Promoting Autonomous Self-sufficient Units in Humanitarian Contexts

An inspection in developing autonomous housing's approach to be applicable to protracted crises

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Abstract: The paper investigates the possible application of autonomous housing units in humanitarian contexts, especially those resulting from prolonged crises, through an innovative design approach and the cooperation between humanitarian sectors and organizations to provide a qualitative sheltering response that affirms human dignity and reflects a better environment. The paper is based on a previous research and design project developed as a master's thesis, with continuity of research and design thinking to fulfill some of the project's aspects more efficiently in terms of building systems and customization.

Key word: Autonomous housing, Humanitarian innovation, Ecological living, Human comfort, Building system.

1. Introduction:

In the context of violence crises, the solution does not lie only in the reconstruction of destroyed homes, as is the case when a natural disaster occurs. In fact, the homes of many victims of violence may still be standing, but they are in an unsafe area. Hence, the response in this situation always concerns temporary sheltering approaches awaiting resolution to the crisis and avoiding the problem of land ownership: “Transitional houses initially appeared to be a politically perfect solution. They would be owned by the government, mass-produced in redundant war-time factories and could be erected on bombed sites, avoiding some of the challenges for land acquisition.” (1) But there still are problems of servicing and protection as the displaced sit in unhabitable, marginalized lands, which keeps recovery of these contexts intractable, leaving a great number of people in emergency shelters for many years.

Consequently, the research urges the development of temporary shelter solutions to be autonomous transportable dwellings, in an attempt to advance these particular communities humanitarianly, environmentally, and economically.

2. Conceptual and theoretical framework:

The condition of vulnerable camps requires working to restore human dignity and erase marginalization. This can be achieved by creating a clean environment, increasing shelters' quality, and reducing the needs of affected people to make them independent, or at least partially independent. All are possibly to be resolved by independent dwellings; Autonomous Units, following the definition by Vale, “an autonomous house is a house that can function independently of services from public power networks, using income-energy sources of sun, wind and rain to service itself and process its own wastes.”(2) Accordingly, the goal is to shift from a normal shelter (linear approach) to an autonomous one (circular approach), which will lead to minimizing humanitarian activities and maximizing human dignity.

As the design-thinking looks at the autonomous units to be the resource of services in unserviceable context, it promotes extending the idea to include self-sufficiency in food to make them work as economic opportunities to empower beneficiaries. Further, these units must concern spatial quality and human comfort depending on the believe that good design, as it is a remedy to environmental issues, is also a cure to social and psychological problems.

To this end, humanitarian agencies are called to collaborate and centralize their activities in one qualitive entity and strategy.

3. Methodology:

The research methodology was based on a multidisciplinary investigation starting from the on-ground practice of shelters to the autonomous house definition, history, and its prominent case studies, dealing with economic, ecologic, spatial, sociocultural, temporal, and technical considerations.

To boost a new strategy in the humanitarian sheltering response, it was essential to start with examining existing shelters to have practical feedback on the adopted approach and determine the weaknesses; this is considered one of the most important steps towards making change. The selected projects were analyzed according to multiple criteria that lead to a dignified shelter. The analysis displayed troubling results regarding to which extent the shelter has answered the question of “adequate housing” and the matter of dignity, and of course, the environment. This led to executing extensive research on the autonomous house, necessarily started with elaborating what is meant by the term “autonomous house” and looking back to its history to understand the causes and motives behind it and the obstacles that prevented it from being widely adopted in the built environment even though it is an ideal of sustainability, the thing that helped shape perception about the possibility of bringing it to refugee camps.

Then, multiple case studies were studied to perceive the mechanism of the autonomous house. The investigation into the possibility of applying it in humanitarian contexts, was set out by picking the most recent three projects (Eco Living Module, Diogene, and Micro Compact Home) to be analyzed and compared to the most relevant on-ground case study “IKEA Better Shelter”. The comparative study highlighted that an autonomous unit is not merely a shelter, rather it could narrow the need for humanitarian aid projects. Therefore, it emphasized that the need for humanitarian organizations to work integrally is fundamental to producing: “autonomous sheltering response”. The study was concluded with an estimation of the quantities for these autonomous units to identify the priorities of the inserted systems that helped in know-how controlling the cost.

4. From Substandard to Autonomous Shelter:

4.1. What is the autonomous house?

In the field of architecture, “autonomy” has two implications: autonomous control and self-sufficiency. Autonomy means that one can independently manage one’s own affairs and make independent decisions without influence or control by others. Self-sufficiency means that one can maintain self-sufficiency in resources such as food, water, and energy. (3)

Consequently, in contrast to a conventional house, an autonomous house is a house that operates solely, separated from public services. It is developed to be totally dependent on renewable energy, thus minimizing environmental load and promoting high quality and sustainable living atmosphere. It is functional, self-sufficient, and steady, as it is meant to resist climactic stresses. It is a body that smartly customizes itself to suit a particular situation and users' needs. A definition for the “autonomous house” was penned by the British architects Brenda and Robert Vale as follows: “The autonomous house on its site is defined as a house operating independently of any inputs except those of its immediate environment. The house is not linked to the mains services of gas, water, electricity, or drainage, but instead uses the income-energy sources of sun, wind and rain to service itself and process its own wastes.” The autonomous house in concept needs custom-designed systems to suit a specific climate and location. Many techniques must be integrated when thinking about self-servicing, such as battery system, passive solar techniques, alternative sewage system, rainwater collection system, etc. Since it is a separate entity, is most of the time intended to be portable, whether airlifted/transported as a package or deployable. This entails a deep-thinking process, considering lightweight with resistance along with environmental sustainability. Moreover, it requires custom designs for the furniture to handle the relatively small space intelligently.

4.2. Towards autonomous shelter:

The idea of autonomous dwellings in refugee camps may seem a fantasy. But with some reasoning, it might be possible.

The autonomous house was invented to solve problems, and an approach was aspired to be widely adopted and compete with the conventional house. But as Vale & Vale state in their book in 1975: "the attractive idea of a house generating its own power and recycling its own wastes is not easy to realize. Apart from the physical limitations on the energy that can be drawn from sun and wind, the system usually has been only marginally competitive with existing methods of servicing houses.."[(2)], and "with houses already more expensive than most people can afford, the idea of an increased capital cost for houses -even though future running costs would be reduced- could never be widely accepted"[(2)] so, competing with the conventional house was somewhat not reasonable. But if we bring the autonomous house out to exceptional problematic contexts it may be the appropriate use of it and the appropriate exploitation of technology for humanity in its hardest times. In refugee camps, having infrastructural shelters is elusive, and if this can be achieved, it would be for a small percentage of those affected and years after a crisis. This has left thousands of people suffering for years providing them only with unsustainable emergency solutions. Architects beside experts must think of high-tech solutions to better bridge the gap between short-term emergency phase and recovery. By comparison, an autonomous house is configured to be with no bills like a tent but powered like a house, it could be with no infrastructure like a tent but stable like a house. Apart from the function, the autonomous house is an example of a dignified design, and at the same time, it implies the idea of survival. These features make it an ideal solution in humanitarian contexts on the service level and, most importantly, the humanitarian level.

Now, given its complexity, looking at how to follow this path in refugee camps, particularly, how to make it affordable. Starting from the quote: "Although the self-serviced house provides a useful starting point for experiments in autonomy, as it forms a small unit that can be designed, built, and tested within a relatively short time, the idea can be expanded to include self-sufficiency in food, the use of on-site materials for building and the reduction of the building and servicing technology to a level where the techniques can be understood and equipment repaired by a person without recourse to specialized training."[(2)] They continue, "although it is possible to survive with pre-industrial technology, this is not what is proposed by autonomous living. At present, however, technology appears to be exploited for its own sake, without thought to its benefits, uses or effects on people or the external environment." [(2)] This is very crucial. The excerpt urges the use of technology, and the solution is not always about eluding it to have economic results. We must tame technology for the interest of humanity. At the same time, it reveals a potential strategy to have a lower-cost version of the autonomous house. Reducing the technological inputs and the ease of maintenance system, aside from installing local recyclable materials, could be a pathway to transform the autonomous house to a cost-effective rudimentary solution.

Cost-efficiency must be always thought of in humanitarian contexts to help benefit a wider number of affected people but must not impact the quality. Besides, it must be studied over the long-term considering multiple dimensions to be provided in the humanitarian shelter: environmental, social, and economic sustainability.
For an autonomous unit, apart from materiality, the cost is a relative topic as increasing the embedded technological systems and devices will affect the price greatly, thereby using technology must be only to cover necessities and apply comfort, not for luxury. For example, the Dymaxion house designed by Fuller is not the appropriate example to follow in refugee camps in terms of the system integrated, size, and furniture. It is deemed a luxurious house. For this reason, prioritizing the technological systems and equipment is paramount to shrink the cost.

Between autonomy and economy:

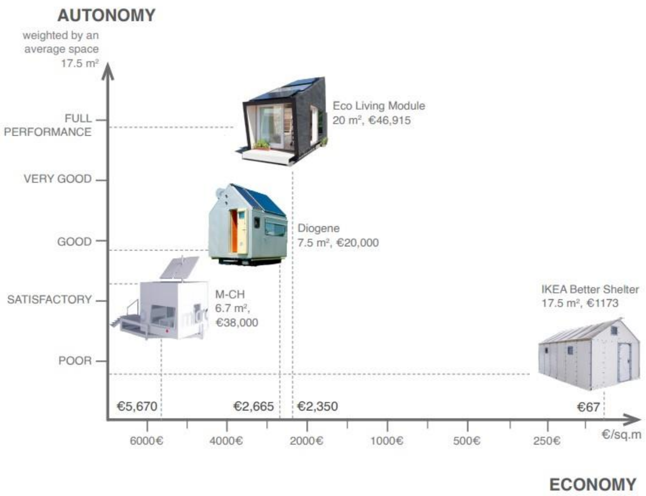

Fig. 1 Schematic comparison

This simple diagram measures a shelter between the autonomous performance and economical state considering the space area that must be an average of 17.5 m2 to host a family (minimum 3.5 m2 per person). As already mentioned, three of the most recent autonomous case studies were selected: Eco Living Module, Diogene, and Micro Compact Home because they are of the most reliable costs. The fourth example is IKEA Better Shelter; it is a flat-packaged shelter that is assembled on-site and equipped with solar system. The diagram shows that the most efficient autonomous unit is ELM: Eco Living Module, so it will be contrasted to IKEA Shelter since both are intended for refugee camps.

<u>“IKEA Better Shelter” case</u>: It is in less than the minimum level of autonomy; it incorporates a photovoltaic panel that generates electricity enough for a small lamp and mobile phone charger (for four hours). And in the maximum level of Economy because it is a very cheap product with only $1,250, but this cost would have been difficult to achieve if it included the necessary equipment for complete autonomy as well as the required utilities and furnishings -even though in its minimum provision- for a dignified housing unit. Additionally, this cost was achieved through mass-producing otherwise the product will cost around $7,500. IKEA shelter is just a

place to stay protected and safe and cannot serve its occupants for other dimensions that a house provides. "The Ikea shelter needs to be comparable to a tent in terms of price and weight" [(4)]. In emergency response, it is indeed "Better" shelter than a tent.

As for "Eco Living Module" case: It is in around the maximum level of Autonomy; the unit integrates all the systems needed to work in proper autonomy providing services sufficient for four occupants along with micro-farming wall. It is expensive. The prototype shows a cost of about $50,000. But it is not merely a covered space; "the environmental systems work in tandem with the ELM's architectural design to address the residents' needs for energy, water, food, and shelter" [(5)]. Consequently, when looking over the long term, it will decrease significantly the expenses paid for services in humanitarian work like Cash Vouchers, WASH (Water, Sanitation and hygiene), NFI (Non-Food Items), but it may even decrease the expenses for healthcare and or mental health because good design, clean air, and pure water are a cure for a displaced person or a human in general. The costs of other services are already included in such unit. So why not collect the budgets of some humanitarian projects and allocate them to a high-quality eco-living autonomous house, in which the difference will be: true dignity for people and a better environment.

Looking at the cost of the IKEA shelter will not allow for a dignified quality design, yet the cost is considerably high for ELM prototype even though it is not the final cost, and it is not a mass-produced yet. So, the estimation of quantities for ELM will be shared here as it represents an examination of the technological and materialization systems to understands the necessities and what could impact the cost.

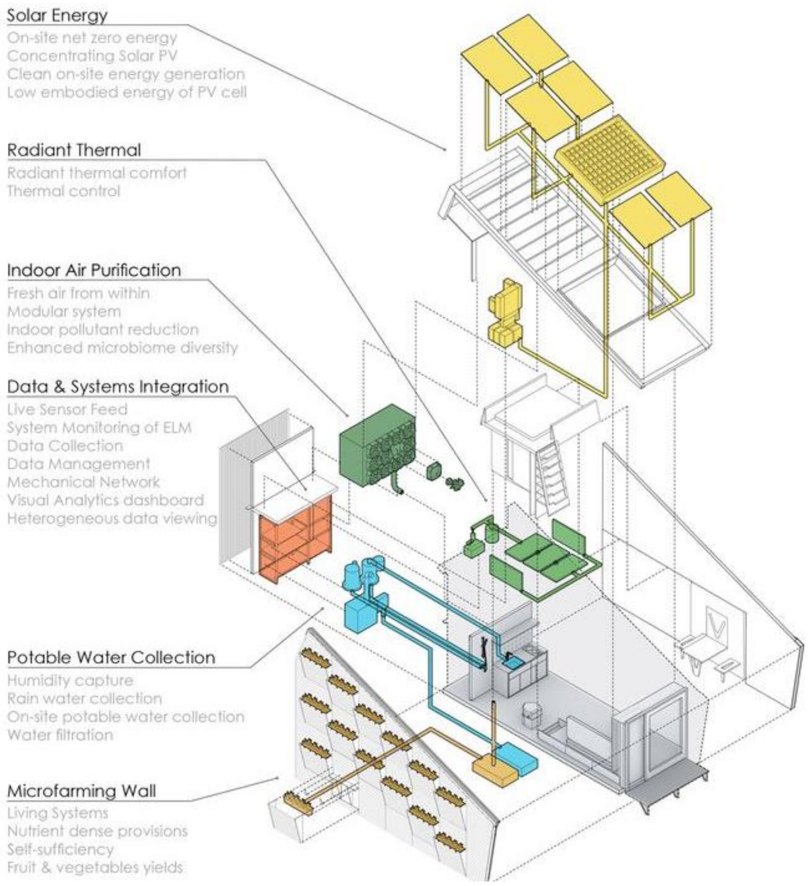

Fig. 2. Systems of the ELM (image form the ELM pamphlet by "UN Environment program" website)

ID	ITEM	SPECIFICATIONS	UNIT	DIMENSIONS				QUANTITY	AMOUNT
				equal parts	length	width	thick.		
1	5-ply CLT structural decking	5-layer CLT plywood panels used for the roof with dimensions 6.7 x 2.5 m. The wood species: yellow pine. The brand: Nordic Structures. A panel dimension could be formed with: Thickness from 89 to 267 mm, Lengths up to 19.5 m, and Maximum width 2.44 m.	m^3		6.70	2.50	0.26	4.36	
2	Black spruce CLT wall panels	This type is applied for the rear wall with dimension 2.5 x 4 sq.m, and for the lateral walls with approximate area: 14.6 sq.m The brand is: Structure Fusion.	m^3				0.07	1.72	
3	LVL main structure	It is the outline of the unit. The wood species: yellow pine. The short sides dimensions assumed: The long sides dimensions assumed:	m^3 m^3	4 2	2.50 6.70	0.20 0.20	0.24 0.24	0.48 0.64 1.12	
4	Wood framing	It is around 44 pieces, with different lengths. Considering the average length is 3.25 (the shortest height is 2.5 and the longest height is 4 m), and assuming thickness/width is around 8 - 10 cm.	m^3	42	3.25	0.08	0.08	0.87	
5	Wood fiber insulation	The wood species: yellow pine. Considering the average length is 3.25 m.	m^3	34	3.25	0.30	0.10	3.32	
6	Wood furring	The wood species: red cedar. Considering the average length is 3.25 m.	m^3	44	3.25	0.06	0.04	0.34	
7	Wood siding	The wood species: red cedar. Covering the three sides of the unit. The rear wall with dimensions 2.5 x 4 sq.m, and for the lateral walls with approximate area: 14.6 sq.m	m^3		3.25		0.04	0.98	
8	Polygal Multiwall Polycarbonate	The brand: Plaskolite Charlotte In the loft clerestory: 2 doors:	m^3 m^3	 2	0.80 2.20	2.50 1.50	0.03 0.03	0.06 0.20	
9	Microfarming wall	14 cells, make up 4.45 sq.m of the wall, integrated into the outer layer of the wall. They accommodate 9 kilograms of fruit & vegetable.	kg					9.00	
10	Paints and stains	The estimated quantity of paints and stains needed is 10 liters using the calculator of the brand. The brand: Benjamin Moore.	ltr					10.00	
11	Photovoltaic Solar Panels and Integrated Concentrated Solar	Clean energy generated from combined PV solar panels (6) and the Integrated concentrated solar panel, which is a system that reduces the building's solar heat gain and enhances interior daylight quality. The system produces 12KWh of energy per person per day. The solar panel brand: Brooklyn SolarWorks. The ICS brand: HeliOptix.	kWh					48	
12	Indoor Air Purification Plant Wall	In the loft clerestory. It is AMPS: Active Phytoremediation Wall System is a modular wall system of pods housing hydroponic plants.	m^2					1.10	
13	Composting toilet	The brand: Sun-Mar	m^2		0.70	0.60		0.42	
14	Bathroom fittings	The brand: Moen	m^2		0.75	0.60		0.45	
15	Kitchen	Fittings by the brand: Kingston Fixtures by the brand: Ruvati	m^2		1.20	0.50		0.60	
16	Water capture	The rainwater is collected through 20.9 sq.m surface in two main tanks, plus harvesting system that produces potable water from humidity in the ambient air. The system provide 20 Liters per person per day. Rainwater tank Greywater tank Potable water (cylinder)	m^3 m^3 m^3	 2	0.70 0.70	0.35 0.35	0.15 0.15	0.04 0.04 0.005	
									≥ 47,000 €

Fig. 3. Estimation of quantities of the ELM

ELM aimed to respond to the challenges set forth in the 2030 Agenda for Sustainable Development. It presents an exemplary design that reduces the carbon footprint and provides extremely healthy atmosphere for inhabitants. It includes high innovative systems to secure better urban life in informal settlements. From the table above, some systems are necessary for true self-sufficiency in energy and water, such as PV solar panels, rainwater collection with filtration system, and harvesting system for potable water. In this design, the Integrated Concentrating Solar Facade (ICSF) system was applied to fulfil the need for energy given the absence of wind turbine, which is a new approach of photovoltaic system: “a concentrating PV cell that produces electricity and captures the remaining solar energy as heat for domestic hot water, space heating and solar cooling” [(5)]. Such technologies and other are undoubtedly welcome but could be dispensable, or installed depending on the locale where the unit will be established, like “building-integrated active phytoremediation” systems that work on reducing the fresh air consumption requirements and contribute to significant energy saving in climates with high heating and cooling loads.

The exploration of ELM interprets the high cost. Apart from being built in USA, the technologies used are innovative and need to be supplied by specific companies in developed countries, in addition to the materialization stratigraphy that ensures high thermal comfort and certainly impacts the cost. Hence, implementing such autonomous off-grid units in refugee camps, especially in developing countries, inevitably requires employing available technologies and relying on natural means to the extent possible.

Nevertheless, for autonomous units, even when decreasing its cost, can’t be compared to economic shelters as products in terms of price. For instance, back to the comparison, ELM includes a 2kW solar system (which is always needed to generate sufficient energy for 4 persons), and the average cost of a 2kW solar system in USA -where it was built- is $5,540. Thus, if the costs of all the systems and fittings are extracted, only then will be comparable to IKEA Better Shelter.

The role of collaborative work:

Beside thinking of cost-effectiveness, employing expertise in how to make best use of money is a keystone in humanitarian responses management. Because even when funding streams are found and money is poured in, the maladministration and the lack of this expertise leads to surrendering to cheap short-term solutions “Across the industry, good ideas and know-how succumb to habit and the need for efficiency, which can stifle invention.”[(6)] So first, we need to emphasize on collaborative work among all actors, which is the most vital step forward applying innovative approaches and avoiding huge waste of money and human dignity. “Competing mandates and donor priorities, weak coordination, fragmented knowledge, and a complete disregard for environmental standards often characterize the failed practices that prevail after a disaster. These lead to new dangers as well as appalling and unconscionable waste.” [(6)]

For the autonomous shelter, it may require even more than collaboration. Working integrally through combining resources could resolve the financial aspect and push it to reality. It will thereafter strikingly depreciate expenditures of the services and future basic needs of the affected people that are paid/provided constantly by the NGOs. Most importantly, the autonomous shelter will stop the industry of humanitarian work and protect relief investment.

5. Achieved results:

The presented design of the autonomous unit, called H[E]AVEN, highlights important segments of the process; maximum energy potentials of the environment, adaptive interior, and futuristic exterior, all thanks to the spherical shape adopted. It includes only fundamental technologies and simple furniture, trying to balance the quality with the cost. The creation of a comfortable atmosphere and contemporary home feel was a priority just as protection to return self-worth to the affected population. The habitat is characterized by a micro-farming space for economic empowerment with forward-thinking to involve different types of micro business to enhance circular economy. The design concerns resistance and risk mitigation and ensures safe way of life through protection against severe storms and flooding.

5.1. Concept:

Choosing the shape of a sphere is supposed to heal up the situation in refugee camps on many levels. As a basic shape, it has many features that will allow for numerous advantages. It makes best use of solar gain and light, concentrates interior heat and uniforms temperature, as well as improves airflow and natural ventilation, all contribute to great energy savings. In addition, it is the perfect shape to resist wind forces since refugee camps are obviously situated in uninhabited lands, which means windy locations. Furthermore, the circular interior is considered much friendlier and reflects a sense of unity and protection for the inhabitants, evoking peacefulness and relaxation that are highly needed for displaced people.

5.1. Design System:

The design approach was about concentrating all generating and supply systems in the centre; pipes and cables are all gathered in a central column that connects equipment placed under the raised floor with the photovoltaic cells and wind turbine above, the thing that required positioning the utilities around the column. This approach contributes to reducing costs and facilitating maintenance greatly.
The rainwater is collected through two gutters, thanks to the streamlined surface, in three 150L water tanks linked to filtration systems, all beneath the unit. In this regard, the unit was raised 45 cm to protect against floods, so it was taken advantage of this move to localize equipment below in order to save interior space and help render effective operating system.
The solar cells are fixed to a rotatable panel to obtain maximum energy, with a surface area 4.8 m^2. The system, along with the wind turbine, is supposed to produce 2 kw per day on average.
As for ventilation, beside the presence of air handling unit among the equipment, the design of the envelop features ribbon apertures, up and down, to support airflow through the shelter.

Leaving the unit’s wrapper free of extensions and wiring is instrumental in material customization. The unit will be replicable and materialized according to each location. The approach also brings the potential of textile enclosure, whose properties will add high value to the unit’s performance. H[E]AVEN was presented with wooden wrapping, however, the investigation on the material and structural systems has not yet been carried out.

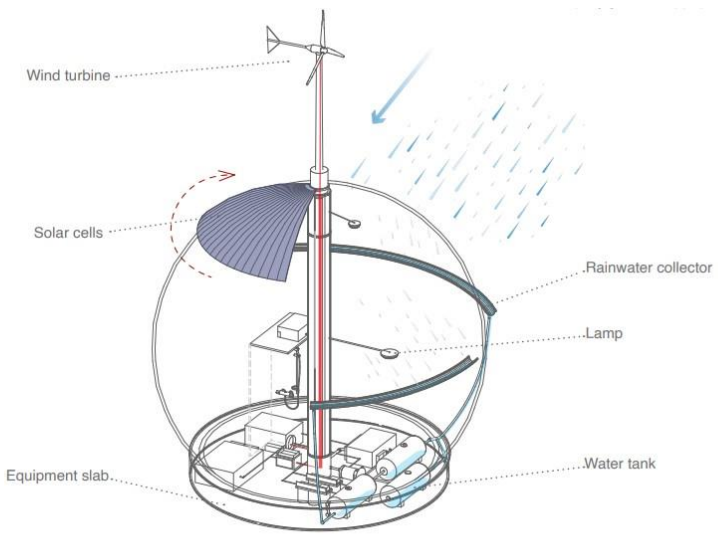

Fig. 4. The systems of H[E]AVEN

Fig. 5. Section

6. Interior:

H[E]AVEN is designed to accommodate a maximum of four people within 37 m^2 total internal floor area and maximum height 5.4 m. It consists of a sofa space, a small kitchen, shower, toilet, and micro farming room on the ground floor that is 15.58 m^2. While on the first floor (21.89 m^2), it includes two sleeping rooms, two- chairs sitting space, and additional space for vegetation. The micro-farming space in total occupies 6.80 m^2 out of the gross internal floor area. The design has adaptability feature; the partitions of the sleeping space could be fixed to another angle to enlarge or reduce the space, and the micro farming room down could be reused for other purposes or as an internal terrace. On the ground floor, storage space is provided under the stairs. A deployable table and two chairs are supposed to be used beside the deployable/inflatable sofa. The kitchenette includes a sink, mini refrigerator (85 cm in height), clothes washer, cooktops (2 burners), and shelves in the upper part. Whereas the tiny sleeping spaces up were treated through simple removable furniture: mattresses and shelves. All the doors are folded to save space.

Privacy is one of the most concerning cultural issues in refugee camps, which can’t be fully addressed without inside partitions and inside bathroom. The design responded to these criteria that would bring about positive changes in social life because it will restore self-confidence and dignity to the people.

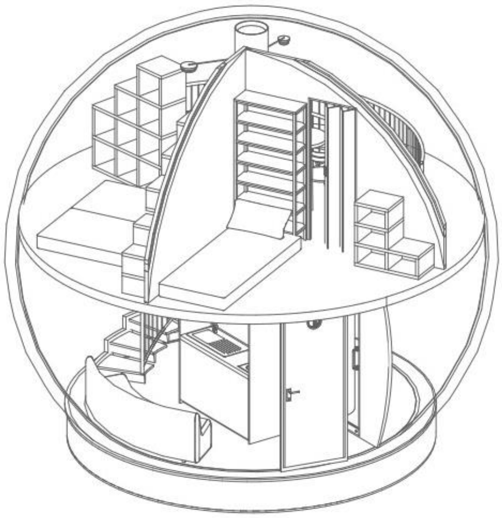

Fig. 6. Inside H[E]AVEN

Fig. 7. Final result

6. Conclusion and future work:

The project was based on the pillar [design and dignity] “Dignity is to design what justice is to law and health is to medicine, in the simplest terms, dignity is about knowing your intrinsic worth and seeing that worth reflected in the places you inhabit...” (7) This link emphasizes on the need for architects’ interventions and designerly approaches to affirm human dignity in humanitarian contexts, which is the only way to advance fragile communities and support social coexisting.

H[E]AVEN is a pathway to a radical solution in a temporary representation, which is a substantial approach that may resolve several contextual intractable problems. It aimed to demonstrate that innovation in sheltering responses is enough to give rebirth to the whole ambience. However, making it accessible to a large number of people is still a challenge. Subsequently, further development is highly needful to achieve even more effective result. The development will exclusively focus on building systems in terms of material customization and easily-erected structural systems, and how to be more regarding DIY approach. The future work will comprise studying insightfully the customization with innovative lightweight materials plus local materials for more than one site to accomplish best version of an autonomous humanitarian shelter.

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