU is positioned above the NICU, PICU, ICCU, and HCU through the implementation of a split-level spatial concept characterized by differences in floor elevation that are interconnected by ramp systems functioning as the primary circulation access between intensive care spaces.

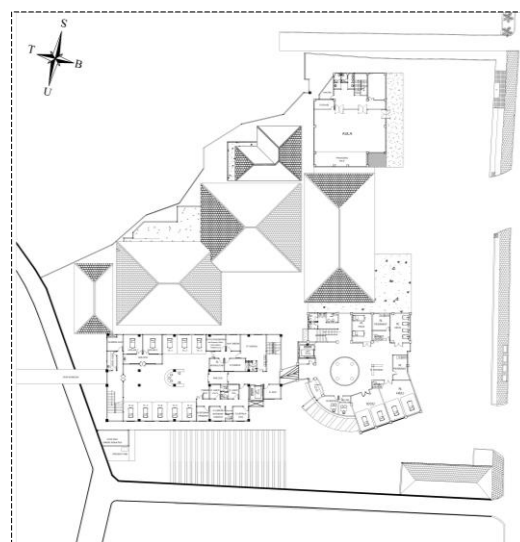


Figure 2a. Layout of the 3rd Floor of the Front Building

This spatial arrangement was designed to accommodate the functional relationships between the critical care units while maintaining continuity of medical services. The interconnected layout also provides accessibility between the treatment areas despite differences in floor elevation.

However, varying floor elevations require careful consideration of circulation efficiency, patient safety, accessibility, and staff mobility. These factors may affect movement between intensive care areas, particularly for patients requiring beds or stretchers.

These considerations are important in intensive care environments, where patient beds, stretchers, medical equipment, and critically ill patients require accessible and unobstructed circulation routes. Therefore, the spatial configuration and ramp connections should be evaluated in relation to patient safety, accessibility, and circulation efficiency [4], [22].

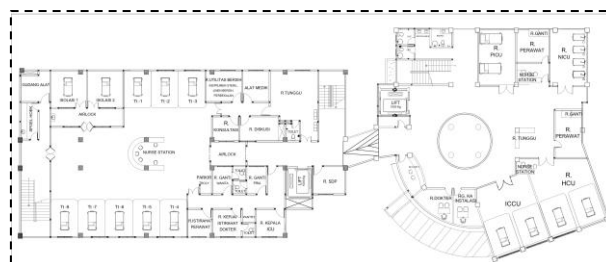


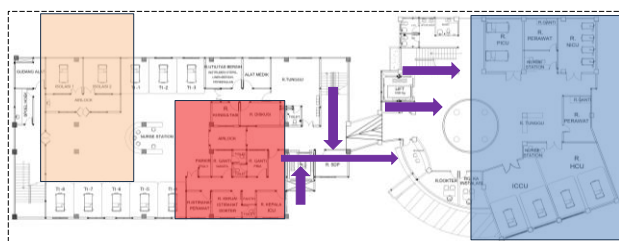
Figure 3a. Layout of the 3rd Floor of the Front Building

Evaluation Results

1. Spatial Zoning

Table 8. Result spatial zoning

No	Indicator	Parameter	Score	Justification
1	Zone separation	Division of clean zones, semi-sterile zones, and contaminated zones	3	Zoning within the NICU-PICU-HCU-ICCU areas is generally organized; however, circulation access between clean and contaminated zones is still intersecting.
2	Clarity of spatial function	No overlapping room functions	3	The functions of each unit are relatively clear; however, the physical boundaries between sterile and semi-sterile zones are not sufficiently defined.
3	Isolation room	Available / not available	2	The position of the isolation bed causes infectious patients to pass through non-isolation areas.
4	Anteroom (airlock)	Available / not available	3	Airlock and transition areas are available, but they are not yet optimally integrated into routine staff circulation.
5	Standart-compliant	Refers to regulations	2	The zoning system does not fully comply with applicable standards, particularly regarding circulation separation after navigation points.
Zoning Subtotal:			13	out of a maximum score of 20 (65%) – improvements to spatial zoning boundaries are still required.



1& 2. The separation and physical boundaries between zones are still overlapping and insufficiently defined.

3. The isolation bed is positioned too far at the rear area, causing infectious patients to pass through non-infectious zones.

4. The anteroom position has not been fully integrated with staff circulation pathways.

5. The zoning separation after the navigation area remains mixed between staff, patients, and visitors.

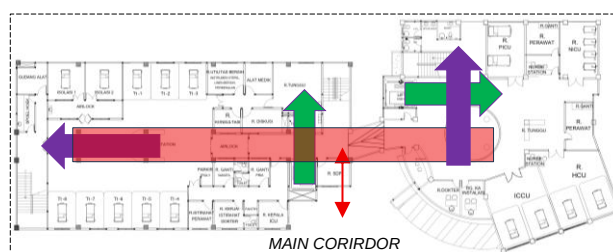
Figure 4a. Spatial zoning analysis

ICU zoning configuration is generally arranged according to hospital requirements, including treatment areas, medical staff workspaces, support service spaces, and circulation zones. Based on field observations, supplemented supported by discussions with a member of the ICU staff to clarify the observed spatial and operational conditions, the existing spatial arrangement between clean and contaminated areas may result in overlapping activities and circulation conflicts. These conditions indicate that the separation between clean, semi-sterile, and contaminated zones could be further optimized to support a more controlled healthcare environment and reduce potential infection-control risks. In the

EBD approach, the separation and organization of service zones are considered important components in supporting patient safety,

operational efficiency, and infection prevention systems in intensive care facilities, especially in healthcare environments with high vulnerability to HAIs [6], [17].

2. Circulation



Distribution pathway for medical waste and contaminated equipment exiting to the CSSD, including the location of the soiled utility room (spoelhoeck).

Distribution pathway for incoming clean equipment and medical supplies.

Figure 5a. Circulation analysis

Table 9. Result circulation

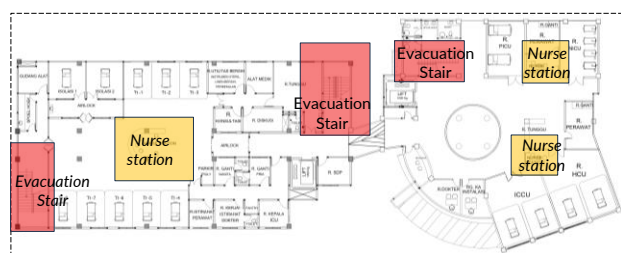
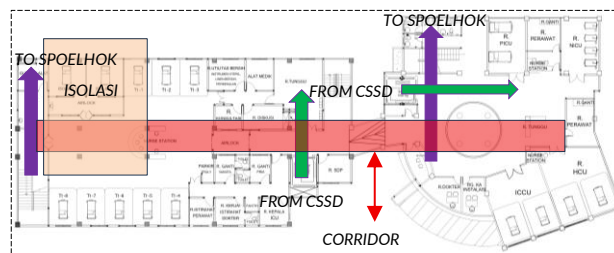
No	Indicator	Parameter	Score	Justification
1	Patient circulation pathway (particularly isolation patients)	Not intersecting with other pathways	3	Patient circulation pathways potentially intersect with staff and logistics circulation because they pass through the main corridor.
2	Medical staff circulation pathway	Efficient and rapid	3	The circulation pathway is relatively centralized near the unit areas; however, it intersects with other movement activities.
3	Equipment and logistics	Separated	2	Logistics circulation is not fully separated and still passes through the main corridor for distribution to and from the CSSD.
4	Medical waste circulation pathway	Does not intersect with clean pathways	2	Medical waste circulation potentially intersects with clean circulation pathways, increasing the risk of contamination.
5	Circulation conflict	Present / not present	3	Several circulation conflicts involving patients, staff, and logistics occur within the same corridor area.
Circulation Subtotal:			13	out of a maximum score of 20 (65%) – stricter separation of circulation pathways is still required.

3. Evidence-Based Design (EBD)

a. Patient Safety

Table 10. Result patient safety

No	Indicator	Parameter	Score	Justification
1	Patient visibility	Visibility from the nurse station to patients	4	The nurse station is centrally located and positioned close to the intensive care sub-units.
2	Rapid access to patients	Ease of access to patients without obstruction	4	Access from the nurse station to patient beds is relatively close and unobstructed.
3	Evacuation route	Evacuation routes with emergency staircases are available through three stair points	3	The landing width is 2 meters, which is still insufficient for b patients.
Patient Safety Subtotal:			11	out of a maximum score of 12 (92%) – evacuation routes and circulation obstacles still require attention.

**Figure 6a.** Patient safety**Figure 7a.** Infection control

b. Infection Control

Table 11. Result infection control

No	Indicator	Parameter	Score	Justification
1	Separation of clean and contaminated pathways	Pathways do not intersect	3	Clean and contaminated pathways still intersect in several areas.
2	Risk of contamination	No intersection between clean pathways and waste circulation	3	There is still a potential risk of contamination due to the placement of the isolation room.
3	Zoning supports sterility	Spatial zoning is organized according to cleanliness levels	3	The zoning system is not yet fully adequate to support sterility requirements.
Infection Control Subtotal:			9	out of a maximum score of 12 (75%) – contamination risks still exist because circulation pathways are not completely separated.

The flow of logistics and medical waste still uses the main corridor, which is also used by staff and patient families during health care activities, indicating that circulation has not fully implemented the principle of path separation, especially in intensive care which requires strict infection control. Overlapping activities can increase the risk of cross-contamination, create movement conflicts, and reduce the effectiveness of services in critical care units. Rashid [10] explained that circulation conflicts within the ICU can increase service complexity, disrupt workflow efficiency, and hinder medical responses in the care environment, especially during emergency situations that require rapid handling and uninterrupted health services.

c. Staff Efficiency

The nurse station provides direct visibility toward the primary treatment areas, supporting patient safety through continuous observation and rapid recognition of changes in patient conditions. This finding is consistent with the Society of Critical Care Medicine 2024 guideline, which emphasizes high patient visibility in ICU design, and with Tronstad et al. [4], who highlighted patient-centred design as an important factor in supporting the quality and safety of intensive care environments [23].

The proximity between healthcare staff workspaces and the primary treatment areas supports staff mobility efficiency in delivering intensive care services.

Table 12. Result staff efficiency

No	Indicator	Parameter	Score	Justification
1	Nursing travel distance	The distance between the nurse station and patients is relatively short	4	The nurse station and doctors' room are located close to the patient units, reducing travel distance.
2	Strategic nurse station location	Centrally located and easily accessible to all patients	3	The logistics room is relatively close, although the circulation pathway is not specifically separated; accessibility remains relatively efficient.
3	Accessibility of medical	Medical equipment can be accessed easily without obstruction	3	Supporting facilities such as staff rest areas, doctors' rooms, activities.
Staff Efficiency Subtotal:			10	out of a maximum score of 12 (83%) – staff efficiency is relatively good, although several shared circulation pathways may reduce operational efficiency.

Conformity Score Recapitulation

Based on field observations and supplementary supported by discussions with a member of the ICU staff, the intersection of logistics circulation, medical waste pathways, and staff movement within the main corridor may pose challenges to infection control. This condition suggests that the existing intensive care

circulation configuration could be further optimized in accordance with EBD principles.

The intersection between medical waste distribution

Table 13. Recapitulation Score

Aspect	Score	Max Score	Percentage	Category
Zoning	13	20	65%	Moderately Suitable
Circulation	13	20	65%	Moderately Suitable
Patient Safety	11	12	92%	Suitable
Infection Control	9	12	75%	Moderately Suitable
Staff Efficiency	10	12	83%	Suitable

pathways and healthcare service activities indicates a potential risk of cross-contamination within the intensive care environment. This finding is consistent with the study by Maurer et al. [16], which stated that the physical spatial configuration and hospital circulation patterns have a direct influence on the risk of healthcare-associated infections (HAIs).

Mourshed and Zhao [13] explained that the physical configuration of hospital environments influences healthcare staff performance effectiveness and the quality of medical services.

This condition is consistent with the study by Sherif and Iskandar [18], which stated that the separation of circulation pathways for infectious patients, logistics, and healthcare staff is an essential component of post-pandemic hospital design to minimize the risk of cross-contamination and improve safety within critical care environments.

Conclusion

Based on the evaluation of zoning and circulation systems in the intensive care units of RSUD dr. Gondo Suwarno Ungaran using Evidence-Based Design (EBD) indicators, the study found that the existing spatial configuration generally accommodates the required functional divisions, including ICU, NICU, PICU, ICCU, HCU, isolation rooms, and supporting medical facilities. However, the evaluation demonstrates that the zoning and circulation systems have not yet fully achieved the spatial conditions required by EBD principles, particularly in relation to circulation separation and infection control.

The conformity assessment indicates that zoning and circulation each obtained a score of 65%, categorized as moderately suitable. Patient safety achieved the highest conformity level at 92%, followed by staff efficiency at 83% and infection control at 75%. These results indicate that the existing configuration performs relatively well in supporting patient monitoring, accessibility, and staff mobility, but remains limited in controlling interactions between different circulation flows. In particular, the use of shared main corridors by patients, healthcare staff, logistics, and medical waste creates potential circulation conflicts and cross-contamination risks. The location of the isolation room also requires infectious patients to pass through non-isolation areas, further indicating the need for improved spatial separation.

The main contribution of this study is the development of an integrated spatial evaluation framework that connects zoning and circulation analysis with three EBD performance aspects, namely patient safety, infection control, and staff efficiency. This approach provides a measurable basis for identifying spatial deficiencies within an integrated intensive care environment rather than evaluating individual units or isolated design elements. The

findings demonstrate that EBD-based spatial evaluation can be used to identify priority areas for improvement in intensive care facilities, particularly the separation of clean and contaminated circulation, the positioning of isolation facilities, and the organization of spatial transitions.

Therefore, the findings provide a practical basis for improving the spatial configuration of intensive care facilities at RSUD dr. Gondo Suwarno Ungaran through clearer zoning boundaries, separated circulation pathways, improved isolation access, and optimized transition areas. Further research is recommended to evaluate the proposed spatial improvements through simulation, user-based assessment, or post-occupancy evaluation to determine their effects on circulation efficiency, infection control, and healthcare service performance.

Recommendations

1. Reorganizing the zoning system by clarifying the separation between clean zones, semi-sterile zones, and contaminated zones through physical barriers and access control systems.
2. Separating circulation pathways for patients, healthcare staff, logistics, and medical waste to reduce movement conflicts and the risk of cross-contamination.
3. Repositioning the isolation room to provide more isolated access without requiring circulation through non-isolation ICU bed areas.
4. Optimizing spatial transition systems such as airlocks and sterility control areas to strengthen infection control within intensive care environments.

AI Use Declaration

The authors acknowledge the use of ChatGPT by OpenAI (GPT-5.3) to assist in grammar checking and language refinement during the translation of the manuscript into English. The AI tool was utilized to improve sentence structure, clarity, and grammatical accuracy while maintaining the original meaning of the manuscript. Although artificial intelligence was used as a language-support tool, the authors confirm that they remain the sole contributors to this article and are fully responsible for all contents, analyses, interpretations, and conclusions presented in the manuscript, in accordance with publication ethics recommendations and journal policies.

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