Designing Affordable, Portable, and Flexible Shelter for the Homeless and the Refugees

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Advances in computational algorithmic design, material science, and fabrication technology have exposed architects to new opportunities in design and enabled them to address contemporary needs of cities and citizens. The far-reaching applications of this technology have provided students with a bewildering array of new tools for their design exploration. Among many of the socio-economic and political challenges facing today's world, homelessness and refugee crisis are the most critical. "Shape Your Shelter" design-build studio aimed to create a portable and transformable shelter using emergent technologies. This paper reviews some of the central concepts of such an endeavor and the role of computational design, digital fabrication, and material behavior as a medium of architectural design education and social services. It describes how these concepts can be used in a pedagogical framework to encourage student Innovation and increase students' engagement in new technological resources as they address critical contemporary and future social issues.

Keywords: Transformable Structures, Portable Architecture, Collaborative and Participative Design, Homeless / Refugee Shelter, CAAD Education, Social Architecture

INTRODUCTION

Amidst the development of big cities towards making better educational, residential, and social spaces, there is a lack of recognition for those who are unable to keep up with the fast pace of capitalistic life. Acknowledging the fact that a lot of people are left behind in this competition ruled by consumerist values, designers' contribution in finding ways to help those people to reunite with society is crucial. How can designers engage in social issues and explore design solutions for improving the community and society?

According to the UN High Commissioner for Refugees, in 2017, 65.6 million people were displaced worldwide because of war, persecution, conflict, violence, or human rights violations alone. Refugee livelihoods have become a crucial topic in contemporary geopolitical relations. People who have a well-founded fear of persecution cannot return home must find a way to contend with their new context. (UNHCR 2017) The 1980s and early 1990s in the United States have been characterized by multiple political and socioeconomic changes that have contributed to the "social construction of homelessness"
These factors include recessions, a shift in the labor market from industry to services, reduced social welfare, and educational programs, all of which trigger an increase in poverty. (Hopper and Hamberg 1986)

Based on the homeless world cup foundation, the last time a global survey was attempted - by the United Nations in 2005 - an estimated 100 million people were homeless worldwide. As many as 1.6 billion people lacked adequate housing. (Homeless World Cup Foundation 2018) Also, in its 2017 Annual Homeless Assessment report to Congress, the U.S. Department of Housing and Urban Development indicated that 553,742 people were experiencing homelessness in the United States. For every 10,000 people in the country, 17 were experiencing homelessness. Approximately two-thirds (65%) were staying in emergency shelters or transitional housing programs, and about one-third (35%) were in unsheltered locations. (Henry et al 2017)

Walk through the downtown core of big cities; look down the alleys, around the hidden corners, and into the dark recessed doorways and you will find people struggling to survive, simply needing a roof over their heads for the night. People who are homeless are most often unable to acquire and maintain regular, safe, secure and adequate housing. Refugees and homeless people are suffering from displacement, lack of safe and adequate housing, and extreme consequences of poverty. Current relief assistance model for refugee / homeless populations is often times the only separation between homeless people and local communities. At Washington State University, a third-year undergraduate studio explored pedagogical framework to the question of homelessness. It sought to propose spatial design and programmatic solutions to ameliorating the life of refugees and homeless people and providing opportunities for them and local communities to strengthen ties while enabling self-agency.

DESIGN CRITERIA AND SOCIAL REQUIREMENTS

Architecture is at its core, the design, and creation of shelter. A simple safe and secure place to sleep and keep belongings is critical to anyone forced to live on the streets. When disabilities put people at risk for continued or recurring homelessness, outreach and services play a crucial part in getting them into housing. For many individuals, homeless prevention is an incremental process.

A problem that exists within a multitude of conditions requires a solution that can be adapted to meet those conditions. When more permanent shelters are not available, flexible and mobile structures serve to bridge the gap that often exists between homelessness and housing assistance. Safety and stability are key elements in establishing and maintaining a path towards the rebuilding of an independent and self-supporting life. Solutions must include affordable housing, along with employment or mainstream benefits sufficient to maintain housing stability. Solutions should also focus on addressing socio-economic concerns regarding refugees and homeless people and finding ways to creatively re-knit the city and expand engagement and interaction between displaced people and their local communities. The key factor is to create shared organization and management activities that involve both refugee / homeless and local communities.

To ameliorate the housing and social engagement issue, this project focuses on designing an affordable, portable, adjustable, foldable, and self-standing home-office, using computational design methods and emergent technologies. The goal was to design a shelter that would not only provide a safe place to accommodate the basic needs of the homeless/refugees, but also one that is at once livable and playful. More importantly, it had to function as a business incubator or a pop-up shop to give a homeless the ability to become financially independent. This would lead to recovery and the regain of dignity. The pop-up shop facilitates face-to-face interactions between these people and their neigh-
bors to inspiring employment, cultural exchanges, or companion support opportunities. It would also help raise awareness of these issues in the society by facilitating gradual assimilation and building vibrant and diverse communities.

The initial cost of the shelter came at $1000, but in time and repetition, that number will decrease substantially. Financial contributions could come through NGOs, governments, UN, donor support and various philanthropic businesses. Given the clear and easy to follow assembly instruction, users can be involved in the fabrication process. This will make it more self-sustaining.

METHODOLOGY

As a design-build endeavor, this project spanned the gamut of architectural steps, from design to building a full-scale. It focused on research and precedent studies, client preferences, budgeting, creative design solutions, materials, construction, and fabrication considerations. The pedagogical framework was defined around various considerations such as architectural, structural, functional, aesthetic, social engagement, emerging technologies potentials, and collaborative construction experience.

While tackling a social obstacle, the studio sought to promote learning of new methods of design as grounded in computational design, digital fabrication, and material behavior, all aimed to enhance students’ perception of algorithms, design computation, mechanism, spatial quality, and human behavior. In order to create a collaborative studio, throughout the semester, students were grouped in teams of two, participating in design charrettes, took field trips, and presentations of design solutions. External consultations with structural engineering and material science students were conducted to enhance the design and fabrication solutions. Serving as a bridge between education, homeless community, and professional practice, this studio provided a creative academic environment punctuated by regular review sessions with industry partners, city council, and homeless representatives. To achieve the objectives of the project, this studio was divided into four phases:

**PHASE 1: FOUNDATION AND RESEARCH**

In this phase, students were introduced to their clients, context, and available literature review to explore the potentials embedded in emergent technologies. They worked collaboratively to understand the applications of flexible, portable, and multi-functional architecture and synthesize an outcome gleaned from the team’s research for designing shelters.

Students began by visiting some homeless facilities and interacting with them to understand their needs and explore the objectives of the project. After interviewing homeless people to learn about their needs, students surveyed scholarly resources on computational methods for transformable, portable, pre-fabricated, and multi-functional spaces. Students’ research investigated possibilities in computational design combined with material behavior, digital fabrication, and origami studies for designing a reconfigurable shelter. At the end of this phase, students made use of cutting-edge architectural software such as Grasshopper for design development, analysis, and making series of flexible and kinetic structures. Here students observed how the built environments could gradually morph based on various program and user’s needs. They investigated how naturally occurring transformable/flexible systems could serve as inspiration for programmable built environments. The scholarly investigation of transformable system exploration led them to find the proper system for their shelter. (Figure 1)
PHASE 2: DESIGN EXPLORATION

In this phase students learned how to design in harmony with the environment, society, and culture to improve community and society. They explored how to integrate the potentials embedded in technology-driven design to create new relationships between the built environment and tangible sites through adaptive architecture. After a comprehensive research in phase one, students individually designed 14 stackable and portable shelters to accommodate both individuals and families with respecting the following design parameters: (i) affordable- under $1,000 a unit, (ii) easily constructed and mass-produced, (iii) temporary and portable, with no foundation because of city and codes regulations (iv) protective of the occupant from the most extreme elements through all seasons, and (v) Not exceeding a 25 sqf footprint and not larger than 6’-0” in height. Students designed their shelters in three categories:

1) Shelter on Wheels: Ability for direct attachment to a bicycle frame, shopping cart, or other forms of transportation.

2) Live-Work-Play Shelter: Giving a homeless person the ability to become financially independent.

3) Shared Shelter: Capability to accommodate 2-3 people. In some cases, cities face homeless/refugees’ families with children. This design option requires the ability to ‘stack’ and expand. (Figure 2)

One student’s project was selected at the end of this phase for full-scale fabrication and exhibition in the AIA Spokane Award Show. This project was collaboratively built in full scale and tested by a homeless volunteer during the summer. The following examples highlight design solutions created by the students focused on different aspects of adaptive design with the creative and innovative use of emerging technologies.

THE LIFE OF A MODERN NOMAD

The project is inspired by early African nomadic architecture and sphere structure was chosen as an optimal solution for not needing inner supports and resistance to environmental loads. The structure is made of five inflatable rings, the middle one being connected to a base. The rings can be deflated to allow the unit to be transportable. The rings sit flat on the ground and are connected to a movable base supported by scissor members. Storage, water collection, and water purification system are embedded in the base of the unit which can be transported like suitcase through the attached extendable handles and wheels. Overall, this shelter can provide ease in daily life and serve as a transition towards permanent living. (Figure 3)

REGENEREST

Regenerest is a deployable, transformable, and multi-functional shelter that could be transported by
Figure 3
This structure is made of five inflatable rings which are connected to a movable base supported by scissor members.

Figure 4
Regenerest is a deployable, transformable, and multi-functional shelter that could accommodate 10 different configurations. The modularity allows for expansion through stacking and attaching. The project consists of six panels that are connected through double knuckle hinges with a locking system to improve feasibility and stability. Movable panels make more than 10 different configurations. The modularity allows for expansion through stacking and attaching. This can create multi-functional spaces that can accommodate various activities and different families’ sizes. This provokes cultural regeneration of neighborhoods by enhancing the unique characteristics of the site and strengthening the relationship between homeless and the locals. (Figure 4)

PARAMETRIC MOBILITY
This is a versatile structure that uses parametric geometry to change its configuration through bending and twisting. Grasshopper was used to create a structural network which virtually demonstrated magnetic fields to alter the shelter’s form and structure. Magnetic field simulation demonstrated the forces and the changes in the structure. Flexible hinges and expandable materials used in this project, allow for re-shaping and rolling up to create ease of portability. In tandem with it’s aesthetic, the shelter
allows for play, storage, marketing, lounging, and etc. (Figure 5)

PHASE 3: DESIGN DEVELOPMENT, PROTOTYPING, AND DETAILING
In this phase, the whole class worked collaboratively to develop, document, prototype, and make the details ready for construction and fabrication of the selected project.

SELECTED PROJECT FOR FULL-SCALE FABRICATION
The selected project is a lightweight, pre-fabricated, and foldable shelter which can undertake eight different configurations achieved by origami flexibility. The structure can also be altered to increase light, natural ventilation or the retention of heat depending on the season. The shelter gives the user options to create a place of gathering, a private space, a pop-up shop or an area for family or communal expansion. (Figure 6)

Also, the colorful tessellation creates a pleasant experience inside by catching the specific colors and shades of the light spectrum. The detachable tessellations found throughout the structure allow for control of natural lighting, ventilation, water collection, social interaction, and personalization. By considering it as an urban sculpture or a portable green installation, it can also serve the public and can be considered as a medium of interaction between society and homeless people to further raise awareness of this issue and increase the community engagement. Here we can fulfill our goal of social interaction with the local community and society with minimum intrusion the city fabric while granting urban residents more self-agency and empowerment. (Figure 7)

ORIGAMI, DIGITAL SIMULATION, AND TRANSFORMABLE SPACES
This shelter capitalized on folding patterns and origami to alter its configurations based on needs and preferences. In this context, origami was used for spatial configurations and form finding, acting as an effective tool for morphological explorations.

This origami and folding system required a lot of revisions, analysis, and visualization in order to successfully transform an ideal folding pattern to a physical model in reality. Relying on parametric design abilities to demonstrate a virtual appearance and estimate potential challenges of a project during a design stage, students visualized the potential challenges virtually and overcame problems before the project was built. They used (i) Kangaroo Physics 2 as a live physics engine for interactive simulation, optimization, and form-finding, (ii) Freeform Origami for evaluating constraints of origami, perturbation based calculation, and mesh modification, (iii) Origamizer for layout algorithm, (iv) Rigid Origami Simulator for simulation of the form and structure, and (v) Ivy plugin in Grasshopper for fabrication and analysis of the stresses and potential weakness area of a structure in a given situation, segmentation and unrolling the structure for fabrication. (Figure 8)

MATERIAL BEHAVIOR AND DEPLOYMENT
In this project, deployment occurs due to high strain elastic materials and folds to apply changes in shape. This waterproof and insulated shelter is made from two layers of corrugated plastic and leather at its joints for maximum flexibility. Material selection and joinery connection were an essential part of our research to allow our structure to easily fold itself (self-folding) without losing its strength, which can reduce the weight of structure compared to rigid structures that rely on joinery system to fold. In this project portability of a structure is created by the inherent
Figure 6
This foldable shelter can undertake eight different configurations achieved by origami flexibility.

Figure 7
The colorful detachable tessellations allow for control of natural lighting, ventilation, water collection, social interaction, and personalization.

Figure 8
This shelter capitalized on folding patterns and origami to alter its configurations based on needs and preferences. It can offer private, semi private, and public usage.
Material selection and joinery connection were an essential part of our research to allow the structure to easily fold itself (self-folding) without losing its strength. This light-weight shelter can be carried by a single person.

**Figure 9**

Form and content. The material selection also helps us to be able to embed environmental consideration and insulation in our design and create a light-weight and portable shelter which can be carried by a single person. This portable shelter allows spreading the refugee/homeless in the city for business and cultural exchanges and weaves their communities within the local fabric, creating a condition that can eventually make our cities more inclusive. This shelter is completely prefabricated and can be transported to the site without any on-site operation or assembly which makes it very cost and time-effective. (Figure 9)

**PHASE 4: FABRICATION AND INSTALLATION**

In this phase, the whole class worked collaboratively to fabricate 1:1 scale of the chosen project. Here students were exposed to real-world construction challenges, material behavior, detailing, building sys-
tems, components, and assemblies, including structural and environmental impact and use.

STUDIO PEDAGOGICAL OBJECTIVES AND TEACHING EXPERIENCE
Starting with the idea that our target is the refugees and homeless population regardless of locations, and that community outreach is a key component of education, this small-scale community-based design/build studio emphasized on:

Collaborative, consensus design experience: As studio based collaborative project, to raise the students’ engagement and share the ownership in the design, all the work was done in groups, using a consensus method with a facilitator (rotating), and a group memory.

Learning-by-doing and real-world design: Technology is most meaningful when integrated into the studio context and there is no substitute for hands-on experience. Design/build projects allow students to move beyond schematic design. Issues that never come up in the classroom arise on the job site. A real-world design issue, detailing challenges, and construction strategy are all debated with a hands-on approach to three-dimensional reality.

Development of digital fabrication skills: The students learned fundamentals of digital fabrication processes including using algorithms in the form making process, using design computation software in the design process and fabricating through the digital tectonic.

Respect to the context: The students learned how to design in harmony with the environment, society, and culture. They analyzed the human factor in the community and they have the opportunity to see the results in the context. As a result, students were able to do a pre-occupancy and a post-occupancy evaluation.

Improvement of communication skills: The numerous community meetings, as well as presentations to city agencies, require communication skills. A polished presentation helps mitigate the doubts that students have enough experience to build quality projects.

Redefinition of values - community service/commitment: Architecture has always been a service profession, but it has traditionally served only those who can afford it. By working for the city, the students were exposed (often for the first time) to community outreach and real clients. Students learned that by working together, projects can happen if they commit themselves to making them happen. They gained confidence in the power of commitment, not just in design and building. Students dealt with design issues in a practical way in this studio, and they learned building techniques and details. However, the real lessons involved self-motivation, perseverance, self-reliance, courage, dignity, teamwork, and service to others.

Figure 10
Final project was exhibited in the AIA Award Show, Baazar Art Festival, and Square River Mall and used by homeless community in Spokane during the summer.
RESULTS
As a result, the full-scale project was built and tested with the homeless community in Spokane. To raise the public awareness a book and website were published that included design and fabrication process. All the projects were presented in AIA Spokane Award show and all the winners (first, second, and third places) of “AIA Spokane student competition” in the homeless shelter chapter were from this studio. (Figure 10)

This was a great social outreach which happened through students’ efforts. However, some existing challenges required revision and need to be addressed more efficiently in future pedagogical experiments. Although the usage of embedded potential in digital software was critical to design and build such projects, creating a balance between analytical thinking and software reliance is crucial. Students need to learn to rely on their architectural and structural senses and use the software as a complementary tool. Also, the timeframe of such design-build projects (based on the level of students) needs to be precisely estimated to avoid adding external pressure on the process.

CONCLUSION
In conclusion, in this studio, students identified proper methods of design inquiry and problem-solving processes to generate creative solutions to a social problem. They synthesized information from multiple sources to establish design parameters and develop genuine conceptual frameworks. They also applied research, theory, design precedents, regulations, and established conventions as appropriate to inform design decisions. This studio encouraged designers to reinterpret architecture within the emergent technology as a tool to engage in social issues and contribute to finding ways and creative design solutions to help the community, society, and humanity. By showcasing the application of computational design and digital fabrication strategies within a pedagogical context, students’ projects present innovations made possible by our current technological environment. It also showcases how they can be used in a pedagogical framework to nurture student’s creative capacities within an ever-changing technology-driven era to serve better our societies, cities, and people.

In the end, this transformable shelter can hopefully be known as a long-term solution to a significant problem of homeless/refugees’ population and the hardship that they undertake, and it might be considered as a homeless shelter of the future.

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