International Journal of Engineering Research and Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 21, Issue 8 (August 2025), PP 36-42

Foldable Self-Sterilizing Hospital Bench: A Space-Saving and Hygienic Solution for Modern Healthcare Infrastructure

Nafiz Sakeer K. P [1], Mr. Lohit H. S [2]
[1] *M.Des Product Design, Faculty of Art and Design,*
[2] *Assistant Professor, Faculty of Art and Design,*
M.S. Ramaiah University of Applied Sciences, Bengaluru – 560 058, INDIA

ABSTRACT
Hospital seating in outpatient departments and waiting areas is often overlooked in design, despite high usage and hygiene concerns. While innovations have advanced in ICU equipment and diagnostics, shared furniture remains outdated. This paper presents the design of a foldable, self-sterilizing hospital bench that improves infection control and space utilization. Developed through ethnographic research and hospital surveys, the bench features UV or spray-based disinfection after each use and folds to reduce its footprint by nearly 50%. Constructed with antimicrobial materials, it ensures durability and easy maintenance. A functional prototype was tested with real users, demonstrating its cost-effectiveness and suitability for both urban and rural healthcare settings.

IndexTerms – *Healthcare furniture design, hospital seating, foldable bench, disinfection, patient hygiene, ergonomic design, space-saving solutions, automated sterilization, antimicrobial fabric.*

Date of Submission: 27-07-2025 Date of acceptance: 05-08-2025

I. INTRODUCTION

Hospitals are designed as healing environments, yet many aspects of their physical infrastructure do not support the very goals they are meant to achieve. Shared seating—especially in outpatient and emergency areas—is often fixed, rarely disinfected between uses, and built with cold, non-ergonomic materials like stainless steel or moulded plastic. In most Indian public hospitals, such benches are bolted to the ground, making floor cleaning difficult and leading to dust, hair, and medical waste accumulating underneath. Patients, already vulnerable, are forced to sit on these surfaces without assurance of cleanliness, while sanitation workers struggle to maintain hygiene in tight spaces. Figure 1 shows the needs for hospital benches with disinfecting features.

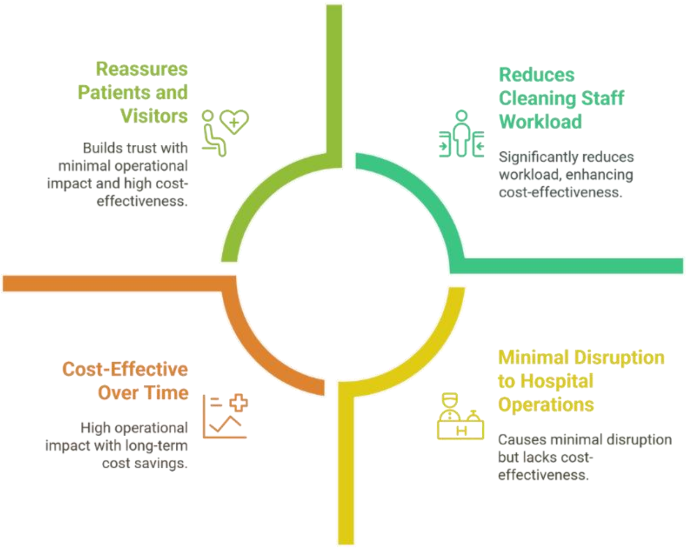

Figure 1: Need for Hospital Benches

The COVID-19 pandemic dramatically reshaped the conversation around hygiene, especially in public and semi-public spaces like hospitals. The transmission risks associated with frequently touched surfaces led to rapid adoption of contactless systems in diagnostics and sanitation, but seating remained an untouched category. There exists an urgent need to revisit this everyday object through the lens of infection prevention and hospital workflow optimization.

This paper details the creation of a foldable hospital bench integrated with a self-sterilization system—a design that allows hospitals to improve hygiene standards while also reclaiming physical space. Unlike traditional benches, this seating solution actively disinfects itself between users and folds upward when not in use, enabling easier floor access and dynamic space management. The product was developed as part of a postgraduate design thesis, combining ethnographic research, iterative prototyping, material testing, and electronic integration.

II. RESEARCH AND CONTEXTUAL STUDY

The initial stage of the project involved an extensive literature review to understand the state of hospital seating, standards for space allocation, and disinfection technologies. Sources included WHO's infection control frameworks, NABH guidelines for hospital infrastructure, and Indian anthropometric design standards. These frameworks shaped the performance goals of the product: compactness, comfort, and hygiene assurance.

Simultaneously, field research was conducted across a diverse set of hospitals, ranging from government-run facilities like SSM and NRR to larger private institutions such as Ramaiah and Prakriya. The aim was to observe real-time user behavior, understand hospital cleaning practices, and identify practical constraints on the ground. Sanitation workers shared their difficulties in cleaning under and around fixed benches. Nurses and administrators pointed out how seating is often overlooked during procurement, leading to hygiene gaps.

Patients provided some of the most critical insights. Complaints included discomfort due to cold, slippery steel surfaces; overcrowding during peak OPD hours; and a general lack of trust in the cleanliness of shared spaces. In one interview, a patient named Rilwan pointed out how leather seats make patients sweat in humid weather, while steel seats feel unstable and unhygienic. Another patient, Arman, remarked that when paying ₹1500 for consultation, a comfortable and clean place to wait shouldn't feel like a luxury.

A Google Form survey further validated these insights with quantitative data: over 90% of respondents felt current hospital seating was uncomfortable and rarely cleaned, while 76% supported the idea of self-sanitizing benches. Importantly, more than two-thirds indicated that a price range of ₹15,000–₹25,000 would be acceptable if the seating significantly improved hygiene and comfort.

This comprehensive research phase made it clear that there is both a functional gap and an emotional disconnect between users and current seating infrastructure in hospitals. It established the need for a solution that blends infection control, space economy, user comfort, and cost-efficiency.

III. DESIGN DEVELOPMENT AND CONCEPT EVALUATION

The design development phase of this project was shaped by empathy, observation, and the practical realities of Indian hospital infrastructure. As the research data accumulated from field visits, interviews, and user surveys, it became evident that the hospital bench was not just an object of convenience, but a point of discomfort, infection risk, and operational inefficiency. It was clear that the seating commonly found in outpatient departments and corridors — rigid, fixed to the floor, often made from cold steel or uncoated plastic — failed to reflect the human-centered care ethos hospitals aim to provide.

Table 1: Methodology

Objective	Approach/Methodology
Literature Review	Collection of articles, journals, standards (WHO, NABH), and case studies of hospital furniture innovations
User Understanding	Ethnographic study, field visits, user interviews, Google Forms surveys
Concept Development	Brainstorming, sketching, rough prototyping, peer and mentor review
CAD Modelling	Fusion 360 / SolidWorks for 3D visualization, joint simulation, and ergonomic validation
Mechanism Design	Selection of suitable hinges, folding structures, and sterilization modules based on space and safety
Fabrication	Material selection, laser cutting, welding, circuit integration for disinfection
Testing & Feedback	Testing with users and professionals, feedback incorporation, refinement of design

Design began with framing the problem not just in terms of utility, but also in terms of public health and emotional perception. There was a need to offer patients and staff reassurance in hygiene, improve access for cleaning personnel, and utilize space more efficiently, especially in congested or high-footfall hospital corridors. These insights became the foundation for the design objectives: improve hygiene through built-in sterilization, optimize space through a folding mechanism, ensure ease of cleaning, deliver patient comfort, and achieve feasibility in cost and production.

To transform these goals into tangible concepts, the ideation process included hand sketches, quick mockups, and digital models. A wide range of ideas emerged, ranging from simple interventions like clip-on sanitizer holders and antimicrobial cushion overlays, to more complex, technology-integrated models with programmable disinfection cycles. Through iterative refinement and peer reviews, five core concepts were shortlisted. Each concept took a different approach to balancing form, function, and innovation. One concept used a slim vertical headrest with a minimalistic sanitizing spray, prioritizing simplicity. Another offered wider seats and contoured backrests to enhance comfort for long waiting durations. A third introduced under-seat storage compartments, useful in outpatient clinics where patients may carry personal medical documents. A fourth concept embraced futuristic geometry, with angular legs and seamless backrests, aiming for a premium, visually striking presence in private hospitals. The fifth concept, however, presented the most compelling balance of all: a foldable seating structure paired with an integrated disinfection system.

This fifth concept stood out due to its alignment with multiple stakeholder needs. The foldable seat addressed both cleaning and space limitations — by folding upwards, it gave cleaning staff full access to the floor below, while also reducing bench depth by nearly 50% when not in use. The built-in disinfection system, activated automatically after a person vacated the seat, added a visible and functional layer of hygiene assurance. Visually, it maintained a clean, modern profile that could blend into both public and private settings. From a mechanical standpoint, it was feasible to produce with standard acrylic panels, off-the-shelf servo motors, and programmable microcontrollers. And economically, it promised to stay within a production cost similar to or even lower than many existing hospital benches, which offered none of its added features.

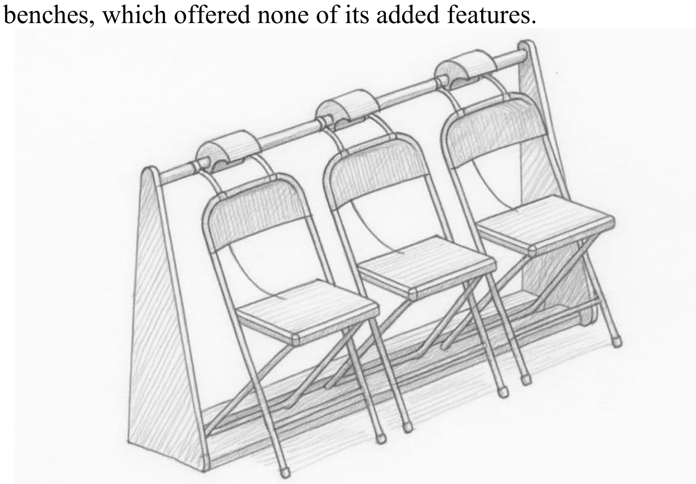

Figure 2: Selected Concept

To support decision-making, a detailed comparative evaluation was performed using a Pugh matrix. Each concept was scored against fixed parameters like compactness, cost, visual appeal, eco-friendliness, and ease of prototyping. The foldable concept scored the highest overall, outperforming the others in space-saving capability and mechanical simplicity. Although the ergonomic and aesthetic-focused concepts had certain strengths, they were less aligned with the immediate needs expressed by hospital staff and patients in interviews. Ease of implementation was a major consideration, especially in resource-constrained environments where maintenance capacity is limited.

Figure 3: 3D Model

The foldable self-sterilizing bench, therefore, emerged as the final design direction. It captured the essential aspects of safety, spatial intelligence, and patient-centricity. The concept was refined through CAD modeling and ergonomic mapping, considering user anthropometrics based on Indian population data. The mechanism of folding was adjusted to operate smoothly and safely, while the electronic disinfection unit was calibrated to cover all seating surfaces efficiently. Every detail — from material textures to visual signals — was approached with the question: how can this bench silently communicate hygiene, care, and trust?

The evolution from sketch to final concept was driven not just by innovation, but by the emotional and practical needs of people who use hospitals every day — patients looking for comfort, staff struggling to maintain cleanliness, and administrators tasked with balancing budgets and expectations. This phase of the project confirmed that truly meaningful design emerges when empathy meets function, and when each component is justified not by aesthetics alone, but by impact.

IV. PRODUCT DESIGN AND DEVELOPMENT

The prototyping and fabrication phase represented the physical manifestation of months of research, concept refinement, and design development. It was the stage where ideas were tested not just for function, but for feel, feasibility, integration, and real-world impact. The goal was to produce a working, presentable prototype of the foldable self-sterilizing hospital bench that embodied all critical features — compactness, comfort, hygiene, and reliability — within the constraints of available tools, materials, and time.

The process began by sourcing a commercial hospital bench similar in size and frame to what is commonly used in public hospitals across India. This bench served as both a point of reference and a base for reverse engineering. It was dismantled carefully to study the joinery, support structures, and load-bearing elements, which informed the dimensions and folding angles of the new design. Observing how traditional benches were welded and fixed, it became clear that modularity and detachability were necessary for future maintenance and upgradability — guiding the choice of fasteners over permanent fixtures.

Figure 4: Rendered Image

Parallel to mechanical disassembly, the structural parts of the new design were planned and cut from acrylic sheets, chosen for their lightweight nature, easy workability, and clean aesthetics. These sheets were laser cut using pre-rendered CAD files to precise dimensions, forming the side panels and folding brackets. Acrylic offered a smooth, medical-grade finish that was easy to sanitize and aesthetically aligned with clinical environments. Post-cutting, the edges were flame-polished and smoothed to remove burrs, ensuring both safety and visual appeal.

Simultaneously, material selection for the seat cushioning and upholstery was underway. Based on user feedback, it was clear that traditional steel or leather seating caused sweating, discomfort, and even slipping — especially among elderly patients. To solve this, a layered cushion system was developed using a combination of natural coir and polyurethane sponge. Coir provided breathability, firmness, and eco-consciousness, while sponge contributed softness and resilience. This combination allowed the seat to support various body types while maintaining hygiene and airflow.

The outer fabric chosen for the seat was sourced specifically for its ability to handle hospital-grade sanitation. A poly-viscose blend was selected and subjected to chemical finishing, imparting antibacterial, water-repellent, and odor-resistant properties. This fabric was then sent to Intratek Testing Facility, where its antimicrobial performance and durability were validated under laboratory conditions. Once cleared, the fabric was used to stitch the seat cover, which was tailored to fit tightly around the cushion unit. The cushion was then adhered to a laser-cut seat board and fixed onto the folding frame.

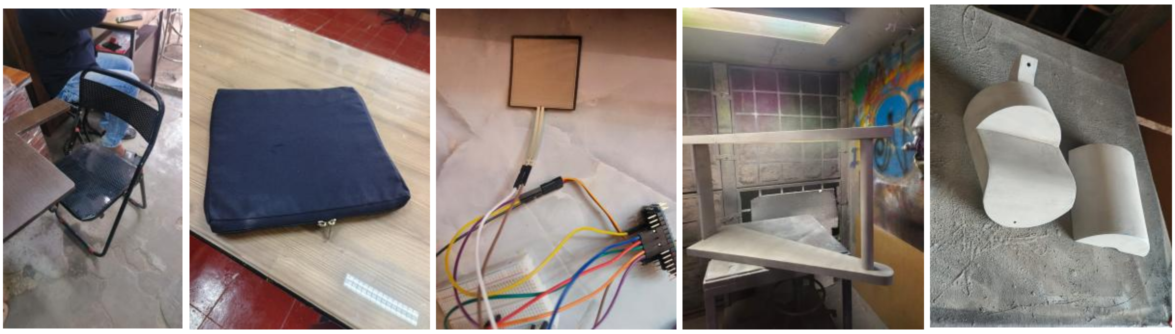

Figure 5: Prototyping Stage

With the physical components taking shape, focus shifted to the electronic system integration. The sterilization mechanism revolved around a pressure sensor (FSR) embedded beneath the seat surface. When a user sat down, the sensor detected weight and remained inactive. Upon user departure, the sensor triggered a relay circuit connected to a servo motor, which in turn actuated a mini diaphragm pump connected to a disinfectant spray bottle. This sequence created a fully automated, contactless sterilization cycle, activated after each use.

The electronics were housed in a custom acrylic casing, which was shaped, sanded, and painted to match the bench's aesthetic and protect the circuitry. Indicator LEDs were installed to signal seat readiness: red during sterilization and green once the bench was safe for use again. Wiring was neatly routed through the structural panels to maintain a clean appearance and ensure patient safety.

Once all modules — structural, cushioning, electronic — were ready, the final assembly began. Acrylic panels were joined using high-strength adhesives and stainless-steel screws to ensure both durability and removability. The folding mechanism was tested repeatedly to refine the pivot resistance and locking positions, ensuring that the seat stayed firmly in place both while folded and when open. Spray coverage was tested using colored water to verify that all seating areas received disinfectant. The bench underwent multiple cycles of occupancy, disinfection, folding, and unfolding to validate endurance and response time.

Additional touches included putty and surface finishing over joints, final spray painting in a medical off-white palette, and tightening of all mechanical fasteners. The bench was then cleaned and presented in a near-marketable condition, ready for field demonstration and user trials.

Through this entire process, the importance of hands-on problem-solving became evident. The transition from concept to prototype brought out challenges not always visible in CAD models — like wiring management, spray angle optimization, and user safety around moving parts. Each problem required iterative fixes, material adjustments, and design tweaks, culminating in a prototype that not only demonstrated the intended functionality but also reflected the rigor and depth of the design thinking behind it.

This prototype stands as a proof of concept, one that blends practicality with empathy, and technology with simplicity — showing how even a single bench, when redesigned thoughtfully, can contribute to the future of safer, smarter healthcare infrastructure.

Figure 6: Final Product

V. VALIDATION AND TESTING

The prototype was presented to key stakeholders including administrators, doctors, and patients for real-time interaction and review. Dr. Madan, administrator at Ramaiah Hospital, remarked that the current benches cost ₹20,000 but lack any self-cleaning feature or durability guarantee. He noted that if this bench could be offered even slightly above that cost, it would be a justified investment.

Dr. Iqbal from a government mission hospital suggested submitting the project under the Startup Kerala Mission, citing its relevance in the post-pandemic healthcare infrastructure. Other users like Bhaskar (SSM Hospital) and Dr. Ajay (planning a new facility) saw the product as both a practical tool and a marketing statement, projecting hospitals as more patient-friendly and hygiene-conscious.

Feedback from patients was equally supportive. They appreciated the idea of a seat that visibly sterilizes itself, making them feel safer and more respected. Sanitation workers were particularly pleased with the folding function, which made floor access easier, reducing cleaning time and physical strain.

VI. CONCLUSION

The Foldable Self-Sterilizing Hospital Bench successfully addresses multiple challenges present in conventional hospital seating. By integrating folding architecture with a sterilization mechanism, it solves for both space and hygiene—two crucial parameters in high-traffic healthcare environments. Its ergonomic design, user-centered features, and affordable prototyping make it a strong candidate for mass implementation across public and private hospitals.

Future work could explore touchless activation systems, mobile app-based control for IoT integration, solar charging for remote areas, and customization of size and color schemes based on hospital branding. Partnerships with health tech startups, government missions like Ayushman Bharat and KSUM, and corporate CSR initiatives could help scale the product across India's tier 2 and 3 cities where such solutions are most needed.

In conclusion, this project demonstrates the transformative power of context-driven design in healthcare. It shows how small innovations—when grounded in real user needs—can make a big impact on patient dignity, staff efficiency, and public health outcomes

REFERENCES

[1]. Chakrabarti, D. (1997). Indian Anthropometric Dimensions for Ergonomic Design Practice. National Institute of Design, Ahmedabad.

[2]. World Health Organization (WHO). (2020). Infection prevention and control during health care when COVID-19 is suspected: Interim guidance. Retrieved from: https://www.who.int/

[3]. National Accreditation Board for Hospitals & Healthcare Providers (NABH). (2022). Guidelines for Hospital Infrastructure and Infection Control Standards. Quality Council of India.

[4]. Intratek Testing Services Pvt. Ltd. (2024). Antimicrobial Testing Report on Chemically Treated Fabric for Hospital Bench Upholstery (Internal Report – Bengaluru, India).

[5]. Government of India – Ministry of Health and Family Welfare. (2021). Swachh Hospital Initiative: Guidelines on Cleanliness, Hygiene and Infection Control.

[6]. Rao, M., & Ramamurthy, S. (2021). Design Interventions in Indian Public Healthcare Infrastructure. International Journal of Design Studies, 9(2), 33–45.

[7]. Personal interviews conducted with medical professionals, patients, and administrative staff (Dr. Iqbal, Dr. Ajay, Dr. Madan, Dr. Jagdish, Mr. Bhaskar, and others) across SSM, NRR, Ramaiah, Prakriya, and Saptagiri Hospitals between March–June 2025.

[8]. Google Form Survey. (2025). Self-Sterilizing Bench User Feedback Survey. Conducted with 70+ respondents including patients, caregivers, and hospital staff. Raw data archived by the author.
[9]. Arduino.cc. (2023). Servo Motor and Relay Integration for Disinfection Systems. Open-source documentation retrieved from https://www.arduino.cc/en/Tutorial/HomePage
[10]. Design History Society. (2022). Designing for Dignity in Health and Public Infrastructure. Proceedings of the DHS Conference, Lisbon.