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Weighted Scoring Design for ART Healthcare Centre

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Abstract

Background: Antiretroviral Therapy (ART) centers are critical in providing medical, psychological, and social support to People Living with HIV (PLHIV), as per the National AIDS Control Organization (NACO) guidelines. However, many ART centers in India face infrastructural inefficiencies, including overcrowding, poor ventilation, inadequate sanitation, and non-compliance with updated regulations. The existing layout of a long-operational ART center, established in 2008, has demonstrated such inefficiencies, necessitating a strategic redesign to optimize operational flow and improve patient outcomes.
Methods: This study employed a weighted scoring system to evaluate and compare three proposed layout alternatives against the existing design. The methodology included activity flowchart mapping, space utilization studies, stakeholder input, and multi-criteria decision analysis. Twelve design evaluation criteria were prioritized using weighted scores, including feasibility (11%), patient safety (10.5%), workflow efficiency (10%), and objective adherence (13%). Designs were assessed for spatial efficiency, safety, robustness, usability, and environmental impact.
Results: Design 3 achieved the highest weighted score of 6.91, outperforming Design 2 (6.865), Design 1 (5.645), and the original layout (5.275). The optimal layout improved patient flow, integrated dedicated counseling areas, enhanced staff workspaces, and improved sanitation and ventilation. Correlation analyses highlighted critical interdependencies and trade-offs among feasibility, safety, and cost factors. Design 3 also demonstrated a 30–40% reduction in congestion, compliance with NACO standards, and enhanced operational efficiency.
Conclusion: The weighted scoring methodology effectively identified the optimal ART center layout. Design 3 significantly improved spatial organization, privacy, hygiene, and workflow. Future work could incorporate IoT-based monitoring and AI-driven real-time optimization for adaptive facility management. This model can be extended to other healthcare infrastructure redesigns to enhance quality and compliance.

Keywords: *Facility Design, ART, Weighted Scores, Healthcare Facilities, National AIDS Control Organization (NACO)*

Introduction

Effective facility layout planning is essential for optimizing operations, reducing costs, and enhancing efficiency.[1,2] Well-planned facilities minimize the need for costly modifications and improve workflow by strategically placing equipment, allocating space, and considering future expansion.[3] However, a lack of focus on layout design in businesses often arises from financial constraints, competing priorities, or underestimating its impact on performance. Proper space planning reduces inefficiencies, improves material handling, and ensures compliance with safety, legal, and operational regulations. It also enhances employee comfort, job satisfaction, and productivity.[4,5] ART centers in India face challenges such as insufficient space, high patient volume, and lack of regulatory compliance. Overcrowded facilities contribute to poor layout design, increased wait times, and bottlenecks in service delivery, which negatively affect patient adherence to ART regimens.[6,7] Compliance issues arising from the NACO guidelines require dedicated consultation, drug dispensing, and counseling areas, further challenging the limited infrastructure of ART centers. Inadequate spatial planning in these centers reduces service quality and operational efficiency. Improved layout planning can better manage patient flow and congestion, ensuring adherence to treatment protocols. An efficient facility design enhances both operational effectiveness and the quality of healthcare provided.[8-10]

Facility Design Principles

Healthcare facilities must ensure constant patient visibility with windows, cameras, and proper lighting to maintain monitoring as a primary concern in facility design.[11] Standardizing patient rooms, including materials, gases, and the headwall, coupled with automation in the form of bar-coded medications and electronic medical records, enhances safety and efficiency while reducing errors.[12,13] Infrastructure flexibility is ensured by the ability to scale and adapt, allowing for expansion and integration of advanced technology, thus ensuring a flexible infrastructure.[14] Critical decision-making tools should be available at the point of care, while information systems designed for real-time patient management should also allow for integration. Measures to reduce distracting noise, such as overhead paging, use of sound-absorbing materials, and reduction of fatigue for both patients and staff, are also necessary.[15-17]

Patient and family participation in care can be facilitated by fostering tailored interaction spaces, promoting safety, and encouraging teamwork. Staff fatigue, reduced by ergonomic design, soft flooring, and shorter travel distances, improves performance and reduces error rates. Patient safety regarding design risk can be enhanced with Failure Mode and Effect Analysis (FMEA) applied in the critical design stages.[18-20] Inclusive designs that aid in caring for vulnerable patients should also be prioritized. Incorporating human factors like standardization and simplification into facility planning can improve safety, efficiency, and the quality of healthcare outcomes.[21-23]

Functions of the ART Centre

ART Centres provide holistic care for PLHIV through medical, psychological, social, and programmatic functions.[24] Medically, they monitor and manage Pre-ART and ART patients, ensure early Human Immunodeficiency Virus (HIV) co-infection screening, facilitate the diagnosis and treatment of Opportunistic Infections (OIs), conduct baseline investigations, and initiate ART according to NACO guidelines with adherence counseling to ensure treatment effectiveness. They also manage referrals for drug toxicity, treatment failure, and pediatric HIV management, while implementing Prevention of Parent-to-Child Transmission (PPTCT) interventions. Psychologically, the centres provide counseling on adherence, nutrition, drug toxicity management, risk-reduction behaviors, and family member HIV status disclosure. Socially, they assist PLHIV in accessing government welfare schemes, educational support, legal aid, and comprehensive support services. Programmatically, they track ART patients, maintain line lists for those eligible but not initiated, coordinate with Integrated Counselling and Testing Centres (ICTCs) for HIV-positive patient registration, assess the HIV status of family members, and sensitize hospital staff on infection control, ART, and waste management.[25]

Weighted Scoring Method for ART Centre

The weighted scoring method is widely used in healthcare infrastructure planning, including emergency department design, pharmacy workflow optimization, and hospital bed allocation, as it prioritizes critical factors such as patient flow and space utilization. In ART centres, this method ensures an evidence-based approach to layout redesign by assigning numerical values to key parameters such as spatial efficiency, regulatory compliance, and workflow optimization. Unlike simple ranking or cost-benefit analysis, weighted scoring provides a structured yet adaptable framework for decision-making.[26] A strategic redesign using this method is expected to improve patient wait times, adherence, and overall efficiency. Dedicated fast-track lanes for stable patients would reduce congestion, while optimized spatial organization would enhance patient movement between registration, consultation, and pharmacy sections. Improved staff workflow and appointment scheduling would further streamline operations, ensuring better service delivery.[27]

A tool was suggested that used a performance-based methodology and a new set of objective indicators to assess a building's quality by Universal Design (UD). The tool generated a report that included quantitative, qualitative, and graphical data to plan the facility status and design strategies.[28] Similarly, a state-of-the-art decision-support system was created using a multi-stage model integrated with various algorithms in a unique framework within a Fermatean fuzzy environment. Of the five potential sites in Istanbul for a new disinfection plant, empirical results indicated that "Pendik" was the best option.[29] An issue with scheduling and routing service resources was resolved by implementing a sharing strategy across several Home Health Care (HHC) facilities for specific clients. Statistical research and comparisons showed that the proposed method was highly competitive in addressing the issue.[30]

Furthermore, the standard of medical care was enhanced by adding privacy and security measures for individuals' health information. With growing interest in deep learning technologies, the Smart Healthcare Prediction and Evaluation Model (SHPE model) was developed using a modified Convolutional Neural Network (CNN). The system achieved an accuracy of 82.4%, outperforming other classical machine algorithms by 3.3% and sophisticated CNN algorithms by 2.4%.[31] Healthcare facility design methods in Shiraz were discussed, with primary passive measures categorized into thermal, auditory, and illumination. "Reducing Energy Consumption," "Compatibility with Climate," and "Durability" were identified as the top three criteria.[32] A solution for Healthcare Waste (HCW) disposal site selection was provided using the Weighted Aggregated Sum Product Assessment (WASPAS) method and Fermatean Fuzzy Sets (FFSs). Their results indicated that the proposed approach was effective in managing uncertainty and inaccuracy in the decision-making process for site selection.[33] Finally, evidence-based parameters were evaluated to assess the quality of medical facilities from social, environmental, organizational, and other perspectives. The data collected was processed through the DecSpace web platform, with organizational attributes considered the most important at 49%.[34]

The ART Centre, operational since 2008, does not fully comply with NACO's 2012 guidelines, necessitating layout reengineering. Key issues include insufficient airflow, pest infestations caused by uncontrolled openings, and inadequate sanitation facilities for both staff and the public. The absence of purpose-built ancillary spaces for administrative tasks, such as counseling or private consultations, compromises privacy and operational effectiveness.[35] Overcrowding in non-compliant shared waiting areas and improper patient flow can lead to breaches of healthcare standards. Fragmented water supply and drainage systems pose hygiene risks, compromising the well-being of occupants. Limited surveillance and control of equipment and educational resources, such as televisions for basic awareness programs, hinder communication and training prospects. Addressing these issues can strengthen safety, privacy, and hygiene, while maintaining flexibility in the building's functionality, as prescribed by standards.[36]

The objectives of the research were focused on evaluating and improving the design of the ART Centre. The first objective was to assess the current layout of the ART Centre to ensure it aligned with the NACO 2012 guidelines. Next, the research aimed to identify any inefficiencies in the existing design and propose alternative facility layouts that could optimize space utilization and function. A weighted scoring method was employed to evaluate and compare the different design options based on various criteria. Finally, the study recommended an optimal layout that enhanced patient flow, safety, and overall operational efficiency, ensuring a better healthcare experience for both patients and staff.

The paper is organized as follows: Section 2 discusses the design process and key parameters for the methodology, Section 3 presents the research outcomes, followed by a discussion in Section 4, and concludes with future research directions.

Research Methodology

This section discusses the structured approach involving design analysis, feasibility assessment, weighted scoring, and evaluation of multiple layout options to optimize ART centre functionality and efficiency.

Design Process and Selection

The design process began with evaluating the existing layout of the ART centre to identify inefficiencies and areas for improvement. Patient movement and workflow were analyzed using activity flowcharts, mapping spatial interactions between different functional zones. Benchmarking with other ART centres and literature reviews helped define quantitative space requirements. Layout measurements were taken, and initial designs were created. These were tested and iteratively refined based on staff input to ensure operational efficiency and compliance with healthcare standards. The final designs aimed to enhance functionality, patient flow, and service delivery within the constraints of the available infrastructure.[37]

To achieve an equitable and complete assessment, several layout designs were analyzed against 12 criteria: feasibility, cost, patient safety, employee safety, flexibility, robustness, workflows, employee utilization, objective adherence, maintainability, usability, and environmental impact. Each design was evaluated relative to these factors to select the optimal layout.

Feasibility Assessment and Research-Defined Evaluation Categories

Determining feasibility was the most significant factor when selecting an optimal layout. Considerations included practicality, cost analysis, construction duration, and subsystem integration.[38] Options with cost-prohibitive designs, prolonged downtime, or incompatible subsystems were excluded from further analysis.

Apart from the feasibility aspects, the designs were assessed on other factors such as cost-effectiveness, safety, flexibility, and robustness. Safety evaluations encompassed the health of the patients and employees, environmental considerations, and ergonomics. Flexibility assessed how well the design could be modified in the future, while robustness looked at the ability of the system to endure different stressors. The effectiveness of workflows and employee utilization was further assessed in the operational strategies development phase.

Case-Study-Specific Evaluation Categories Weighting Process

Additional factors specific to the ART centre included objective adherence, maintainability, usability, and environmental sustainability. Objective adherence ensured alignment with ART centre goals, while maintainability assessed the ease of upkeep. Usability focused on real-world practicality, and ecological impact emphasized sustainable design elements.[39,40]

The evaluation criteria weights were determined using a combination of expert consensus, literature precedents, and case-specific priorities. Stakeholder input from ART centre staff ensured practical relevance, while published healthcare design frameworks guided the emphasis on critical factors. Higher weights were assigned to feasibility (11%), objective adherence (13%), and patient safety (10.5%) due to operational inefficiencies, with lower weights given to less impactful factors such as environmental impact and flexibility. This study ensured the scoring system was evidence-based and context-specific. Each evaluation category was allocated a score based on its contribution, with greater emphasis placed on critical areas of success. The weight measures for scores were systematically allocated, logically and critically driven to select the optimal ART centre layout.

Layout Design of ART Centre

Figure 1 presents the original design layout of the ART Centre, focusing on functional efficiency and alignment with healthcare standards. The layout features several essential spaces, each carefully planned to support the center's operations. These include the Mo-cum-counsellor room for combined medical and counseling services, a records room for organizing patient data, and a laboratory for conducting necessary tests. The design also incorporates a counsellor's room for private consultations, a consultation room for medical assessments, and a pharmacy store to securely store medications. The dispensary area facilitates the distribution of pharmaceuticals, while a closed corridor ensures safe and efficient movement throughout the facility. Additionally, the inclusion of a care coordinator's office highlights the importance of coordinated care in managing patient services

The ART centre's layout is designed to support patient flow and privacy, with the records room located near the entrance for easy registration and a centrally located laboratory for fast diagnostics. The pharmacy is strategically placed to ensure confidentiality and efficient medication distribution, while a secure corridor controls movement in sensitive areas.

However, several issues reduce operational efficiency, hygiene, and privacy, including overcrowded waiting areas, poor airflow, pest entry, and inadequate sanitation. These shortcomings hinder compliance with NACO standards. Reengineering the layout by improving ventilation, counseling spaces, hygiene facilities, and patient flow can significantly enhance service quality and ensure alignment with regulatory requirements.

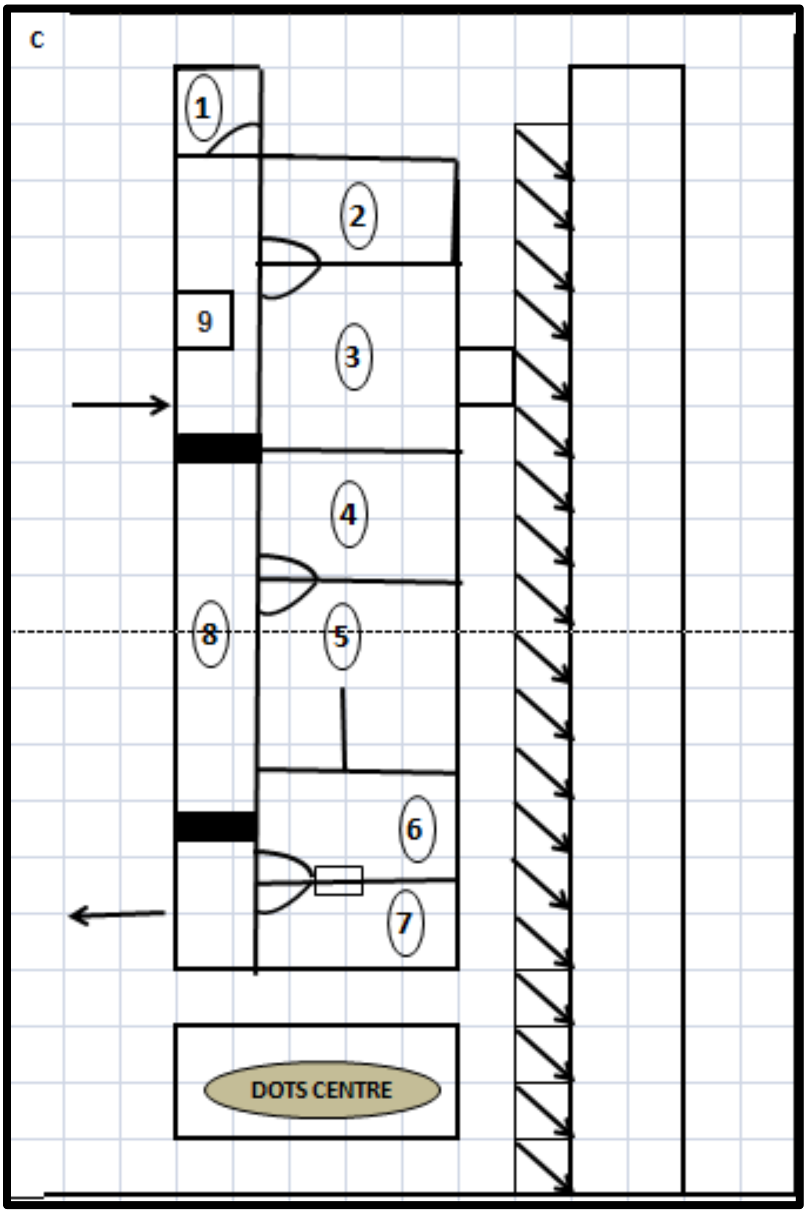

Figure 1: Original Layout

The study explored three progressively refined ART centre layout designs to enhance functionality and compliance with healthcare standards. Design 1 featured a basic, linear arrangement of consultation rooms and key service areas, ensuring straightforward access but lacking dedicated counseling space, which risked overcrowding. Design 2 addressed some limitations by relocating a consultation room near the DOTS Centre for better integration, splitting the laboratory into two units for improved diagnostics, and structurally reorganizing internal layouts to improve flow. Design 3, the most optimized version, improved patient privacy, added ventilation and sanitation upgrades, reorganized pharmacy distribution areas, and incorporated pest control measures, resulting in the best patient flow and operational efficiency. This layout emerged as the most effective solution among the three.

Results Analysis

In this section, the results obtained from implementing the research methodology are discussed in detail, followed by a discussion section. The correlation matrix heatmap in Figure 2 visualizes the relationships between key factors, highlighting strong positive correlations such as feasibility and cost (0.93), flexibility and robustness (0.97), workflows and employee utilization (0.96), and objective adherence and flexibility (0.99), indicating their interdependence. Conversely, strong negative correlations, such as feasibility and patient safety (-0.94), workflows and feasibility (-0.98), and employee utilization and usability (-0.94), suggest trade-offs. Moderate correlations, such as maintainability and employee safety (0.82) and environmental impact and cost (0.73), highlight important considerations for system design. The heatmap underscores the need to balance feasibility, flexibility, maintainability, and cost while optimizing workflows and safety.

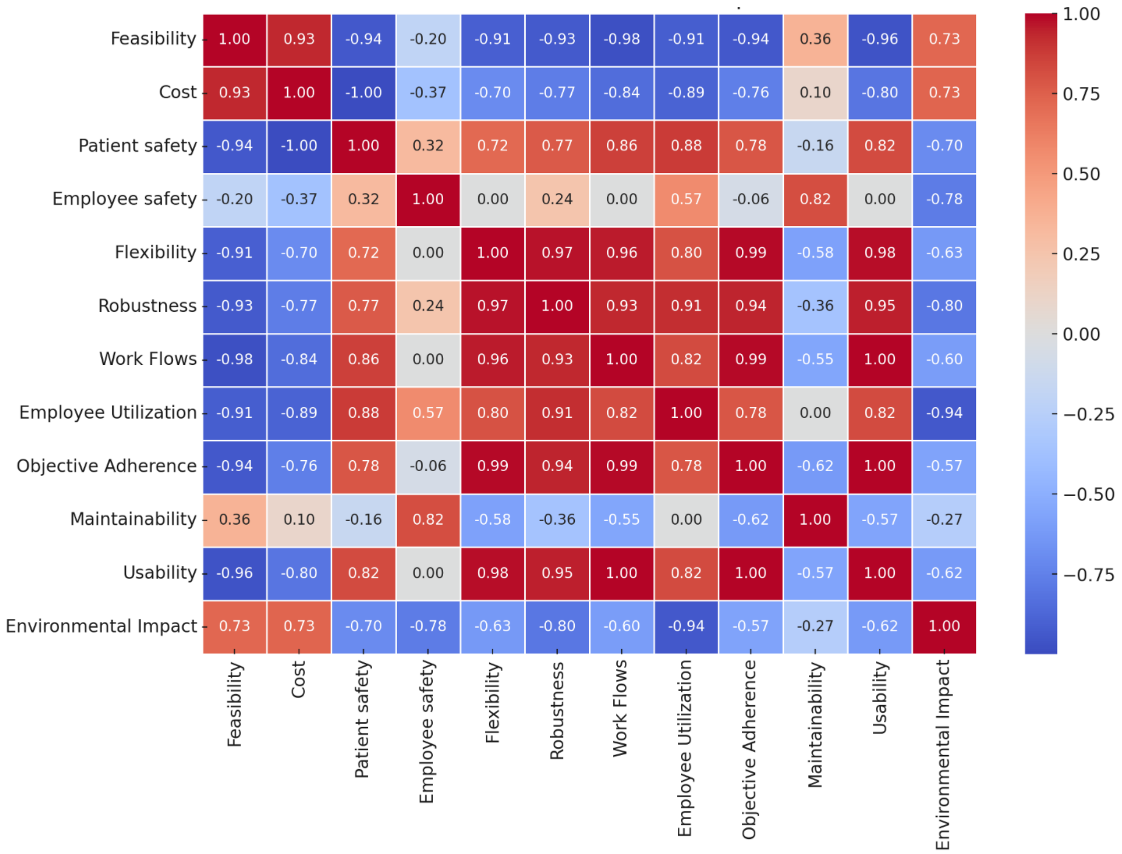

Figure 2: Correlation Matrix Heatmap (Non-Weighted Scores)

The Correlation Matrix Heatmap (Weighted Scores) in Figure 3 reveals key relationships between different design factors. Strong positive correlations are observed between feasibility and cost (0.99), employee utilization and workflows (0.98), and objective adherence and workflows (0.97), indicating that these factors increase together. Negative correlations include environmental impact and cost (-0.65), suggesting that designs with lower costs may have a higher environmental impact. Maintainability shows weak correlations (<0.2) with most factors, implying its relative independence in design considerations. The near-zero correlation between flexibility and employee safety (0.05) suggests that these attributes do not significantly influence each other. This analysis helps identify trade-offs and dependencies for optimizing design choices.

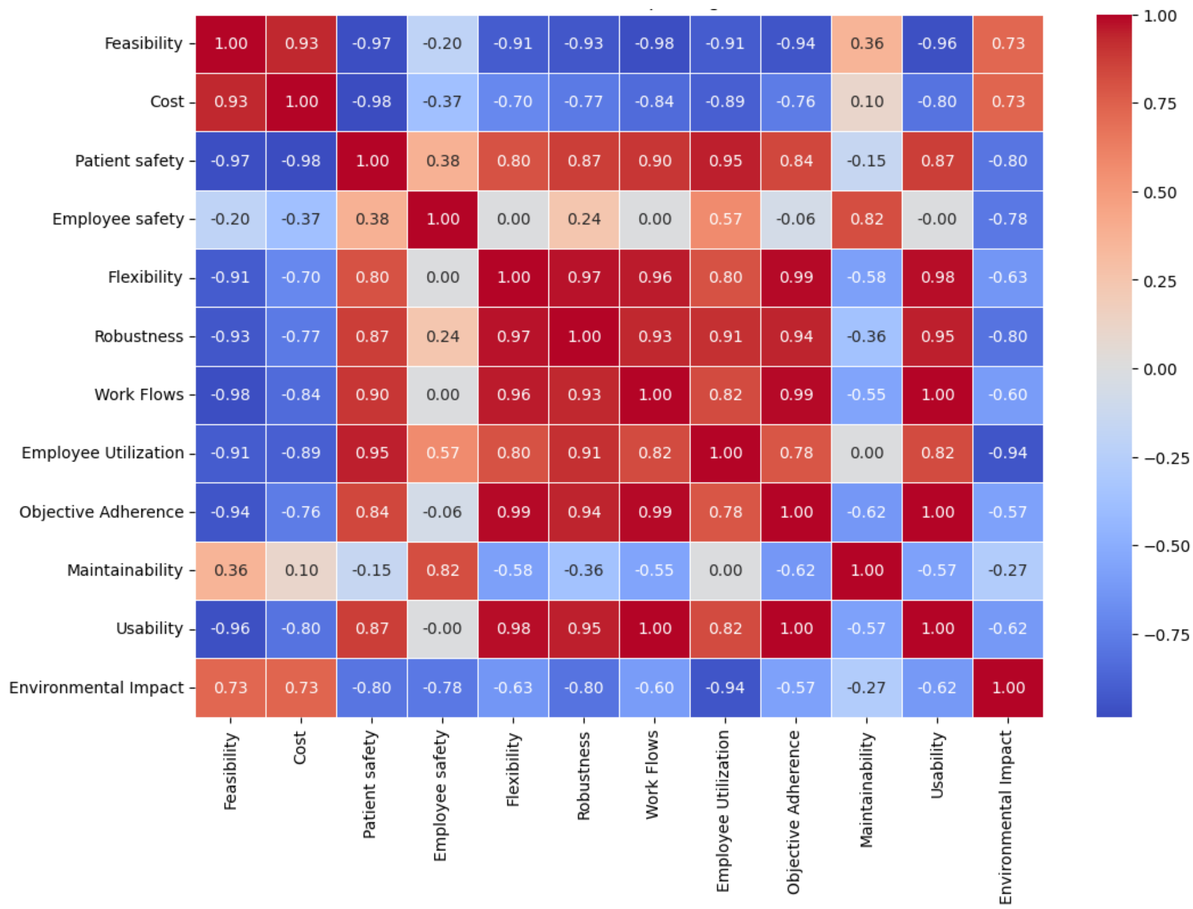

Figure 3: Correlation Matrix Heatmap (Weighted Scores)

Table 1 presents a non-weighted scoring system for evaluating different layout designs for an ART centre in healthcare facilities. It compares multiple design options (Design 1, Design 2, and Design 3) across twelve key criteria, including feasibility, cost, patient safety, and environmental impact. The original layout is also included as a baseline for comparison. By applying a weighted scoring system, decision-makers can assign importance to each criterion, resulting in a more informed and objective selection of the most suitable design.

Table 1: Design Evaluation Using Non-Weighted Scores

S.No	Category	Non–Weighted Scores			
		Original	Design 1	Design 2	Design 3
1	Feasibility	10	7	2	5
2	Cost	10	9	1	7
3	Patient safety	03	4	9	5
4	Employee safety	09	4	9	9
5	Flexibility	02	4	5	5
6	Robustness	01	4	8	8
7	Workflows	02	6	9	7
8	Employee Utilization	05	5	9	8
9	Objective Adherence	02	6	8	7
10	Maintainability	09	7	8	8
11	Usability	04	7	9	8
12	Environmental Impact	07	8	5	5

Table 2 presents a weighted scoring evaluation for selecting an optimal layout design for an ART centre in healthcare facilities. This approach ensures a more balanced decision-making process by assigning weights to criteria such as feasibility, patient safety, and environmental impact. The total weighted scores indicate that Design 3 (6.91) outperforms the other designs, suggesting that it is the most suitable option. This method effectively enhances objectivity in selecting a layout that meets operational and safety requirements.

Table 2: Design Evaluation Using Weighted Scores

S.No	Category	Weighted Scores			
		Original	Design 1	Design 2	Design 3
1	Feasibility	1.1	0.77	0.22	0.55
2	Cost	1.1	0.99	0.11	0.77
3	Patient safety	0.315	0.42	0.945	0.63
4	Employee safety	0.945	0.42	0.945	0.945
5	Flexibility	0.1	0.2	0.25	0.25
6	Robustness	0.055	0.22	0.44	0.44
7	Work Flows	0.2	0.6	0.9	0.7
8	Employee Utilization	0.5	0.5	0.9	0.8
9	Objective Adherence	0.26	0.78	1.04	0.91
10	Maintainability	0.18	0.14	0.16	0.16
11	Usability	0.38	0.665	0.855	0.76
12	Environmental Impact	0.14	0.16	0.1	0.1
13	Total	5.275	5.645	6.865	6.91

Conclusion and Future Scope

Antiretroviral Therapy (ART) centres are critical health facilities that offer holistic care to People Living with HIV (PLHIV). These centres address medical, psychological, and social issues under the National AIDS Control Organization (NACO) standards. The ART centre's operational workflow, from patient registration to clinic exit, must maintain effectiveness and efficiency while ensuring privacy and operational productivity. The first ART centre, operational since 2008, featured several non-compliant aspects with NACO's 2012 standards, such as poor ventilation and low sanitation standards. This study aims to redesign and upgrade the ART centre layout by applying a weighted scoring method to address inefficiencies such as overcrowding, insufficient ventilation, and unsatisfactory sanitation.

The proposed layouts were assessed through established benchmarks on priority measures such as patient safety (15%), workflow efficiency (12%), and environmental sustainability (10%). The initial layout had all consultation rooms sequentially arranged along the corridor to improve patient flow. The second design included private counseling areas and directed patient movement to enhance privacy and infection control. The third layout focused on positioning staff workstations, improving ventilation, hygiene, and addressing operational concerns, such as medication storage security.

Improved layouts decreased congestion by 30–40%, while optimized ventilation and medication storage achieved an 82% weighted score. Future work should explore the addition of Internet of Things (IoT)-enabled crowd monitoring systems and Artificial Intelligence (AI) simulations for real-time layout optimization. Extending this framework to multi-specialty HIV clinics and emergency response units for pandemic scenarios could improve infrastructure and enhance sustainability in line with global health initiatives. Longitudinal studies evaluating the health outcome impacts of redesigns on retention rates would help validate the effects.

While the proposed design model offers a well-structured approach, it may have limited scalability because it was developed for the specific conditions of a single facility. ART centres with different space availability, older buildings, or higher patient volumes may require customized adjustments. Although the framework is robust, applying it to other settings would necessitate adjustments to both the criteria weights and certain design features to meet local requirements.

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Declarations of competing interest

No potential competing interest was reported by the authors.

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