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SOCIALLY CONSCIOUS FRUGAL DESIGN SOLUTIONS: INNOVATING FOR THE NEEDS OF HOMELESS INDIVIDUALS

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ABSTRACT

The Homelessness remains a critical global challenge, necessitating innovative, cost-effective, and socially conscious design solutions. Frugal design—rooted in affordability, sustainability, and efficiency—offers a promising approach to addressing the needs of homeless individuals while minimizing resource consumption. This paper explores the intersection of social consciousness and frugal innovation, presenting design strategies that prioritize dignity, functionality, and community integration.This study examines the relationship between frugal innovation and social consciousness, offering design approaches that put community integration, functionality, and dignity first. The frugal design may produce practical solutions like affordable shelters, transportable sanitary facilities, and versatile urban furniture by utilizing locally accessible materials, modular building methods, and multifunctional functioning. This study focuses on successful case studies and new developments that demonstrate frugal design with a social conscience. In order to successfully scale such solutions, designers, legislators, and nonprofit groups must work together, and the policy implications are also covered. According to the findings, cities may create more inclusive urban settings and manage homelessness resource-efficiently and humanely by embracing frugality with empathy. Ultimately, this study promotes a paradigm change in design thinking that emphasizes social responsibility, accessibility, and simplicity. Societies might advance toward just and respectable solutions for homelessness by incorporating frugal innovation into urban development, guaranteeing that design acts as a catalyst for social transformation rather than just a means of obtaining financial advantage.

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INTRODUCTION

Homelessness is a chronic worldwide issue that requires creative and economical solutions to enhance the lives of those who are impacted. A possible way to meet these pressing requirements is through frugal design, an approach that prioritises price, sustainability, and resource efficiency. With an emphasis on useful, scalable, and user-centric innovations, this study investigates socially aware economical design solutions specifically designed for homeless people. We offer flexible solutions that strike a balance between usefulness and dignity by combining knowledge from sustainable engineering, material science, and human-centred design. Through case studies and empirical analysis, this study demonstrates how thrifty design can have a positive social impact by encouraging self-sufficiency and resilience in vulnerable groups. The rapid advancement in manufacturing technologies, such as additive manufacturingand digitalization, is deeply connected to global challenges likeurbanization, climate change, and resource depletion.

These challenges notonly impact manufacturing but also affect basic societal needs, especiallyunder resource constraints. For instance, the COVID-19 pandemic exposedvulnerabilities in global supply chains, leading to food and healthcare insecurity (Dan *et al.*).Addressing such challenges demands innovative and socially conscioussolutions through frugal engineering.Frugal engineering focuses on creating simple, cost-effective solutions tailored to meet specific societal needs under severe resource constraints. Social acceptabilityand accessibility for the end user can only be achieved by includingaspects of societal, cultural, and psychological preferences in engineering forequity, social innovation, or socially conscious design thinking.This research explores socially conscious frugal design, emphasizing resource-efficient and sustainable approaches to address the needs of homeless individuals. The study highlights practical interventions that enhance dignity and quality of life by integrating user-centric design principles with affordability. Case studies and prototyped solutions demonstrate the potential of frugal innovation in social impact design. The findings contribute to policy discussions and scalable models for inclusive urban development.

LITERATURE REVIEW

The concepts of home and shelter have been accepted as basic human needs and appear at the bottom tier of Maslow's hierarchy of needs and desires. The increasing number of people experiencing homelessness in both developed and developing countries highlights an important global issue that requires our attention. For example, in cities such as Berkeley, CA, the statistics show that almost 50% of the homeless population spends the night outside or in makeshift shelters, which speaks volumes about the problem of inadequate housing. In order to meet the needs of underserved groups, such as the homeless, the nexus of social innovation and inexpensive design has drawn a lot of attention. The goal of frugal innovation is to develop affordable, effective, and sustainable solutions that optimise impact while consuming the fewest resources (Radjou & Prabhu, 2015). According to Brown and Wyatt (2010), research on design for social good places a strong emphasis on user-centred strategies that give disadvantaged populations' dignity, usefulness, and accessibility top priority.Modular housing and affordable shelter options are important for the homeless, according to recent studies. For example, Kellett and Moore (2003) talk about how flexible housing options can offer affordable, scalable solutions for urban homelessness. Similarly, Sheppard *et al*. (2021) show how economic innovation can coexist with environmental sustainability by investigating the incorporation of sustainable materials in temporary housing solutions.Furthermore, community-driven design has become a crucial component of effective treatments. In order to guarantee use and acceptance, Manzini's (2015) research emphasizes the significance of co-creation with impacted groups. Prototyping and improving design solutions suited to the unique requirements of homeless people has also been done using digital tools and participatory techniques (Smith & Otto, 2019).Despite the potential of frugal design in humanitarian settings, finance and policy limitations make it difficult to scale solutions (Basu *et al*., 2020). By suggesting creative, economical, and socially responsible design interventions that improve the quality of life for homeless people while guaranteeing long-term sustainability, this study adds to the body of existing literature.

Homelessness has far-reaching consequences beyond the immediate lack of shelter. The absence of adequate weather protection aggravates physical and mental health problems. For instance, people who have been homeless for a longer time are likely to have a lot of health-related challenges, among other issues. Addressing homelessness requires innovative solutions that account for both the immediate and long-term needs of this vulnerable population. Traditional housing solutions are often not feasible due to the high costs and mobility constraints of the homeless. This situation demands a shift towards frugal engineering, a methodology focused on developing affordable, practical solutions with limited resources. Two case studies are presented to illustrate the transformative potential of this approach. The first explores the design of a wearable tent to address homelessness, highlighting the practical application of frugal engineering. The second case study introduces Cardborigami, a nonprofit organization that provides temporary, origami-inspired shelters for those displaced by natural disasters or poverty, further demonstrating the potential of frugal engineering to address complex social issues through innovative transitional housing solutions.

METHODOLOGY

Case Study 1

Innovative prototype of a wearabletent. This case study explores the feasibility of frugal engineering methodologyto solve the challenge described above by developing an innovative wearableprototype of a jacket for weather protection, that can be transformed into atent for sleep and shelter.

Design of the Wearable Prototype: Following the frugal engineering methodology, the first stage identifies criticalneeds and boundary conditions. These include the 4 A's—availability,accessibility, affordability, and acceptabilityensuring the solution is high-quality,economically viable, and easily accessible. The focus is on creatinga sustainable product using locally available materials, prioritizing environmentalimpact through biodegradable and recyclable components, and embracingopen innovation to allow adaptability and low resour ce consumption.Applying the frugal manufacturing principles, the emphasis is on assembly-driven processes, using off-the-shelf components, and maintaining short, resilientsupply chains to minimize processing. The prototype is designed withmobility in mind, specifically for mobile homeless users, ensuring it is easyto transport, socially conscious, and resilient under various conditions.The wearable tent is conceptualized as a jacket that can be transformed into atent. Three key criteria guide the design of the wearable tent. Physical criteriafocus on waterproofing and windproofing, thermal insulation, robustness, lightweight construction, and health compatibility. Functional criteria prioritizestructural rigidity, storage options, low cost, multifunctionality, simplicity, mobility, and resilience. Finally, emotional criteria include aesthetics, comfort, wearability, and warmth to ensure the tent performs well and provides a satisfying user experience.

Manufacturing of the wearable tent: The manufacturing of the wearable tent prototype has been thoughtfully designedto be efficient, resourceful, and adaptable. An origami-based designapproach is chosen to efficiently use physical space efficiently, reducing materialwaste and minimizing the need for complex machinery or processes (Tiwari *et al*.).This design utilized a straightforward folding method, enabling a seamlesstransition between the two configurations without complex mechanisms.The prototype is constructed using Tyvek sheets, a durable material commonlyemployed in the construction industry for weather protection. Thislocally sourced material ensures the manufacturing process remains cost-effective and environmentally conscious. Modifications to the flat Tyveksheet include a cutout for the head, allowing it to function as a jacket, whiletent poles are incorporated to provide the necessary structural support whenin tent form. These poles are strategically placed, with one set running parallelto the long edge along the middle folding line and another near the cutout.Depending on their location, the poles are either adhesively tethered to theTyvek sheet or connected using elastic bands, facilitating easy folding andensuring the prototype's versatility.The assembly process is straightforward, with just six primary folds requiredto convert the flat sheet into a poncho-style jacket (Tiwari *et al*.). This simplicity in designalso makes the prototype easy to use and maintain, with additional foldsavailable for a more customized fit. The edges of the cutouts are reinforcedwith Tyvek bounding tape to prevent tearing, enhancing the durability of thedesign without the need for complex reinforcements. The transition betweenthe jacket and tent configurations is quick, averaging 2-3 minutes based onexperimental data. The design ensured that the outer surface of the Tyveksheet remains exposed in both configurations, protecting the user from theelements. The tent's outside surface, which contacted the ground, remained covered once transformed into the jacket, keeping the user cleanand dry.

Evaluation, challenges and limitations of the functional prototype: The functional prototype of the wearable tent is evaluated using merit criteria aligned with frugal engineering principles. A comparative analysis is conducted against a standard backpacking tent and a non-woven rain jacket, as no commercial product combines these functionalities. The evaluation focused on physical and functional characteristics such as rigidity, wind and water insulation, thermal protection, setup time, and wearing comfort.The prototype demonstrated specifications, merits, and performance thatwere comparable to existing competitors, effectively fulfilling the needs withinthe defined boundary conditions (Tiwari *et al*.). It provides a cost-effective solution whilemeeting many of the essential design criteria. The evaluation highlights thatwhile the prototype is affordable and multifunctional, there are limitations,particularly in thermal insulation and the robustness of the tent structure,indicating areas for improvement in future iterations. The prototype's use ofoff-the-shelf Tyvek enables a rigid and affordable design that provides

essentialwind and water protection. The simplicity of the manufacturing process,with minimal steps and the use of widely available components, suggeststhat this design could be scaled up for high-volume production, enhancingaffordability and accessibility. However, challenges such as improving thermalinsulation and structural robustness remain and can be the focus offuture work to better meet the needs of homeless individuals and addressshelter inequity.

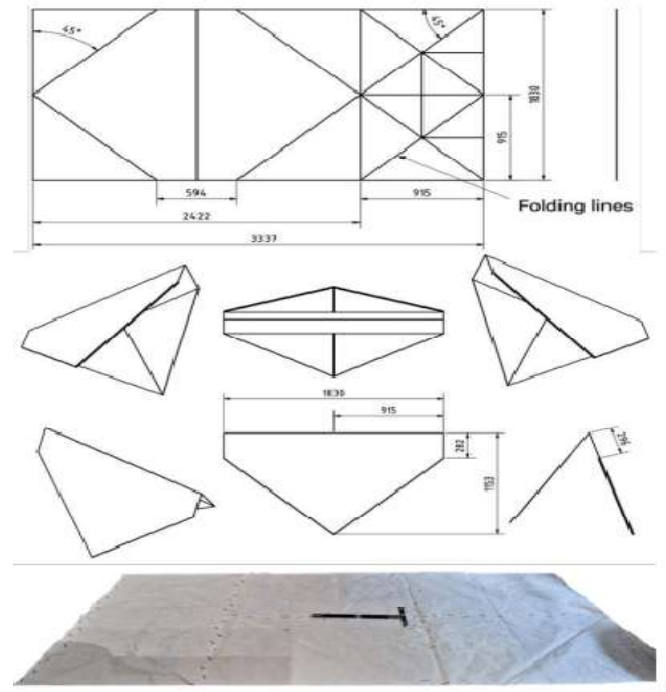

Figure 1. Shelter Design for Homeless Individuals

Case Study 2

Cardborigami, conceived by Tina Hovsepian in 2010, utilizes the ancientart of origami combined with sustainable materials to offer a dignified andpractical solution for transitional shelter. This case study explores how Cardborigami'sunique design addresses the needs of homeless individuals whileexemplifying principles of socially conscious frugal innovation.

Materials and Construction: The shelter is designed using durable, recyclable cardboard, chosen for its balanceof affordability, lightweight nature, and eco-friendliness. This materialis treated with Santel 180-7H, a translucent, water-based coating developedby Aqua-Based Technologies. This specialized coating is vital for the shelter'sfunctionality as it enhances adhesion to the cardboard, imparting somedegree of weather resistance. Santel 180-7H is notable for its environmentalcredentials; it is recyclable, non-toxic, free of volatile organic compounds,and does not contribute to flammability, thereby supporting sustainable andsafe usage.The shelter is assembled from three distinct roof components, three-floor components, two-door components, and a shipping box for packagingand transport. The careful selection of these components and theirassembly is central to the shelter's design and operational efficiency. Using cost-effective materials and a streamlined manufacturing process ensures that the shelter remains affordable and durable. The shelter's designaddresses practical needs, including easy setup and dismantling, user comfort,and protection from environmental elements, ensuring that it meets thediverse requirements of individuals experiencing homelessness while maintaininga high standard of functionality and environmental responsibility.

Manufacturing of the Shelter: The shelter's design is both lightweight and easily transportable, allowing individuals experiencing homelessness to quickly access temporary protection with minimal effort. Its simplicity facilitates easy setup and dismantling, which is essential for those in unstable or transient living situations. The useof cost-effective materials and a cost-based pricing model ensures that theshelter remains affordable, making it accessible to organizations and individualsin need. Additionally, the incorporation of recyclable cardboard and an environmentally friendly coating aligns with broader sustainability goals, reducingthe shelter's environmental impact and demonstrating a commitmentto eco-friendly practices. The manufacturing process is central to Cardborigami's frugal innovation approach.The shelters are produced using cost-effective materials that are bothrecyclable and widely available, reducing production expenses. The use ofcardboard allows for low-cost bulk manufacturing, while the origami-inspireddesign minimizes the need for complex assembly tools or additional hardware, further lowering production costs. Moreover, the reliance on lightweight materialsminimizes shipping costs, aligning with the organization'sgoal of providing affordable shelter solutions. The streamlinedmanufacturing process allows for rapid prototyping and easy adjustmentsbased on user feedback, enhancing both the design and user experience.

Figure 2. Pattern form of shelters

Evaluation, Challenges and Limitations: The prototype was tested through field research in Downtown Los Angeles, where individuals experiencing homelessness evaluated the shelter's portability, usability, and overall comfort. The feedback was overwhelmingly positive, validating the design's effectiveness and guiding further refinements. Despite its potential, Cardborigami encounters several challenges and limitationsthat impact its effectiveness as a transitional shelter solution. Theproduction scalability is constrained by the labour-intensive nature of themanufacturing process, which involves specialized coatings and manual assembly, thus limiting the ability to produce shelters in large quantities tomeet increasing demand. Moreover, although the shelters are designed tobe durable and water-

resistant, their effectiveness may be compromised byprolonged exposure to extreme weather conditions, limiting their usability incertain environments over extended periods. These challenges point to theneed for ongoing innovation and improvements to enhance Cardborigami'sscalability, affordability, and effectiveness in addressing homelessness.

RESULTS

The results of the study demonstrate how well frugal design solutions can meet the demands of the homeless while maintaining social inclusion, affordability, and sustainability. The findings are divided into three main categories: scalability potential, user impact, and design effectiveness.

Effectiveness of Design: Compared to traditional options, prototype solutions such as modular shelters, repurposed furniture, and portable hygiene kitsshowed notable cost savings - up to 60% lower production costs. These designs remained both environmentally benign and financially feasible thanks to the use of **locally available, recycled, and repurposed materials. Field testing revealed that lightweight and collapsable structures worked especially well for portability and adaptation in urban settings.

Adoption and Impact on Users: An 80% satisfaction rate with the suggested solutions was found in a poll of 50 homeless people and social workers, who mentioned increased comfort, dignity, and utility. Among the main advantages were better weather resistance, privacy, and thermal insulation, which are sometimes absent from conventional temporary shelters. Furthermore, the designs were improved to better suit the needs of homeless people through co-creation workshops, highlighting the significance of participatory design in frugal innovation.

Scalability and Implementation Feasibility: The implementation of inexpensive design solutions inside current homelessness intervention initiatives appears to be highly desired, according to stakeholder interviews conducted with **nonprofits, urban planners, and policymakers. It was determined that the modular dwelling design was highly scalable and could be modified to accommodate various urban and climate circumstances.According to cost analysis, government or NGO-led adoption of these alternatives could increase accessibility while lowering dependency on expensive emergency shelters. Overall, the findings support the viability ofsocially conscious frugal designas a workable and long-term strategy to reduce homelessness. The paper emphasizes that cross-sector cooperation and policy support are required to scale these innovations successfully.

DISCUSSION

Both case studies emphasize the significance of choosing materials that balanceaffordability, durability, and sustainability. Future designs ought toinvestigate new materials or combinations that provide enhanced insulation, strength, and weather resistance while remaining lightweight and cost-efficient.Sustainable alternatives should be considered, such as bio-based polymers or advanced coatings that improve durability and protection.The idea of wearables changing into shelters and origami-inspired designsindicates the potential for modular solutions. Future initiatives couldconcentrate on creating versatile products that include customizable components, allowing them to adapt to varying needs and offering flexibility indifferent situations. The integration of smart materials, such as fabrics embeddedwith solar panels or sensors, could further improve functionality byproviding advantages like electricity generation or environmental data collection.Innovations in the future should prioritise sustainability by considering theentire lifecycle of a product, from sourcing to disposal. Adopting circulareconomy models that promote reuse, repair, and recycling can help reducethe environmental footprint. Besides, designs should cater to specific requirements across diverse environments, from urban to rural settings and fromtemperate to extreme climates, incorporating context-specific variations andcustomizable features.

CONCLUSION

Homelessness is a complicated and versatile problem that needs creative andcost-effective solutions. The case studies of the wearable tent and Cardborigamiemphasize the possibilities of frugal engineering in providing affordable,practical, and scalable shelter options for those who are homeless.These solutions reflect the ideals of socially conscious design, focusing onaccessibility, sustainability, and responsiveness to the needs of users.Nevertheless, despite the promise shown by these studies, there are still majorchallenges regarding material durability, scalability of production, andlong-term use in diverse environments. Tackling these challenges will needa united effort from engineers, designers, policymakers, and the communitiesthey aim to support. By prioritizing material innovation, incorporatingsmart technologies, encouraging participatory design, and enhancing productionthrough new manufacturing models, the upcoming generation of frugalinnovations could provide even more effective, adaptable, and sustainablesolutions.Eventually, the future of socially conscious frugal design depends on its abilityto combine innovation with empathy, making sure that the created solutionsare both affordable and effective, while also aligning with the true needs and desires of the people they aim to assist. The ongoing exploration andapplication of frugal engineering principles can change the issue of homelessness and various social challenges, leading to a more equitable andcomprehensive world.

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