

# Situating Shelter Design and Provision in ICT Discourse for Scarce-resource Contexts

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## ABSTRACT

The world is facing a shelter crisis that is only expected to worsen in the future as resources become scarcer and climate change, economic decline, and mass migrations pervade. In this paper, we argue that the ICT community has a major role to play in the crisis of shelter provision, and we explore the relevant challenges and limitations, as well as the role ICT systems can play to mitigate them. We break shelter provision into four fundamental processes: land procurement, design, construction, and maintenance, and we sketch four research themes to address them. Through specific project examples, we show that the abundant present is the time to use ICT systems to investigate, collect, analyze, develop, test, and preserve a variety of tools, techniques, knowledge bits, construction kits, and algorithms that will guide us in the future to produce shelters with limited design, computing, and construction resources.

## CCS Concepts

• Applied computing

## Keywords

Shelter; design; construction; resource-scarcity; ICT; HCI.

## 1. INTRODUCTION

Architecture, which is the art and science of orchestrating the built environment, has become increasingly dependent in the past three decades on computing prowess for the design, drafting, modelling, evaluation, structural verification, and construction of its edifices. Furthermore, computing has not only made it possible to materialize designs of unprecedented complexity and exquisiteness, but is drastically altering the way the discipline operates. For example, advances in fabrication and 3D printing technologies are fueling a serious impetus towards manufacturing rather than building architecture. And from rotating skyscrapers to floating fortresses, disaster proof shelters, LED-clad towers and interior envelopes that sense and respond to their occupants,



Figure 1. Futuristic trends in architecture [53, 54]

architecture of tomorrow is promising to fulfill many imagined and unimagined fantasies.

As an interdisciplinary architecture and computer science research team, we are excited by the prospect that present and future generations will experience environments vastly improved, even revolutionized by advances in manufacturing and information and communication technology systems (ICT). At the same time, we cannot disregard the possibility that the future might be much grimmer, as we experience rapid climate change, prodigious forced displacement, degrading ecosystems, and diminishing resources. Work is therefore needed to ensure the sustainability of this vision for the future of architecture under reduced prosperity.

In this paper, rather than focusing on future-proofing mainstream computing-intensive architectural trends (such as those depicted in figure 1), we seek to direct the attention of the ICT community to the challenge of providing shelter, primarily housing, in existing and future scarce-resource contexts. Current approaches, for example in disaster relief and forced migration camps, almost entirely neglect computational support. By developing techniques here and now, where resources are still abundant, we argue that computing can potentially enable millions of people to better procure, design, construct, and maintain shelters.

We start by defining shelter, relevant ICT research, and anticipated limitations in scarce-resource contexts. We then propose four research arcs in which the bulk of the work happens in the present, using abundant computing resources, so that fewer tools are necessary when resources are limited. The first arc is finding space for future settlements based on GIS data synthesis and predictive modelling. The second arc is superseding the role of architects and builders when/where their intervention is impracticable, using unconventional interfaces, HCI principles, optimization algorithms, and fabrication processes. The third arc is building a collective knowledge of largely forgotten vernacular construction strategies and encoding it into ICT tools so that it is available when needed. The last is restoring knowledge and agency between human beings and their built environment.

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## 2. BACKGROUND AND MOTIVATION

Shelter is a place or assembly that covers and protects. Humans, in pursuit of protection, first looked to nature to shelter themselves from nature – refuge under a tree or projected stone, in the side of a cliff, or inside a cave. Then we started to mimic nature and use what was around us to build shelter [1]. Primitive shelters were built using the limited resources in the ambient environment. In exploring the human journey to creating shelter, Vitruvius traces the origin of the dwelling house “... to construct shelters. Some made them of green boughs; others dug caves on mountain sides, and some, in imitation of the nests of swallows and the way they built, made places of refuge out of mud and twigs”. Every community, as architect Hassan Fathy recognizes, “... produced architecture that has evolved its own favorite forms, as peculiar to that people as its language, its dress, or its folklore” [2].

Vitruvius also specified in his first century B.C book “The Ten Books on Architecture” three Virtues of Architecture: *utilitas* (function or commodity), *firmitas* (solidity, firmness or materiality), and *venustas* (beauty or delight) [3]. These three virtues have for centuries represented construction principles and the human needs they satisfy. We therefore build shelter to attain protection from climate and harsh conditions, comfort, pleasure, healthy indoor environments, privacy, security of personal belongings, and safety from injury, fire, or intruders. And we attain shelter through a provision process that involves (1) finding a land, (2) designing a structure, (3) building it (or procuring a dwelling unit such as an already existing property or a delivered pre-fabricated module), and (4) maintaining it.

Shelter requirements have changed over time; they started as providing protection and safety and other basic human needs. Increased resource utilization and technological advances introduced more features that have now become necessities: beauty, delight (think of what it feels like to enter a glass atrium filled with sunlight), heating and cooling, furniture, artificial lighting, power outlets, modern appliances, and connectivity. Our houses have become so complicated that it is difficult to imagine how millions of people lived one hundred years ago. But can upcoming generations enjoy the same luxuries for centuries ahead? Can we still build our shelters the same way? And what is the realistic future of shelter? For billions, it will most likely not be 3D printed structures and microprocessor-augmented interiors.

### 2.1 Shelter in Human Rights Laws

Shelter is imperative for the physical and psychological wellbeing of human beings. We need it as much as we need food, water, and social connectivity. International human rights laws therefore recognize adequate living standards, including adequate shelter, as a universal prerogative. This includes the 1948 Universal Declaration of Human Rights and the 1966 International Covenant on Economic, Social and Cultural Rights. Other international human right treaties have since recognized or referred to the right to adequate housing or some elements of it, such as the protection of one’s shelter and privacy [4]. To further emphasize the importance of shelter, the United Nations Refugee Agency (UNHCR) reports that “[o]ne of the first things that people need after being forced to flee their homes, whether they be refugees or internally displaced, is some kind of a roof over their head. Providing shelter is a priority ....” [5]. It is no surprise then that the agency’s logo also symbolizes shelter. Yet shelter is also one of the most involved human needs. It entails many contested resources such as land, material, upkeep, and territoriality. It is further impacted by several, often unyielding external factors such as

neighboring plots, municipal bylaws, regional politics, and natural and manmade disasters. Contexts with scarce resources are often prone to unfavorable combinations of such factors [6]. For example, they are more disposed to destructive disasters, or are subject to discriminatory land ownership laws, austere expansion restrictions, and threats of eviction or destruction, etc. This causes human needs to clash with imposed restrictions and contested resources. Even when humans challenge the forces acting upon them through their instinct for survival, the forces and limitations are often too tenacious to mitigate or resist. It is plausible that such tension and complexity are the primary reasons why ICT research has largely shied away from resolving shelter issues in contexts with scarce resources, as we discuss in section 2.3

### 2.2 The crisis of shelter

Any natural or manmade structure that is covered and/or affords a degree of protection from exterior forces is considered a shelter. A cave, a tent, a caravan, a mansion, and a skyscraper are therefore all shelters. Schools, hospitals, community centers, and markets all require one form or another of shelter to function properly. But we use the word shelter primarily in this paper to refer to its most basic form: housing, although most of the upcoming discussion applies to other building functions.

As a form of shelter, housing has simpler requirements and smaller footprints, yet it is where resource scarcity manifests the most. Indeed, there has been a housing crisis since the beginning of the 20<sup>th</sup> century [7]. The Great Depression foreclosures, World War I and II austerities, mega-scale natural disasters, ongoing wars, and global poverty have consistently left millions without a proper roof on their heads. Today, there are 60 million displaced persons around the globe [8] and another 863 million living in slum conditions [9]. UN-Habitat estimates that by 2030, about 3 billion people, or about 40 per cent of the world’s population, will lack proper housing and access to basic infrastructure and services such as water and sanitation systems [9]. Even if local governments pour more money into infrastructure, they will fail to meet people’s needs before a city turns into a vast slum [10]. And the shelter crisis is only expected to propagate in the future, even for rich nations, as the impacts of climate change spread. How fast and what quality of shelter can people with scarce resources build, in the face of wars, rumbling earths, roaring winds, or rising waters? One need not look beyond slums and refugee camps to envision how the projected resource scarcity in the future will manifest in our built environment.

As such, there is an imperative need to adopt innovative methods and new techniques to solve the shelter crisis. Any process or apparatus that improves shelter provision can therefore bring about massive good in the present and future. As one of the most powerful paradigms humanity has ever conceived, ICT systems have a lot to offer to improve shelter and its provision.

### 2.3 Shelter in ICT Research

Exploiting computing technologies to facilitate shelter provision in contexts with scarce resources is pertinent, in theory, to several ICT-based research fields. First, it impeccably aligns with the research agenda of Collapse Informatics, coined by Tomlinson et al. as “...the study, design, and development of sociotechnical systems in the abundant present for use in a future of scarcity.” Second, because ICT for development (ICT4D) investigates ICT systems that contribute to the economic, social, environmental, and political development of communities in impoverished settings, shelter in indigent contexts is evidently relevant to such discourse. The same argument holds for HCI4D, an ICT4D offspring, which

“addresses the needs ... of people in developing regions, or ... specific social, cultural, and/or infrastructural challenges of developing regions.” Shelter is also relevant to Crisis Informatics, Development Informatics, Postcolonial Computing, Information Technologies and International Development (ITID) and any ICT discipline concerned with basic fulfilling human needs.

We are not fixated on research field classifications, but we had to identify keywords to search the relevant literatures. But what we found is very little. Shelter, whether in scarce-resource contexts or not, remains relatively unexplored in ICT research. For example, the literature review Patra and colleagues carried out, along with a survey of 50 researchers and practitioners, reveals that ICTD is primarily active in agriculture, education, communication, governance, healthcare, and business [11]. A survey by Gomez et al. [12] found that 36% of ICTD and development informatics research published between 2000 and 2010 focussed on business (e.g. e-commerce, entrepreneurship, employment, industry, or microfinance), 31% on empowerment (e.g. community development, citizen participation, or social capital), 22% on education, 18% e-governance (e.g. politics, democratization, government services, or corruption), 11% minorities, 11% health, 7% gender, 6% agriculture, 3% youth, 3% environment, 2% relief; and 1% on disabilities.

Although these findings are several years old, recent publications in relevant journals concur with the reported results, with newer topics encompassing cellular networks (reliability/access/rapid deployment), open source software, entertainment, ICT use and access amongst women, and 3D printing. The use of satellite imagery analysis, agent-based modeling, and evidence-based design to assess shelter damage after disasters [13, 14, 15, 16], improve shelter resiliency [17], and allocate shelters in disaster [18] are other popular arcs of inquiry relevant to ICT. But such endeavors are concerned with solving present challenges from contexts with abundant resources (such as a lab at Harvard) rather than preparing for future limitations. Finally, there is a rich body of literature in the social sciences, public health, sociology, civil engineering, and architecture on adequate shelter requirements, challenges and evaluation of shelter provision in indigent situations, and future prospects [19, 20, 21]. But no work to the best of our knowledge correlates shelter provision in scarce-resource contexts with computing.

### 3. SHELTER AND SCARCE-RESOURCE CONTEXTS

So far, we have refrained from explicitly defining what we mean by *resource-scarce contexts* because its meaning is generally well understood. But having introduced enough background on shelter and relevant ICT research, we now describe our notion of resource-scarce contexts from a shelter perspective, as well as what the provisioning of shelter in such contexts necessitates. We will then make the connection between shelter in scarce-resource contexts and computing.

Resource scarcity entails inadequate fulfilment of human needs as well as access to critical infrastructure such as food, medicine, transportation, power, energy, capital, communication networks, and vast manufacturing capacities. Given the shelter requirements discussed earlier, we extend scarce-resource contexts to refer to any location in the present or future where, in addition to or because of

the deficits above, there is limited or no access to one or more of the following:

1. Architects (or civil engineers) due to financial, physical, logistical, political, or social constraints
2. Common modern building materials such as concrete, steel, glass, prefabricated modules, or various construction components such as beams, columns, bolts, mechanical systems such as heating, cooling, and ventilation, machinery, etc.
3. CAD tools such as drafting software, structural analysis programs, BIM models, etc.
4. Minimum covered shelter area of 3.5m<sup>2</sup> per person<sup>1</sup>
5. Informal/collective knowledge and expertise of safe construction and appropriate material
6. A collective body responsible logistically and financially for general maintenance and upkeep
7. Sewage and other site management infrastructure

A context need not have a certain number of impacted populace to be identified as scarce with respect to shelter. Jorgen Randers for example sets one billion as the threshold for observing global collapse [52] and the United Nations High Commissioner for Refugees (UNHCR) uses 25,000 refugees as a minimum for defining refugee crises. Because shelter is a basic human need, a threshold is irrelevant; it could be for millions of people who escaped a sinking peninsula or a single family who were forced to leave their country to escape prosecution. One need not imagine a global collapse to foresee a world in which many regions continue to experience acute needs for shelter during times of severe shortage of resources. Existing slums, informal gatherings, and refugee camps (figure 2) are example of contexts where all or most of the above limitations pervade, and squalid shelter conditions arise due to scarce resources.

Future scenarios that can induce such limitations include hurricanes, earthquakes, drought, heat waves, rising seas, wars, regional or national government failures, mass migrations, declining economies, and acutely diminishing resources. Cities in the developed world might seem largely unhampered by such limitations, but can be surprisingly vulnerable, as witnessed by hurricane damage to New Orleans and New York, and the recent forest fire that ravaged Fort McMurray in Canada. Impacts of climate change increase these risks to cities throughout the world, primarily due to extreme weather events and rising sea levels.



Figure 2. Al Zaatari Refugee camp in Jordan [56]

<sup>1</sup> This figure is an evidence-based standard used in humanitarian response situations and was set by The Sphere Project [51].

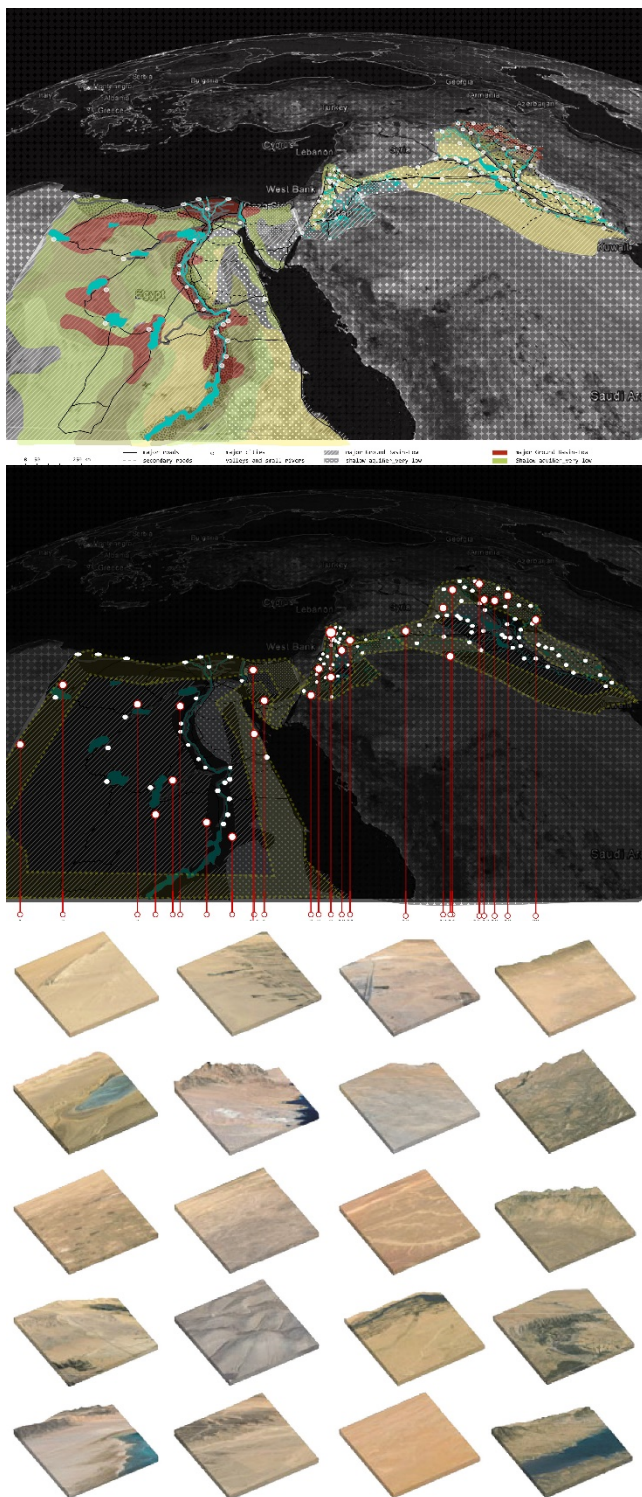


Figure 3. Potential locations for future settlements in Egypt, Jordan, and Iraq [23]

## 4. ICT FOR SHELTER IN SCARCE-RESOURCE CONTEXTS

There are several areas in which current ICT systems can help mitigate shelter crises in a future of limited energy, manufacturing, and computing resources, or areas of the world already experiencing resource scarcity, such as in refugee camps or in

developing communities. The four research arcs we propose address the four shelter provision components identified earlier (1) finding land, (2) designing a structure (3), building the structure, and (4) maintaining it.

Our work envisions two distinct ways of leveraging abundant computing resources in the here and now for times and places of scarce resources. One is geographic, in which abundant computational resources in some parts of the world are harnessed to provide support for the above activities in parts of the world where little or no computational support is available. The other is temporal, where preparations can be made for future resource scarcity by developing architectural design tools that require little or no expertise to use, and offer support for local, vernacular building styles needed in a post-collapse setting.

### 4.1 Finding Shelter Loci

This first proposed arc addresses land procurement to situate shelters in the future. It is politically involved, because land is precious and contested, that even the most generous host communities are parsimonious when it comes to offering their soil to displaced populace [22]. To keep the discussion focused on ICT, we leave that conversation to our colleagues in political science and international law. The point is that rising sea levels, overcrowding, and resource-induced wars are already generating massive population influxes in search of new habitation. A possible action is to use GIS data and predictive models to find [un/under]inhabited or [un/under]developed sites around the globe with access to resources based on 10/25/50/100 year timeframes. Publicizing the findings through paper and interactive digital maps will guide fleeing populace to the closest and most prosperous points of refuge.

Using Iraq, Jordan, and Egypt as examples, Sabie and Sabie [23] plot groundwater conditions, lakes, rivers, precipitation levels, primary roads and railroads, and major towns. The resulting maps (figure 3, top) reveal several uninhabited locations within 50-100 kilometers of major urban centers with decent access to resources and mobility networks. But habitability measures are not enough for siting temporary shelters as they might yield loci too lucrative for the host governments and land speculators. Hence, three more selection criteria are applied. First, sites must be within 100 km of national borders. Second, they must be at least 50 kilometers away from urban areas (i.e. in the middle of nowhere). Third, they must be close enough to existing, small, often struggling or poor communities. This deters property developers and keeps “precious” urban areas in safe distance from “perilous” influxes as often perceived by the host communities. Furthermore, it situates the new arrivals close to, but safe enough from, their original homes. Finally, by seeding the resources, talents, expertise, effort and global relief momentum (if applicable) to such areas, the expected growth can potentially spill over and spark economic and social development in the adjacent communities.

Synthesizing all these metrics in a modelling environment narrowed down the options to 20 potential areas/locations (figure 3, middle). As expected, they are primarily under-used agricultural fields, marsh lands, and desert plots which governments do not have the interest, staff, and/or resources to develop yet (figure 3, bottom). Through further data analysis of each location, its context, resources, and developmental needs, specific sites can be pre-designated as strategic seeds for future occupancy, potentially fueled by displaced populace. Other ICT and non-ICT systems can then be used to preserve the data and make them available when needed.

To summarize, while allocation of land resources will always remain a deeply political challenge, there's an important role for ICT in accessing and analyzing multiple data sources about the physical and human geography of a region, and for visualizing the results to support decision making, especially for evidence-based policy-making around land use and seeking future [re]settlement loci.

## 4.2 Superseding the role of Architects and Builders with Technology and Self-Help

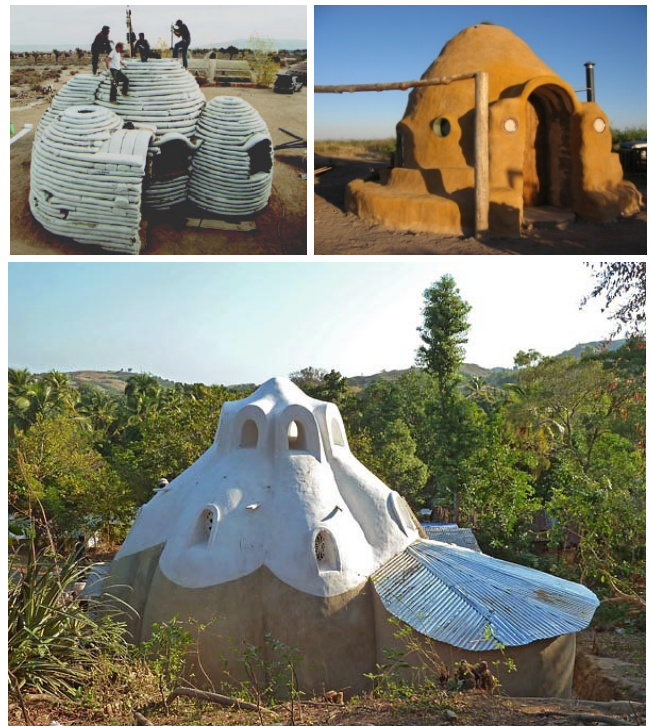
This second arc targets shelter design in contexts with the limitations described in section 3. Such contexts already exist in post-disaster and refugee camps. However, current design practices in such situations use very limited models, largely based on mobilizing disaster relief resources.

In the simplest case, relief agencies such as the UNHCR distribute tents, plastic sheeting and matting, or deploy, based on available aid and displacement period, concrete barracks, caravans, and pre-fabricated modules. We refer to such housing provisions as conventional shelter models.

More novel models are sometimes provided through partnerships with NGOs and design or manufacturing practices. Examples include inflatable concrete tents [24], flat pack shelters [25], shipping pallet houses [7], laminated cardboard huts [7], and straw bale housing [27].

Most of these shelter options exhibit serious shortcomings. First, tents and their equivalents provide negligible privacy, safety, sanitation, and thermal comfort. When used as homes for months or years (which is not uncommon [27,28]), they cultivate appalling environments that leave occupants in highly distressed living conditions. Second, tents and manufactured units follow a pre-packaged shelter model and offer no capacity for participatory design. [29, 30]. Third, the procurement of better alternatives such as caravans and prefabricated modules rely on donors and available relief funds and are greatly impacted by delays or disruptions in the aid system. As an example, we examined shelter provision in al Zaatari camp for Syrian refugees in Jordan. Located in a desolate desert 70 kilometers north of the capital city Amman, al Zaatari (figure 2) opened in July 2012 to host the tens of thousands fleeing the catastrophic Syrian war. Camp dwellers lived in canvas tents until prefabricated caravans were introduced in June 2013. Caravans took nearly two years to distribute to 80,000 individuals (on a household basis) due to tension on allocation priorities and various delays [31]. Finally, as Tomlinson et al. note [32], in a future of limits, there may not even be an external agency delivering support (such as shelter) to those in need.

A third approach, self-help, is also implemented in some contexts with limited resources such as disaster, displacement, development, and social housing. The Oxford English dictionary defines self-help as the “use of one’s own efforts and resources to achieve things without relying on others”. Self-help housing schemes are implemented in a variety of flavors. Most commonly, the agency in charge procures site, extends infrastructure, and erects service cores (kitchens and bathrooms) and potentially structural frames. Occupants often contribute labor, and later on, build the rest of the shelter as their resources permit. The result is often more permanent and proper shelters than the basic and novel models mentioned above, but self-help schemes require extensive support,



**Figure 4. Sandbag construction [45]**

coordination, and capital. This is further exacerbated by the fact that architects are often absent from scarce resource contexts, and design is often perceived by policy makers and relief agencies as a luxury rather than a necessity [7]. This is not to dismiss all the impressive, soul-draining design work that architects are increasingly creating for the displaced and disfranchised [7, 33], but the reality is: architects only contribute to 3% of the built environment [34].

In al Zaatari, for example, refugees had to endure at least one winter of freezing temperatures, heavy rainfall, cold winds and snow inside deteriorating canvases.<sup>2</sup> But shelter provision could have been orchestrated differently. With support from the UNHCR, camp dwellers could have designed and built their own shelters, by obtaining burlap or polypropylene bags (rice sacks for example) from local farms or international manufacturers, filled them with the abundant earth and sand, and built sandbag shelters (figure 4) tailored to the needs of each family in three weeks. Such self-help process would have been clearly challenging: it requires education, detailed construction steps, and architect intervention to customize the shelter design. But what if there was in place a shelter DIY kit (paper or software based)?

Guided by usability and accessibility design principles, such a kit can enable users to sketch their own shelter and an optimization algorithm converts the sketches to valid geometric forms and generates step-by-step construction directions. Such an algorithm could be capable of suggesting optimum ventilation holes and window placement, and work with or without certain resources (for example beams or active HVAC systems). With a few consumer or business grade laptops, scanners or high-resolution cameras, and printers, thousands of families in a scarce resource context can embark on building custom vernacular shelters.

<sup>2</sup> In other, less affluent camps and informal gatherings the shelter situation is even worse.

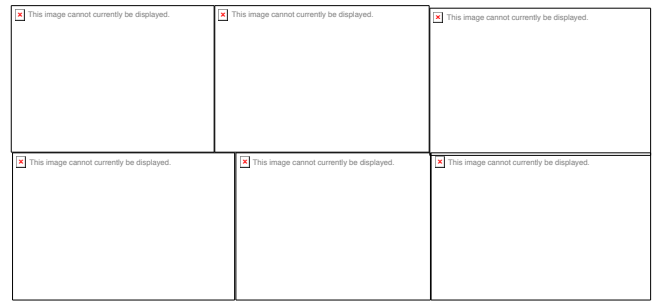
We have developed such a kit that guides target dwellers to design their own sandbag shelters using a combination of templates and annotated free hand sketching [35]. The kit includes construction terminologies, surveys to help users discern their shelter needs and spatial qualities, time and effort vs quality trade-offs, measuring guides, and resource/ construction constraints. The kit also permits future dwellers or entities in charge (camp management for example) to specify available resources (beams, formworks, cement, etc.). If users end up sketching designs that require unavailable resources, the optimization algorithm would be aware of the limitations (conveyed through a scanned parameter sheet or a conventional interface) and would adjust the design accordingly. Example adjustments would be to estimate a free-form room with a group of adjacent or intersecting domes if beams are not available locally, or re-scale windows if they exceed a certain fenestration safety margin. But the algorithm is not intrusive to the point of dictating material type (adobe or straw bale over sandbags for example), because the design possibilities and properties differ slightly by material. We assume that local organizers or dwellers will determine the most appropriate material and use the appropriate tools (different tools would be optimized for different materials and construction means).

The central idea for this research arc is to seek ways of supporting local, vernacular building designs based on principles of self-help and local materials. This prescribes a fundamentally different way of thinking about shelter provision. It is not that dissimilar from custom design fabrication tools for example, but to be practical, it must offer a simplified, primitive, and universal user interface (i.e. paper). Existing tools employed in architectural practices have no capacity for untrained users, are not optimized for low-tech construction techniques, and rely on conventional computer interfaces. As such, there is no clear route to repurpose them, even with a simplified user interface. Instead, we need software support tools and low tech design kits to replace the missing expertise. Existing architects cannot provide this support either, as they would need retraining on vernacular building techniques, and even then would be difficult to hire in scarce resource contexts. The abundant present is therefore the time to investigate, design, test, and deploy a variety of building techniques, construction kits, and efficient algorithms that will guide us in the future to produce shelters with limited design and construction resources.

### 4.3 Preserving the Vernacular for Present and Future Generations

Vernacular architecture emerged as a response to shelter needs since the earliest civilizations, exploiting the limited resources and building materials available in the ambient environment such as mud, earth, straw, wood, and stone. Through trial and error, community members, builders and craftsmen, often untrained professionally, developed over generations local techniques derived from their needs and material properties as evident in figure 5. For roofing and openings, they created arches, vaults, and domes from brick, and trusses using wood. They also developed brilliant passive cooling, heating, and lighting systems using natural resources to placate the exterior climatic conditions indoors. Vernacular architecture is therefore the result of constraints imposed by limited resource availability [36].

The industrial revolution triggered a pivotal change in architecture. It provided modern materials such as steel, concrete, and glass that helped to erect new types of buildings such as factories, workers' housing, and exhibitions and paved the way for new construction systems and wide span roofing. The Crystal Palace (1851) in London and the Eiffel Tower (1889) in Paris were great examples



**Figure 5. Vernacular architecture built in accordance with environment and available resources [57]**

of the new era of architecture and building materials [37]. In addition, new energy resources made the transportation of material from factories to far sites possible. During the 20th century, architecture witnessed more drastic changes in material, construction systems, and design technologies along with economic and social development. Modern high-rise buildings with big glass facades provided comfortable indoor environment, regardless the climate, with the virtue of artificial air-conditioning and cheap fossil fuel affordability. This trend became the international style all over the world, and vernacular ways of building were abandoned.

Building with sandbags is an inherently vernacular (indigenous) architecture that we no longer see, at least in the developed world. We first became aware of sandbag construction in 2014 through Architecture for Humanity's renowned book *Design like You Give a Damn: Architectural Responses to Humanitarian Crises* [7]. A fascinating aspect of sandbag construction is that it yields a wide range of shelters by improving upon the technique used for many decades in the military forces for creating bunkers, flood barriers, and refuges. Since then, we have found a limited number of books and published research on sandbag construction [38, 39, 40, 41, 42], a very small online community of builders and construction enthusiasts [43, 44, 45], and one research institute [46]. We also had many conversations with architects, landscape designers, urban planners, public health practitioners, and refugee researchers in Canada and the US; the vast majority were not aware of sandbag construction.

Yet during a casual conversation with a Filipino architect who has recently immigrated to Canada, he immediately recognized the method and spoke about its wide use in the Philippines. Such incidents clearly demonstrate the dissociation in North America (and potentially Europe) from the vernacular. And this is not surprising given the wealth of resources which enable the construction and upkeep of our elaborate edifices.

The challenge for this research arc is thus to curate knowledge about the construction methods for vernacular architecture that are rapidly being lost because of current building trends. In a world of scarcity, we will need this cultural memory. This research arc aims to rediscover, analyze, and conserve vernacular construction practices and expertise the way archeological artifacts are uncovered and preserved. This research arch is very much akin the Wisdom of the Years project [47], and the intricacies of cataloging, storing, and conveying information efficiently to locations where it is needed is in the hands of ICT research.

### 4.4 Assessing the Quality of the Built Environment

The last research arc targets the maintenance and upkeep of the built environment generally, and shelter specifically, in scarce-



**Figure 6: Shatila refugee camp in Beirut [58]**

resource contexts. It anticipates situations in which no supervising authority (municipality, for example) is available to assess and maintain buildings, and dwellers have to play that part on their own.

In existing slums and refugee camps, resource limitations often lead to a squalid environment. Researchers have catalogued the impact of such environments on the health and overall wellbeing of inhabitants [48]. Others have devised various quality indicators and benchmarks [49, 50]. These checklists are primarily to inform architects, planners, NGOs, and policy makers during future constructions and renovations. They are not for the dwellers who live and interact with the environment and its shelter everyday.

The objective of this research arch is to give dwellers a connection with, interest in, understanding of, and even agency on the built environment they inhabit. While they instinctively might know what needs to be improved or maintained, collectively the issues might be too chaotic and overwhelming (as evident in figure 6) to fathom on their own. As such, tools are needed to help them answer questions such as: How bad is our built environment? Where does it fail the most? Does it exhibit any positive traits? Can its quality be measured? Is it possible to visually represent such qualities? And can it be captured as a set of simplified benchmarks?

One promising approach is to develop a set of indicators in the form of yes/maybe/no questions that encompass the major parts of the built environment: the school, street, house, neighborhood, clinic, and work, and which can be used directly with local communities. The questions must be specific, clear, and provocative, to inspire action. For example, imagine asking children face-to-face about their school: How is your classroom? Is it too hot in summer? Too cold in winter? Can you hear the teacher? Can you see the blackboard? Do you have a place to play? Is your route to school safe?

These questions, along with hundreds others pertaining to the house, clinic, street, neighborhood, and workplace, are specific, broken into categories, and help dwellers particularize what they might know instinctively and devise the interventions needed. Each answer can be represented by a color (yes is green, maybe is orange, and no is red). Colors for each category can then be summed up together to generate a hue. The cumulative hues then generate a score indicative of the overall quality of the space surveyed. The meaning of the three colors/overall hues is:

- Green: an empowering built environment, where access to basic services is easy (shelter, market, employment); the environment is free from dangerous objects (loose electric wires, armed individuals, pronounced military

presence), health hazards (over flowing sewage), and discomfort (mold, irritants, etc...).

- Orange: a restricting built environment that poses certain limitations and difficulties on daily and seasonal activities.
- Red: is a disempowering environment that incubates harm, causes anxiety, hardship, and disease, poses constant obstacles, and inhibits the occupants' daily activities and future aspirations.

Conveying the indicators in a way such that the overall quality of each built environment component (house, school, clinic, etc.) can be understood without the involvement of experts.

The challenge then for this research arc is to develop tools and techniques that give the occupants of the built environment agency over the upkeep of their own dwellings. This requires tools that channel a frustration over crumbling buildings into a constructive process for taking local actions to repair and improve buildings. Software tools can guide this process by helping non-experts identify problems early, and empower them to act by offering repair guides (e.g. via videos), and by connecting local communities to share knowledge and experience in a structured way.

## 5. CONCLUSION

If we ask people about their perception of future homes, they are most likely to imagine towering buildings, hi-tech skyscrapers, floating projects, responsive envelopes, and smart interiors where everything is computerized and managed with a remote control. This optimistic futuristic vision, shared by a lot of people and building professionals, need to be revised for a future of scarcity, in especially in situations where natural or man-made disasters have led to economic or social collapse. In such settings, resources, including fossil fuel, water, food, and even digital (computer) resources, will be limited. With accelerating climate change and ecosystem damage, such settings are likely to be increasingly widespread in the next few decades.

A thorough analysis for the future requires us to rethink our existence in this planet. Rethinking of the past as an inspiration for the future is becoming vital. Building shelters using limited available resources with local techniques in accordance with the ambient climate will be increasingly necessary in the future. This will entail the re-discovery of traditional knowledge, re-acquainting people with vernacular architectural techniques and re-engaging people in creating their own shelters and deciding how to build based on their resources and needs. We argue that such an approach will be essential for the majority of the population if coming generations are to survive and thrive on this planet.

The research themes and project examples we proposed in this paper have the potential to assist in shelter provision both in a future of scarcity as well as in regions where limitations already manifest such as in slums and refugee camps. All of the arcs discussed share the same inherent principle of using current ICT systems to generate, synthesize, preserve, and present knowledge to populaces in distant spatial or temporal contexts. This knowledge then becomes the basis for agency: to design, build, upkeep, survive, and secure access to shelter.

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