Transitional architecture in emergency scenarios

Clickhouse case study: modular shelter made of advanced composite materials

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Extended Abstract

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1. Introduction

1.1. Context

At the end of 2014, more than 50 million people were either living in emergency or transitional shelter or in urgent need for them. The ever-growing numbers of disaster-affected people around the world represents large-scale humanitarian crises that urge humanitarian assistance response, so to ensure that the fundamental human rights such as the right to food, potable water, adequate shelter, education, and health are met. From the early emergency relief until reconstruction or return phase, the need for shelter is imperative for people's survival and crucial for an effective humanitarian response

Given that the reconstruction, securing land tenure or resettlement often takes several years, (between 2 to 15 years [1]), the commonly used emergency shelter relief solutions become inappropriate. Extending emergency or temporary shelter solutions beyond the strictly necessary, has proven to be the cause of delaying permanent reconstruction, affecting negatively the health, dignity, and livelihoods of the disaster-affected population, which leads to huge indirect costs at both the social and economic levels.

Therefore, a new shelter approach, for closing the existing gap between emergency shelter and permanent reconstruction, was needed and so the concept of transitional shelter was adopted by the humanitarian leading agencies with the assignment to coordinate the shelter's and settlement's humanitarian response.

Transitional shelter is an incremental process, not a final product, of supporting disaster-affected people to find alternative shelter options during the transitional period that runs from their displacement until the end of the reconstruction of their houses. It supports people to construct culturally and sustainable permanent shelters, starting from the initial relief items distributed post disaster.

Instead of diverting the funds of reconstruction through a typical 3-phase stage, namely relief, temporary and reconstruction phases, the transitional approach aims to integrate and reuse the incremental provided materials into the building of the permanent home. Beyond the initial protection, it aims to promote privacy, dignity, livelihood support, health, safety, and community.

1.2. State of the art in transitional shelter

Although no complete prefabricated shelter has proven to be able to meet the demanding requirements that a transitional period entails, mostly due to the lack of community involvement in the solution, cultural inappropriateness, delivery delays, and overall cost of the response, many attempts were made.

As the transitional shelter approach aims to “maximize the choice of shelter and settlement options for each household” the solution should allow “beneficiaries to recycle, upgrade, reuse, resell, and relocate their shelters as required, and through the selection of assistance methods provided.”[2]

That said a transitional shelter should enable:

1. Upgrade, into part of a permanent house;
2. Reuse, for different means than the original one;
3. Relocation, from a temporary site to a permanent one;
4. Resell, in parts or in the whole, for income generation; and
5. Recycle, in parts or in whole, for the reconstruction of permanent houses.

Additionally, as it aims to answer the shelter demands in an economically and environmentally sustainable way, both materials and human resources are preferably locally procured, so that local and regional economic development can be reinforced. Also fundamental for the success of the shelter solution, is the community involvement and participatory design to agree the standards, “considering local hazards, climate, available labor and skills, available material, traditional building practices, cultural requirements and social and household activities” [2], and therefore they should be an integral part of the strategical development plan carried in these situations.

However, whether in the case of unsustainability or unavailability of local material’s resources, the existence of alternative stockpiles of transitional shelter items or pre-fabricated shelter kits, along with its timely distribution, enabling the implementation of transitional shelter approach is desirable; requests more study and still wait for an efficient solution.

1.3. Case study: the Clickhouse project

In order to reflect on the transitional architecture’s theme, this dissertation will report on a pre-fabricated and modular transitional shelter’s case study development - the Clickhouse project -, from its inception to conclusion, to ultimately analyze and discuss its effectiveness to respond to emergency scenarios.

The Clickhouse´s project is the result of a collaborative investigation taken among *ALTO - perfis pultrudidos, Lda, Instituto Superior Técnico* and *Universidade do Minho* to build a prototype of an emergency/modular/transitional shelter in 2015 made of advanced composite materials, namely Glass fibers reinforced polymer (GFRP). The advantage of this material are its high ratios of stiffness/weight and resistance/weight, which enables it to withstand high loads, while being considerably lighter than similar structures; its insulation performance; and its durability in corrosive environments.

The purpose of the project was to develop a transitional shelter, which could be both used in emergency scenarios or in construction sites as transitional shelter for the displaced construction workers, a common issue regarding Portuguese construction companies currently spread in Mozambique, Angola, Morocco, Venezuela, Colombia, and Mexico.

The project goals were to guarantee a better performance at a competitive cost, when compared with the existing temporary shelter solutions in the market, regarding:

(i) lightness; (ii) ease of transportation; (iii) quickness and facility of assembling and disassembling; (iv) possibility/flexibility of reutilization; (v) fulfillment of structural safety and thermal performance regulation requirements and recent international recommendations for this type of housing; (vi) self-sufficiency regarding energy and water supply; and (vii) durability.[3]

Following a proposed performance ponderation of 15% for lightness; 15% for ease of transportation; 15% for quickness and facility of assembling and disassembling; 7,5 % for possibility/flexibility of reutilization; 10% for fulfillment of structural safety; 10 % for fulfillment of thermal performance regulation requirements; 10% for self-sufficiency regarding energy; 10% for self-sufficiency regarding water supply; and 7,5 % for durability.

2. Methods

The architectural design of the case study solution is the further development of a previous dissertation on the development of a constructive solution in advanced composite materials for emergency shelters [4]. The architectural contribution for the development of the Clickhouse system is the result of:

- the study of the specific guidelines, requirements, and program design for this kind of scenarios;
- the analysis of the construction constraints imposed by the chosen material; and
- the architectural study to improve its internal living conditions and optimize its functionality, versatility to address different uses, standardization of components, modularity and customization possibilities.

2.1. Guidelines, requirements, and program design study

The Sphere project [5], the Handbook for emergencies [6], and the UN Request for proposal for the provision of shelter solutions for different climates [7], were the main source for the study of the guidelines, requirements, and standards to consider in the development of the project.

The purpose of these publications is to, simultaneously, improve the humanitarian response quality to disaster-affected people, and enhancing the accountability of the humanitarian system in its response, while helping to set the program design for shelter and settlements, and mitigate the damages on the already affected-population.

The Sphere project framed the Humanitarian Charter, the Protection principles and the Core standards for humanitarian agents, and set what was to become the internationally recognized standards for the four life-saving sectors of human lives, namely: 1) Water supply and sanitation; 2) Food; 3) Shelter and settlement; and 4) Healthcare.

In the shelter and settlement chapter, it defined the right to a standard of adequate living to be [5]:

- Sufficient space and protection from cold, damp, heat, rain, wind or other threats to health, including structural hazards and disease vectors;
- Availability of services, facilities, materials and infrastructure;
- Affordability, habitability, accessibility, location and cultural appropriateness;
- Sustainable access to natural and common resources, including safe drinking water and energy for cooking, heating and lighting; sanitation and washing facilities; means of food storage; refuse disposal; site drainage; and emergency services;
- Appropriate siting of settlements and housing to provide safe access to healthcare services, schools, childcare centers and other social facilities and to livelihood opportunities; and
- Building materials and policies relating to housing construction that appropriately enable the expression of cultural identity and diversity of housing.

And then set the shelter and settlements aid response into 5 consecutive steps, namely:1) strategic planning; 2) settlement planning; 3) covered living space; 4) construction; and 5) environmental impact, defining for each one of them the goals to achieve, the actions to take, and guidance notes for monitor the plan implementation on the field.

Of all the quantitative standards regarding the provision of adequate shelter, the 3,5sqm/ covering living space is the one unanimously accepted.

Beyond that, the shelter solution should assess the specific weather conditions where it will be erected, so it can optimize thermal comfort, ventilation, and environmental protection. Likewise it should [7]:

- Provide sufficient covered area for activities such as sleeping, washing and dressing; care of infants, children and the ill or infirm; storage of food, water, household possessions and other key assets; cooking and eating indoors when required; and the common gathering of the household members;
- Be versatile enough to allow for living areas extensions and to climate adaptation;
- Be flexible in use so it could became adaptable to different local cultures and traditional practices;
- Be easily assembled and disassembled for relocation purposes leaving no significant ecological footprint into the environment;
- Be environmentally friendly. It should come from a sustainable source and be prone for recycling;
- Consider the possibility to evolve, by the inclusion capacity of its materials and/or structure, into long-term solutions;
- Be light and packed for cost-effective transport using a standard 20-foot shipping container, thus limiting cost of transport and storage.

2.2. Analysis of the construction constraints imposed by the chosen material and assembling process

The structure of this transitional shelter is composed of a frame of beams and columns, made of pultruded GFRP 12cm tubular profiles, where, for structural reasons, the floor panels have to be arranged alternately, which will affect the interior subdivision of the modules.

The walls, floor, and roof are made of sandwich panels composed by an insulation material in its core - rigid polyurethane foam – lined by two outer sheets of GFRP. The connections, between the structure and the panels and between the panels themselves, are accomplished by a female-male connection adhesively bonded to the beams and columns at the production facilities.

Due to economic constraints in purchasing the metal preform for the pultrusion process of other profiles than the ones already produced at ALTO´s, the assemblage of the roof, which follows a similar design approach as the other panels, dictated its slope to be only 1%. Similarly, the initial idea of using the GFRP profiles for the frame design of the shutters and windows had to be discarded, and led to the incorporation of PVC windows without a shading system.

2.3. Architectural study and input

The architectural design input to the project was to optimize the interior layout, regarding functionality, comfort and privacy; and optimizing the modular features of the shelter, regarding standardization of its components and aggregation of its cells.

For that matter, passive design techniques were taken into consideration, while a layout study based on the standardized dimensions of household appliances and furniture was conducted, and several typology studies, cell aggregation possibilities with customization of the module components were tested.

3. Results and discussion

After several geometrical studies, the proposed T0 shelter is composed of two coupled modules divided into 3 different spaces, namely bathroom, kitchen, and bedroom, as shown in Figure 1**.** The walls and floor panels will incorporate all the required networks for water supply, drainage, sewage, and electricity as further developed in the Clickhouse´s infrastructure task [8]. The dwelling’s entrance is made through the social module, which is composed of the kitchen and bathroom, and gives access to the bedroom module. While the social module will have all the infrastructure networks incorporated in its panels, the private module will only require the incorporation of the electricity network**.**

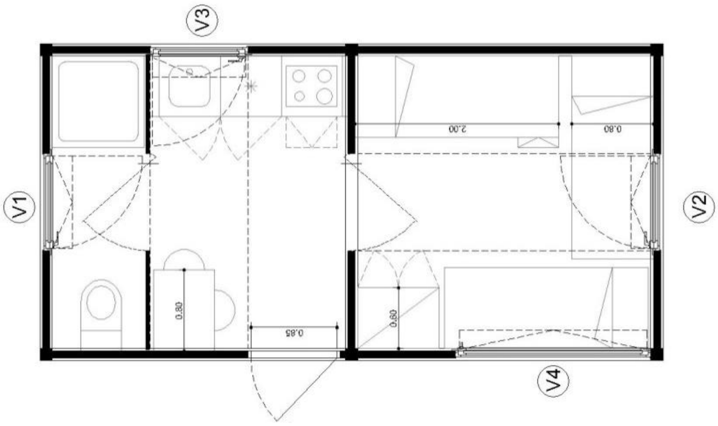


Figure 1 - Plan:T0 transitional shelter for a detached dwelling using two 2,88m^3 base module.

The bathroom occupies one third of the social module and includes a toilet basin and a shower base, being the washbasin disregarded due to its proximity with the kitchen sink. The kitchen includes three 60cm base modules, which obligatory incorporate the sink and can include the hotplate, oven, and refrigerator when required. Additionally, there could be a small table and side chairs. The bedroom accommodates space for three single beds or three 2-storey bunks. However, for complying with the minimum covering living space suggested by Sphere [5], this T0, with its 19m^2 gross built area should not accommodate more than four people, and so it was designed to include two single beds and one 2-storey bunk. The arrangement of the windows, and door, was intended to promote cross ventilation as shown in Figure 2. Every compartment has at least one opening for ventilation and natural lighting purposes. The bathroom and kitchen have one PVC window each, while the bedroom has two. The glazing was replaced by a 16mm translucent polycarbonate with 60% of light transmissibility but good energy performance [9], and the window frame was equipped with a mosquito net from the outside for health issues.

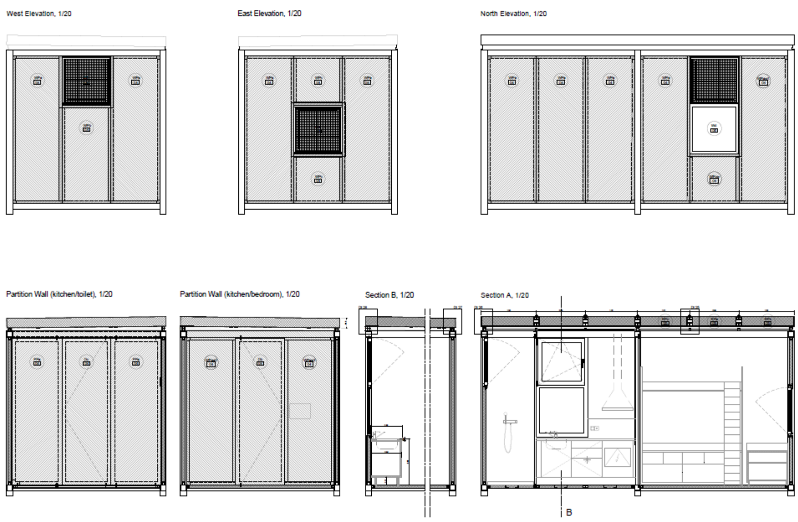


Figure 2 – Elevations and Section: Windows's arrangement in the T0 shelter

There are two sizes of window frames, occupying one or two-thirds of a panel, but three types of windows. The squared windows are positioned at different heights for both functional and privacy reasons.

Once the sanitation facilities had been incorporated in part of a standardized module, it became necessary to develop a partition wall system that allowed subdividing the module. It had to be lightweight and easily assembled, and disassembled, in the already existing construction process. The solution found for the partition walls, consists of thinner sandwich panels framed inside by a rectangular compact GFRP profile. The connection between each panel, the floor, and the upper beam is accomplished through metal pivots, arranged at the lower and upper part of the panel frame, i.e. at the rails. The panel is then 2,5cm smaller than the height of the structural frame so it allows the required operation space to assemble the panel into, first, the upper and, second, the lower pre-drilled profiles. Wherever one of these panels is intended to be a door, instead of being fitted by 4 metal pivots, it only needs 2 vertically aligned pivots and becomes a pivoting door. Figure 3 illustrates the partition wall and door elevation, as well as its horizontal and vertical sections, depending on its assemblage being on the panel-to-panel connection (left vertical section) or on the structural frame (right vertical section).

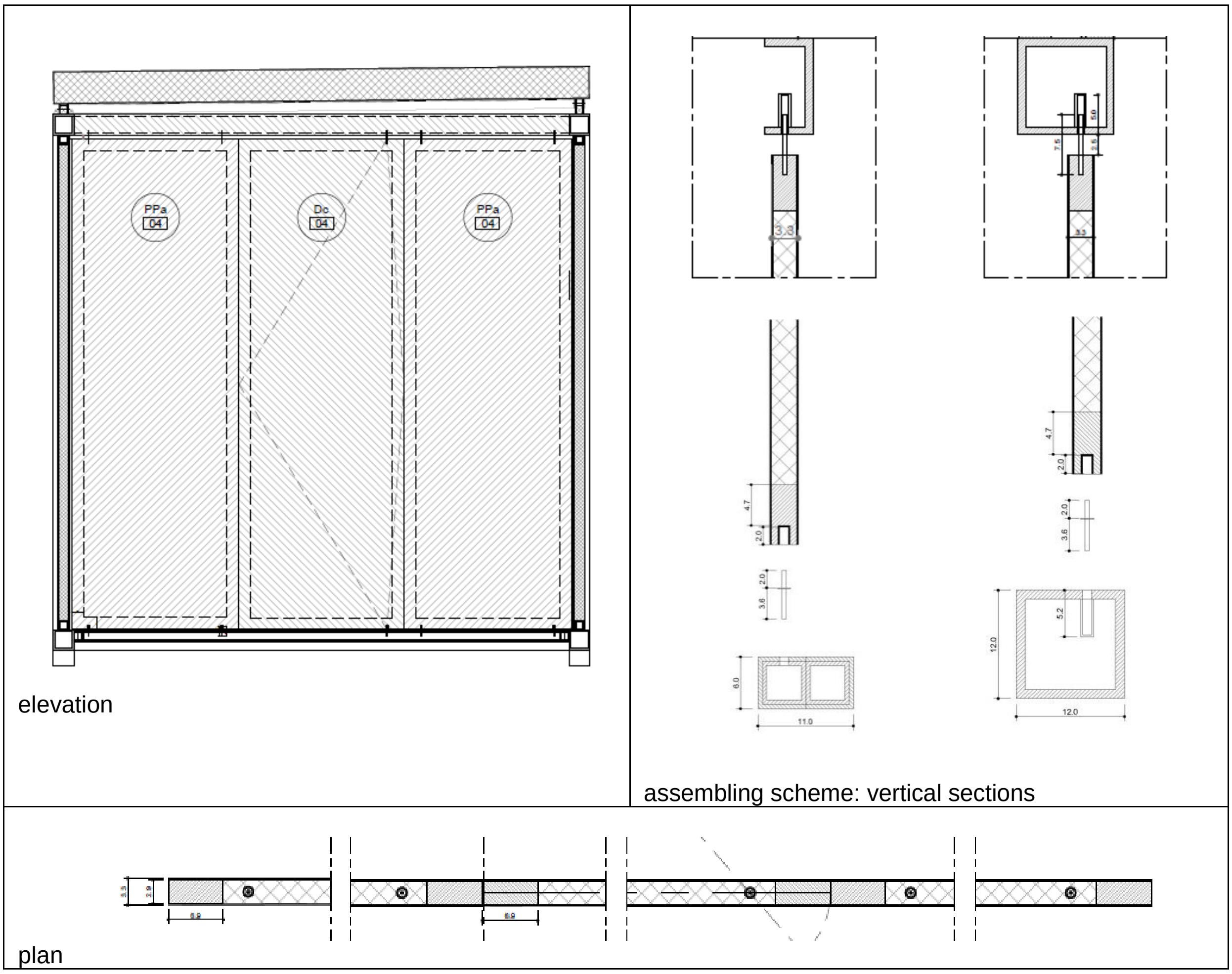
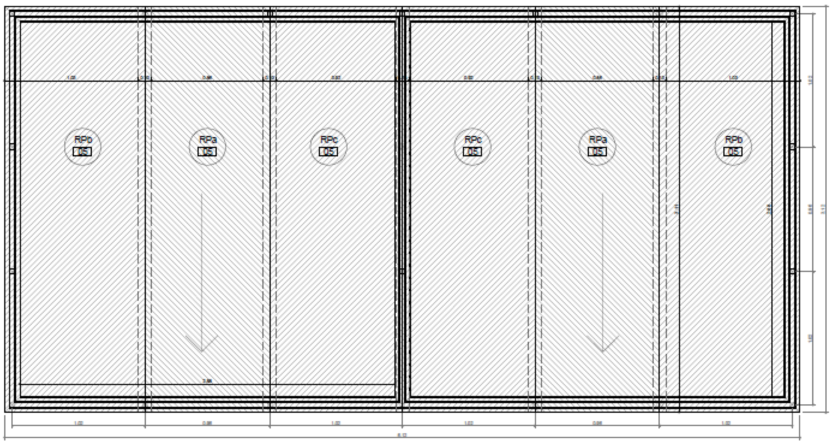


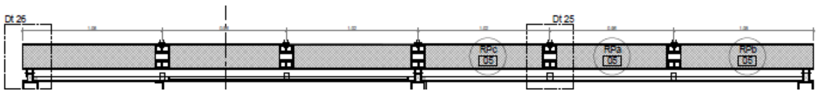
Figure 3 - Partition wall and door construction system

The design approach of the roof followed the same premises as the other components. It had to be split into smaller panels so it could easily be transported and assembled. Initially, it was thought to incorporate the shelter water storage tank, but later that idea was discarded due to increased complexity in the panels manufacturing. For prototyping sake, it was decided that the shelter should be designed for a warm and dry climate, and so the solution followed a flat roof.

The roof of one module is composed of three panels. If grouped only in one direction as shown in Figure 4, and depending on the module's working independently or in aggregation, there will be a need for 2 to 3 different panels, respectively.



plan



section

Figure 4 - Flat roof solution

As the project aims for a one-fits-all modular solution, in which the height of the ceiling is directly related with the height of the structural frame of the shelter, unless there is a different roof and roof's assembly, the volume will remain the same, regardless the shelter is set in a warm or cold climate. Additionally, for use in other than dry climates, there will be a need to provide for a gable roof, with adequate overhangs for the rainwater's and snow's drainage. Therefore, in order to adapt the shelter to these different climate circumstances it is necessary to develop special components that can address both issues of volume and roof drainage.

Furthermore, in order to adapt the shelter for the high levels of humidity of the tropical climates, its walls should be able to maximize ventilation, which as it is they cannot, and so different wall panels would be required.

Another option for addressing tropical climates could be to considering a hybrid Clickhouse shelter, i.e., combining the GFRP Clickhouse's structure and floor panels with local materials for the construction of the other surfaces. Besides the shelter's thermal performance improvement, it would become more culturally appropriate and would ultimately comply with the transitional shelter approach of incorporating local materials and resources in its incremental process.

From a merely theoretical point of view, the module's aggregation possibilities are endless. The structure could be expanded in both directions and simultaneously. However, because the design of the connections between the structural GFRP frame and the reinforced concrete footings only allows heights adjustments of up to 60mm [10], the shelter should be built on a site with a maximum 1 to 2% step, which, depending on the location, could conditioned the correct water drainage and prevention of standing water.

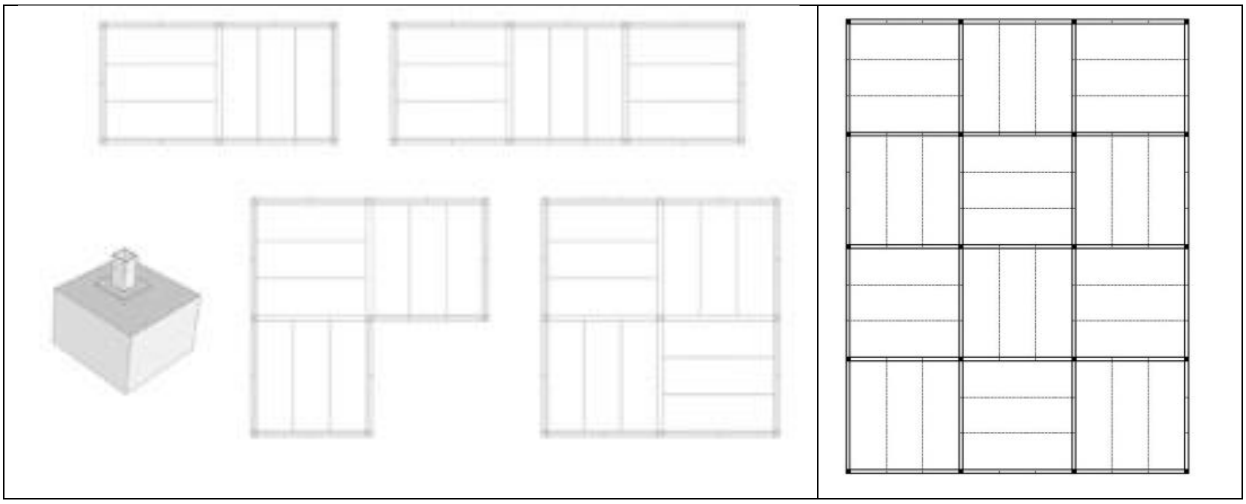


Figure 5 – Reinforced concrete footing [10] and module aggregation structure

If the shelter is manufactured in mass production, it is expected that the production time is 1,5 shelters per week after one initial week to set up a new manufacturing process. It can be packed in volumes of 330 x 230 x 230 meters, approximately, weighting each nearly 2.2 tons. However in order to accommodate two shelters per 20 ft, it will have to be packed in a staggered way.

On the other hand, and for transitional shelter purposes only, if one thinks of the supply of a reduced shelter kit, composed by the structural frame and the floor panels, weighting less than 1 ton, then a 20 ft. container could accommodate up to 11 transitional shelter kits. The ALTO's storage capacity would rise to approximately 100 kits, instead of 20, while the lead time of each kit would drop to 1,5 days.

That means that it would take approximately 2,5 weeks for filling a 20 ft. container, after the 1 week preparation for the pultrusion process, with 11 transitional shelter kits, instead of the 2 weeks required for the filling of the same container with only two complete T0's kits.

Nevertheless the 7.000 € for the production of the transitional shelter kit consisting of the GFRP structural frame and the sandwich floor panels, may not be appropriate for transitional shelter purposes, when compared with the average investment of approximately 1.850€ for this kind of shelter during the last decade. [1][11][12][14]. Additionally, the ALTO's production capacity of less than 250 transitional shelter kits per year is far from the average 5.000 shelter requested in these events.

4. Conclusions

Transitional shelter for emergency scenarios is a complex subject to address and solve. The specificity of the requirements of such solutions is demanding and multidisciplinary. The strategically planning for a humanitarian response entails huge economic and political decisions, in which the shelter solution, that has a great social and economic repercussion on the livelihoods of the people, must be quickly dictated. For that reason we think that architectural professionals should become more engaged in this thematic so they can contribute for the design of the best solution.

Regarding the Clickhouse case study effectiveness to address emergency scenarios, we can foresee this pre-fabricated modular solution entails some logistical and economic issues difficult to overcome if becoming a mass solution in such events. Although it responds to the most demanding structural and design criteria, has a good lifespan, can be upgraded, reused, resold in part for revenue or can be integrated into a durable shelter solution, it falls short of the logistical and cost criteria. It is predictable that the Clickhouse's transitional shelter kit is difficult to deliver wherever and whenever required, at the right quantity, and at a competitive cost. Additionally its weight and volume makes it difficult to be relocated. It also comprehends some limitations regarding climate's adaptation versatility and its capacity to be acculturated and accepted by different peoples.

However, the Clickhouse construction system may be an interesting solution for other purposes rather than of the transitional shelter one. Its pre-fabricated modular components can offer a great variety of shelter solutions to be used at different temporary scenarios such as construction sites, among others. Analyzing the Clickhouse outcome through the proposed performance criteria and its ponderation, we can estimate that the project accomplished 80% of its innovative goals. It failed to fulfil the thermal performance regulation requirements, when performing in different climates, and to be self-sufficiency regarding energy and water supply. Nevertheless, it was successful in being able to fulfill structural safety performance regulations, be able to be shipped in a 20-foot container, be easily assembled and disassemble by unskilled labor with only basic tools, be flexible in its uses through module aggregations, offer possibility of reutilization through more than 5 years lifespan, and be easily maintained.

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