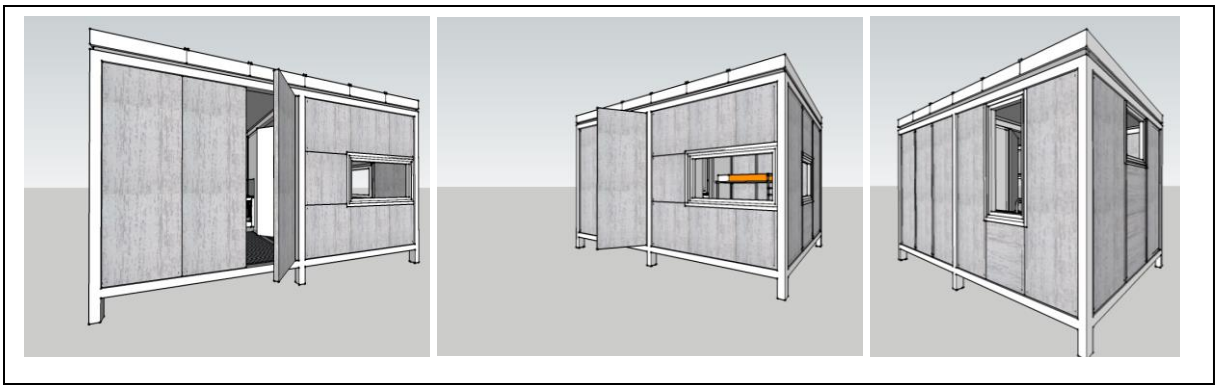

Transitional architecture in emergency scenarios

Clickhouse case study: modular shelter made of advanced composite materials

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Thesis to obtain the Master of Science Degree in

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Abstract

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 purpose of the project was to develop a transitional shelter in advanced composite materials, namely Glass fibers reinforced polymer (GFRP), which could be both used in emergency scenarios or in construction sites as transitional shelter for the displaced construction workers.

The architectural design of this solution results of the study of the specific guidelines, requirements and program design for this kind of buildings; the construction constraints of the chosen material; and the architectural opportunities to improve the shelter living conditions, its functionality and its versatility to address different uses.

As much other pre-fabricated and modular solutions, the Clickhouse's shelter entail some logistical and economic issues difficult to overcome if becoming a mass solution in emergency scenarios. However, its pre-fabricated modular components can offer a great variety of shelter solutions that may be interesting for other purposes rather than emergency shelter.

Keywords: Transitional architecture; Transitional shelter; T-shelter; Pre-fabricated shelter; Modular shelter, Advanced composite materials

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Acronyms

CCCM	Camp Coordination and Camp Management
DDR	Disaster Risk Reduction
GSC	Global Shelter Cluster
IASC	Inter-Agency Standing Committee
IDP	Internally Displaced Person
IFRC	International Federation of Red Cross and Red Crescent Societies
IOM	International Organization for Migration
NFI	Non-Food item
NGO	Non-Governmental Organization
NRC	Norwegian Refugee Council
RFP	Request for Proposal
SIP	Structural Insulated Panel
SWOT	Strength, Weakness, Opportunities and Threats
TOR	Terms of Reference
UN	United Nations
UN-HABITAT	United Nations Human Settlements Programme
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
WASH	Water supply, sanitation and hygiene

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 [1]. Either forced to leave their homes due to man-made conflicts or natural disasters, e.g. earthquake, drought, flood, fire, hurricane, tornado, tidal wave, explosion, epidemic, the number of refugees and Internal Displaced People (IDP) has not stopped growing, reaching in the last year, according to the annual figures from the Norwegian Refugee Council's (NRC), 30.000 people a day. Figure 1 illustrates this evolution over the last decades.

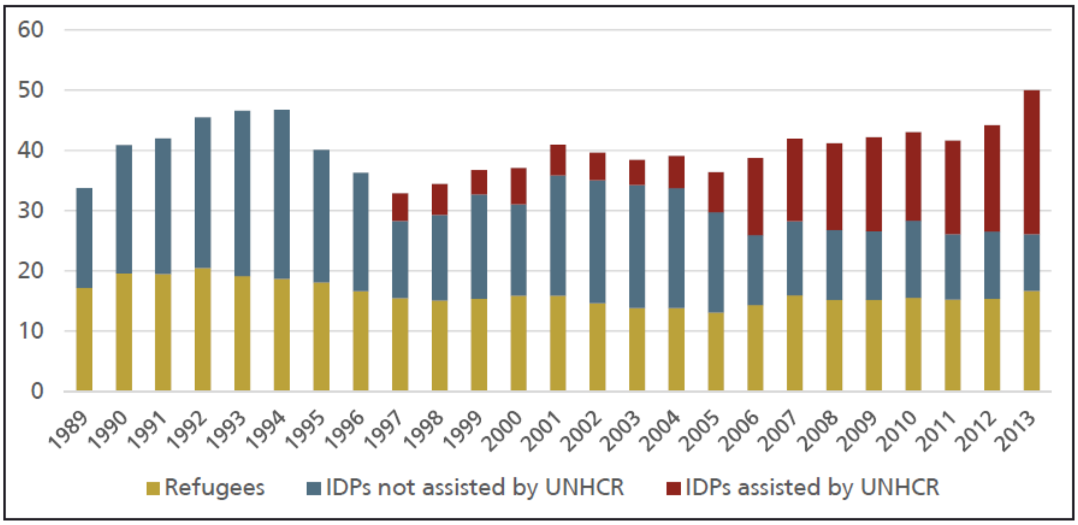


Figure 1 – Refugee and IDP over time (millions). Image taken from [2]

These 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. The quantity of affected people, its geographical distribution, and need for multi-sectoral assistance, requires complex multidisciplinary responses and strong coordination among all sectors and actors involved.

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. Failing to provide adequate shelter can undermine the survival and resilience capability of the people, even if assistance in the other life-saving sectors is being timely provided.

In order to coordinate activities related with the right to adequate shelter, including site and urban planning, the Inter-Agency Standing Committee (IASC) created the Global Shelter Cluster (GSC). Among its 35 global partners, the GSC is co-chaired by United Nations High Commissioner for Refugees (UNHCR), the leading agency for shelter in conflict situations, and by International Federation of Red Cross and Red Crescent Societies (IFRC) in natural disaster situations.

Figure 2 illustrates the mapping of on-going active shelter programs, as well as the agencies leading each of them.

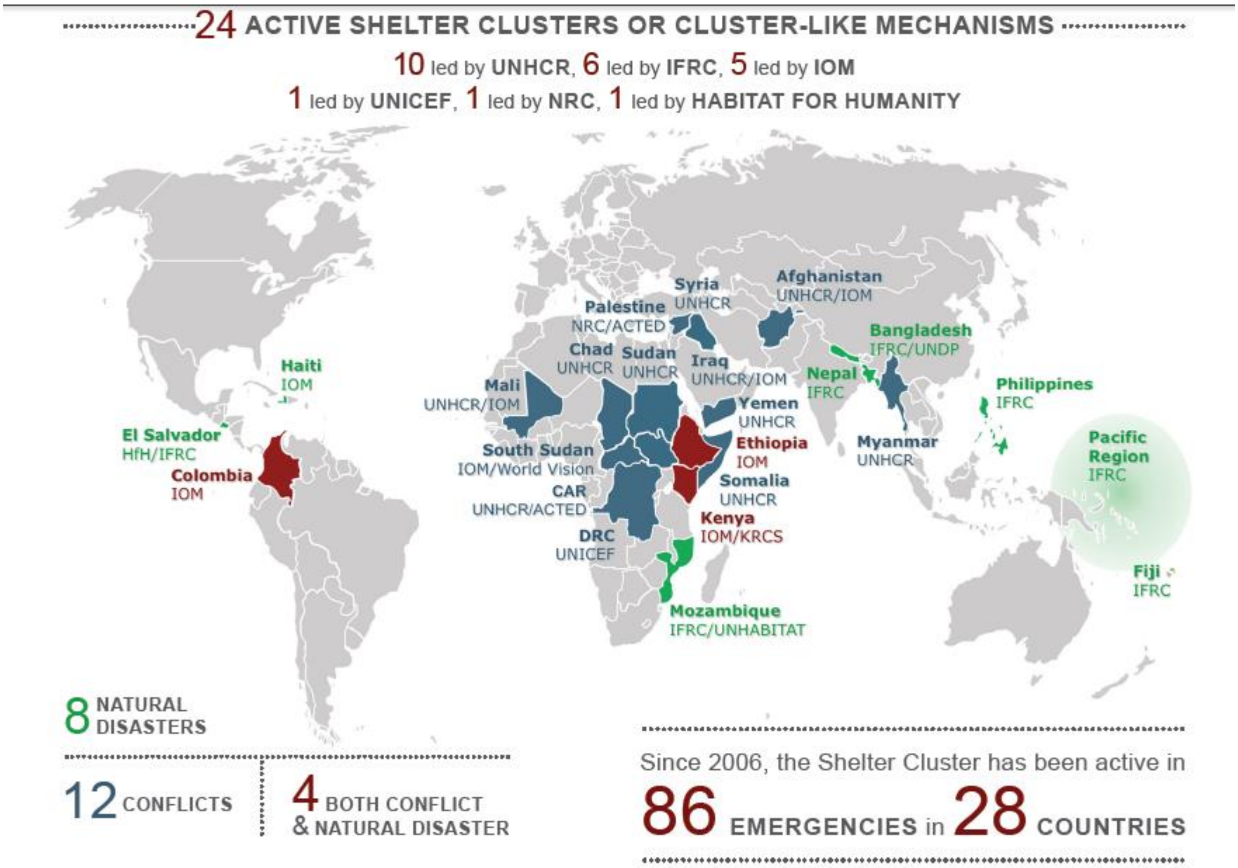


Figure 2 - Current coordination of active shelter clusters around the world. Image taken from [3]

Given that the reconstruction, securing land tenure or resettlement often takes several years, (between 2 to 15 years [4]), commonly used emergency shelter relief solutions, such as tents, might not be the most suitable solution for all families and situations. Although it will enable survival in the short time, for longer periods it will negatively affect the health, dignity, and livelihoods of its inhabitants, leading thus to huge indirect costs at both the social and economic level.

Bearing that in mind, one possible shelter solution is providing those families with the means to begin reconstruction immediately after the disaster through the transitional shelter approach, considering it is a suitable solution and that it takes part of an inter-sector strategy for shelter, settlements and reconstruction. Transitional shelter is an incremental process of supporting disaster-affected 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. **Figure 3** illustrates the transitional shelter concept, which when well implemented has proven to be more cost-effective in the long run.

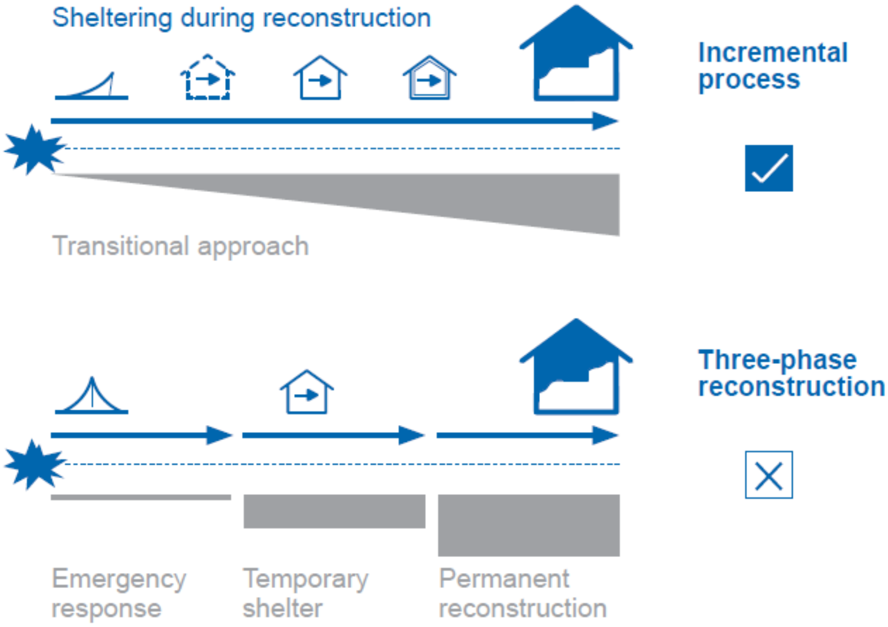


Figure 3 - Transitional shelter as an incremental process rather than a multi-phased approach. Image taken from [7]

1.2. Clickhouse project

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.

After an initial assessment and comparison among existing transitional shelter solutions in the market [5], the consortium come to the conclusion that none of the existent transitional shelters solutions, being high or low performance construction solutions, could meet the desired requirements. The low performance solutions - sand/earth bags, plastic or inflatable tents, hardening plastic or plywood - typically fail to bear the design loads standards, whereas the high performance solutions - wood sandwich panels, wood’s or metal’s Structural Insulated Panels (SIP), composite materials, metal, or concrete - typically requires skilled labor and comprehends a prohibitive cost for such purpose. The fact that any of the existing solutions could comply with the requirements, proposed an interesting challenge to overcome and an opportunity to explore the GFRP potentialities in doing so.

That said, the innovative goals the project proposed to accomplish were to guarantee a better performance at a competitive cost 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.[6]

Table 1 summarizes the criteria in which the Clickhouse project will be tested, comparing it with the existing market solutions.

Table 1- Clickhouse I&D proposal goals. Adapted from [6]

Innovative features	**Unit of measurement**	**Market assessment**	**Project goals**	**Relative importance (%)**
Lightness	Ton and Kg/m^2	> 2,5 Tons	< 2,5 Tons	15%
Ease of transportation	Container 12 x 2,34 x 2,38m	Do not fit	Fit	15%
Quickness and facility of assembling and disassembling	Men x day	3 x 10h	3 x 2 days	15%
Reuse	Possible to be assembled and disassembled many times	Hardly	Yes	7,5%
Structural performance	Degree of compliance with regulatory requirements	75 - 90%	100%	10%
Thermal performance	Degree of compliance with regulatory requirements in different climatic zones	50%	100%	10%
Self-sufficiency regarding energy	Percentage of energy supply needs met	0%	100%	10%
Self-sufficiency regarding water supply	Percentage of satisfied water supply needs in different climatic zones	50%	100%	10%

Durability and maintenance requirements	10 years expenditure versus initial cost	> 50%	10 – 20%	7,5%
Total				**100%**

1.3. Methodology and dissertation structure

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, first, reflect on the transitional architecture's theme, and, second, test it against the transitional shelter requirements [7], [16][18]so as to analyze and discuss its effectiveness to respond to emergency scenarios.

The architectural design of this solution is the further development of a previous dissertation on the development of a constructive solution in advanced composite materials for emergency shelters [5]. It results of the study of the specific requirements and program design for this kind of buildings, the construction constraints of the chosen material and the architectural opportunities to address with this modular construction.

The dissertation is divided into 7 chapters. The first chapter introduces the context, relevance of the theme, the goals of the case study's project and of the dissertation, as well as the methodology used in the development of the project and of the dissertation. The second chapter presents the state of the art in transitional shelter and planned camps and the principles into which the case study will be tested against. The third chapter presents the principles, guidelines, requirements and the more commonly accepted standards regarding transitional shelters and dwellings that will be considered in the design solution. The fourth chapter is about the restrictions and constrains imposed by the material solution of the project to the architectural input. The fifth chapter describes the design approach of the project focusing on what architecture can bring into the construction. The sixth chapter presents the results and initiates the discussion of its potential uses and its further implications. The final chapter draws the conclusions on transitional architecture, on the Clickhouse's system effectiveness to respond to emergency scenarios as a transitional shelter, and on the Clickhouse's project potential to address other uses rather than emergency scenarios.

2. State of the art in transitional shelter

2.1. Transitional shelter and settlements

Transitional shelter is an incremental process, not a final product, of supporting disaster-affected families to find alternative shelter options during the transitional period that runs from their displacement until the end of the reconstruction of their houses. Figure 4 illustrates this concept.

Figure 4 – Transitional shelter's timeline. Image taken from [7]

It should not be mistaken with either pre-fabricated, temporary houses or core houses solutions. Transitional shelter is mainly designed and built by the affected community. It aims to answer shelter demands in an economically and environmentally sustainable way, and therefore both materials and resources are preferably locally procured, so that local and regional economic development can be reinforced. Furthermore, entire pre-fabrication and import, not only results in the lack of community involvement, but often creates delivery delays, which introduces the need for another construction phase and thus raises the overall cost of the response.

In transition periods, where uncertainty regarding the future plays a preponderant role in the lives of the people, it is rather important that the shelter response not only minimizes the constraints imposed on their future choices but also offers a range of different opportunities that allows them to pursue the best path for their own recovery. Having that in mind, the transitional shelter is grounded on five distinctive characteristics [7], namely:

1. It is upgradable into part of a permanent house;
2. It is reusable for different means than the original one;
3. It can be relocated from a temporary site to a permanent one;
4. It can be resold, in parts or in the whole, for income generation; and
5. It can be recyclable, in parts or in whole, for the reconstruction of permanent houses.

That said, in a transitional shelter solution, its inhabitants must be able to upgrade their shelter over time so it becomes a permanent home. It must be achievable through maintenance, extension, or materials replacement. Once parallel reconstruction is completed, the transitional shelter may also be used for another function such as, and among others, an external kitchen, or family business exploitation. As land tenure is often one of the greatest issues, it is important that it can easily be disassembled for relocation purposes. In addition, its dismantlement should allow its materials to be sold as a source of revenue, or recycled into the construction of a permanent solution.

The appropriateness of the transitional shelter approach among other available solutions, namely hosting with families, settling at collective centers, urban self-settlement, rural self-settlement, self-settle camps, or planned camps, must be comprehensively checked prior to its implementation. However, the transitional shelter approach can also support displaced population as part of a transitional settlement programme in any one of these settlement options. Checking for its appropriateness should account the 10 principles on which transitional shelter is built [7], namely:

1. Situation assessment;
2. Community involvement;
3. Strategy's development;
4. Vulnerability reduction;
5. Agreement of standards;
6. Choice's maximization;
7. Time buying;
8. Process incrementation;
9. Site planning; and
10. Re-construction.

For each alternative, a careful analysis of these 10 principles should be performed, considering namely:

- **The situation assessment:** The transitional shelter's strengths, weaknesses, opportunities, and threats (SWOT) should be properly assessed prior to selecting it among the other options. SWOT analyses should consider the desirable solution lifespan, availability of resources, materials procurement, economic opportunities, cost, and beneficiaries' expectations, among other factors.
- **The community involvement:** Knowing that the affected population will likely make the greatest effort in the reconstruction, one should seek community involvement for an efficient and cost effective response. Involvement also brings sense of purpose and with it hope and fulfilment. In addition, the community will bring valuable input to the program, communicating their needs, capacities, and knowledge.
- **A strategy development and vulnerability reduction**: Transitional shelter programs should be part of a "comprehensive inter-sector shelter strategy that considers camp coordination and camp management (CCCM), early recovery, health, protection and water supply, sanitation and hygiene (WASH) issues" [7] in support of the entire population and until the completion of their permanent shelters. They should contribute to disaster risk reduction (DRR) "by using site selection, site preparation, shelter design and construction as a platform for communicating hazard resilient techniques and best practice and by building capacity within the affected population" [7].

- **The agreement of standards:** Transitional shelter does not follow any universal design standards. Its standards should instead be agreed upon, through participatory design, and considering "local hazards, climate, available labor, and skills, available material, traditional building practices, cultural requirements and social and household activities" [7].
- **The maximization of choices**: "The design and construction of the shelters themselves should maximize the choice of shelter and settlement options for each household by allowing beneficiaries to recycle, upgrade, reuse, resell, and relocate their shelters as required, and through the selection of assistance methods provided." [7]
- **Buying time**: As sustainable reconstruction after a disaster, considering participatory design, securing land tenure, and standards agreement, usually takes several years to complete, transitional shelter's incremental approach enables the affected community to buy some time while in that process.
- **The process incrementation:** "The process of sheltering should start with the first distribution of relief items and offer opportunities for incremental upgrading, reusing, reselling, or recycling by beneficiaries at their own pace until durable shelter solutions are achieved" [7]. It is not an additional phase and runs along with reconstruction.
- **The site planning:** Transitional shelter programs should be object of site planning, where hazard risk reduction, zoning, and services are integrated. It is worth mentioning that the location is often more important than its design itself. [7]
- **The re-construction:** Transitional shelter programs must contribute to re-construction programs "through the process of being upgraded, reused, recycled, or resold." [7]

Beyond the appropriateness of the transitional shelter approach, program managers should also have to consider the internal capacities of the affected population, both technical and financial, to conduct the transitional program. Internal capacities should include human resources, logistical capacities, partnership organizations, funding and budgeting/accounting structures.

Then a number of factors must be considered for the design of the transitional shelter and a design brief should be developed. It should balance many competing factors ranging. It should comply with the five characteristics that defines a transitional shelter, reflects the needs, local culture, capacities and available resources; contribute do DRR; consider the logistical implications of the implementation of the program; the lifespan of the solution; its internal conditions; the equity of the response; and its cost. Figure 5 illustrates how those factors must be weighted, bearing in mind that:

1. Transitional shelter is not intended to withstand natural hazards of the same magnitude that may have caused the original displacement. Nevertheless, it should be designed to not cause harm if it collapse; and
2. The criteria to which the design will have to respond varies significantly between contexts, meaning that design solutions are often specific to a particular situation, and hardly a one-fits-all solution.

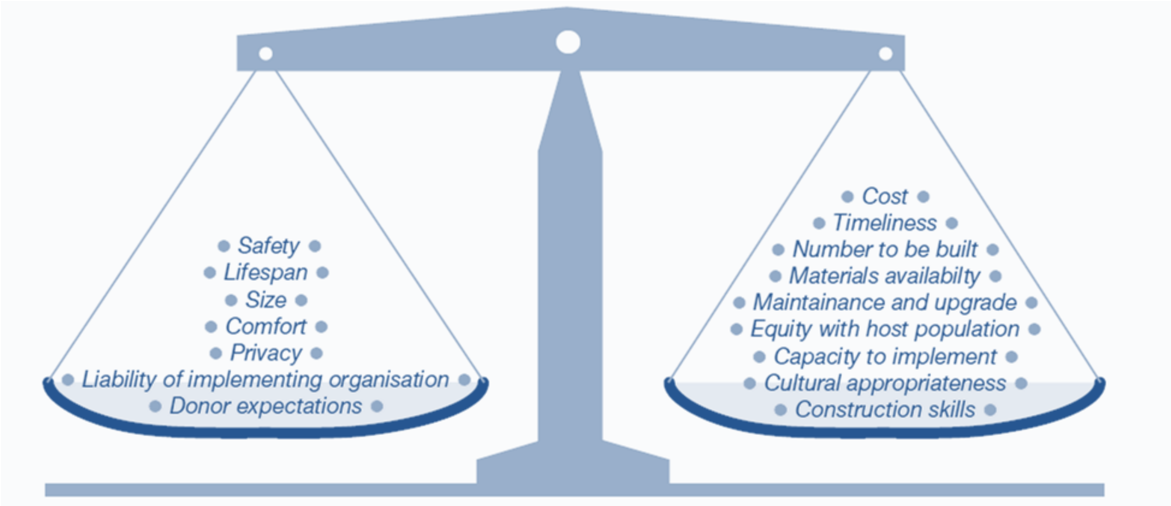


Figure 5 - Balancing competing factors as a design tool for transitional shelter solution. Image taken from [4]

Additionally, the transitional shelter program should also consider the availability of assistance methods to conduct the plan. It includes selecting and considering:

- which labor methods are available - ranging from self-help, community, direct, to contract work;
- which material methods should be procured - from local construction items, pre-fabricated parts, to imported materials;
- which quality assurance methods should be required - from technical expertise, to capacity building; and
- which support methods options could be integrated in the plan - ranging from cash, market interventions, to infrastructure and settlement planning.

Figure 6 summarizes the assistance methods to consider for shelter and settlements planning purposes.

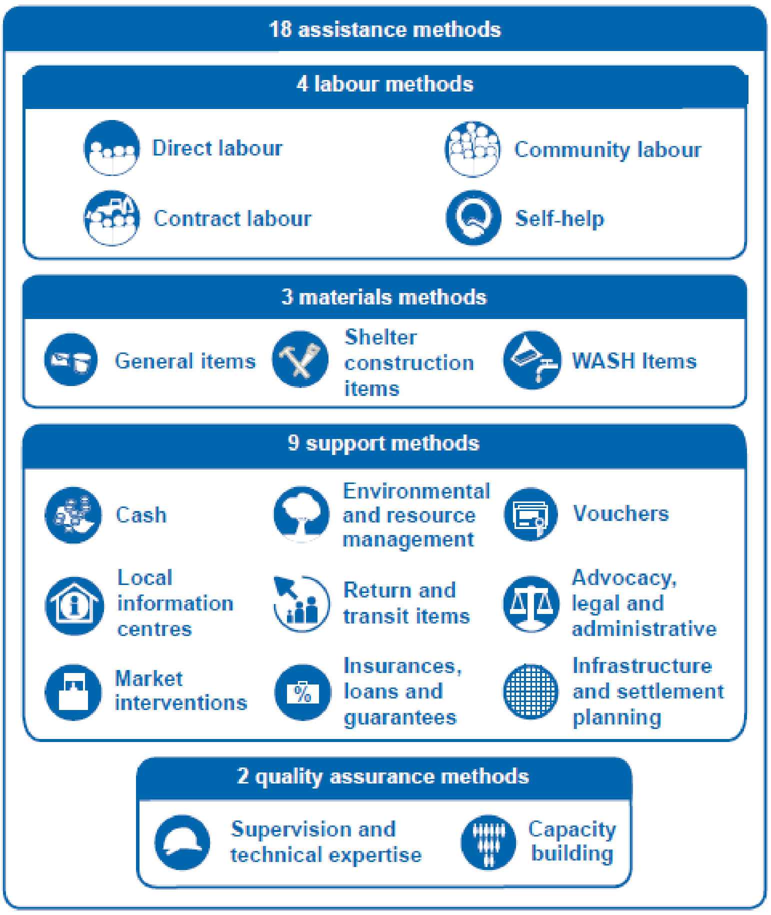


Figure 6 – Assistance methods for transitional shelter. Image taken from [4]

Although the budget availability for transitional shelter programs is a determinant factor on the design approach, it is worth mentioning that the solution should reflect the income level of the affected and host population, so that the aim of offering an effective and equitable response to all can be achieved. Table 2 summarizes the most common negative implications of a transitional shelter failing to meet the acceptable standards of living.

Table 2 – Transitional shelters design's risks of being at too high or too low standard or cost. Image taken from [4]

Too high	Too low
Programmes risk being slow, and the shelters being delivered too late for the transitional phase of a response.	Shelters may risk collapse and inhabitants risk injury.
Number of shelters that you can afford to build is small, limiting the number of people that the project can support.	Shelters may be refused by affectees.
	The quality of materials is low and not sufficiently durable to be reused in a permanent house.
Shelters risk being to a higher standard than for households who will not receive a shelter. This can lead to divisions in society and increased dependance for future disasters.	The design life of the shelters will be too short.

Despite, and for the reasons already mentioned above, the inclusion of local materials be of paramount concern of this kind of design approach, international procurement occasionally are also required and become a valid option to respond to local capacity shortages or disruption of production due to the exceptionally high demand that this kind of situations impose. Figure 7 illustrates the typical post-disaster supply demands.

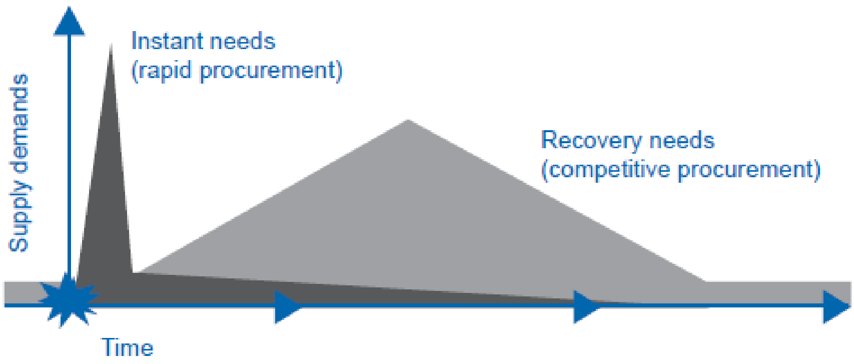


Figure 7 – Post-disaster supply demands. Image taken from [7]

Whether in the case of unsustainability or unavailability of local material's resources, the existence of alternative stockpiles of transitional shelter items, may make the difference between delivering the first items within the first phase of the humanitarian response, enabling thus the implementation of the transitional shelter approach. In such cases, the timely distribution of pre-fabricated items or shelter kits is desirable, and as long as it does not contradict the principles of the transitional shelter, it can also be appropriate. It is worth mentioning that the complete import of prefabricated shelter units contradicts several principles of the transitional shelter. However, the delivery of transitional shelter's prefabricated parts, which enable further upgrading of the shelter with local materials, along with the flexibility, versatility, and adaptation of use by its inhabitants, as well as its relocation, resale or recycling, does not necessarily go against the transitional shelter principles.

2.2. Transitional shelter prototypes and existing solutions

Acknowledging the challenges that local construction industry faces in these situations, a consortium of leading humanitarian actors launched in 2008 a project so that manufacturers could develop a transitional shelter's prototype to be easily stockpiled.[8] Although the shelter's criteria had rather focused on optimizing transport and stockpiling over the other characteristics that defines what a transitional shelter actually is, as this project represents an effort towards the manufacturing of a transitional shelter prototype, a short selection of them will briefly be presented.

Among the majority of the proposed solutions composed of aluminum frames and tarpaulin surfaces, which turns out not to bring much improvement over the emergency solutions already in use, two of them stand out from the others by bringing different features into the design discussion.

The *M2* model from *Maddel International* is one of these two proposals. It proposes an unfolded flat-packed module made out of Polypropylene core-flute board that takes less than 30 minutes to erect by unskilled labor. It can be joined with other module units to form clusters of 4 to 6 aggregated units, accommodating 2 mats in each unit. The total package is 78kg in a volume of 0,37m³ and it can be packed vertically onto a 120x80cm Euro pallet for easy transport. The material is repairable, reusable and is said that it can be collapsed, relocated and re-erected multiple times without losing its structural integrity. Figure 8 illustrates this transitional shelter proposal.

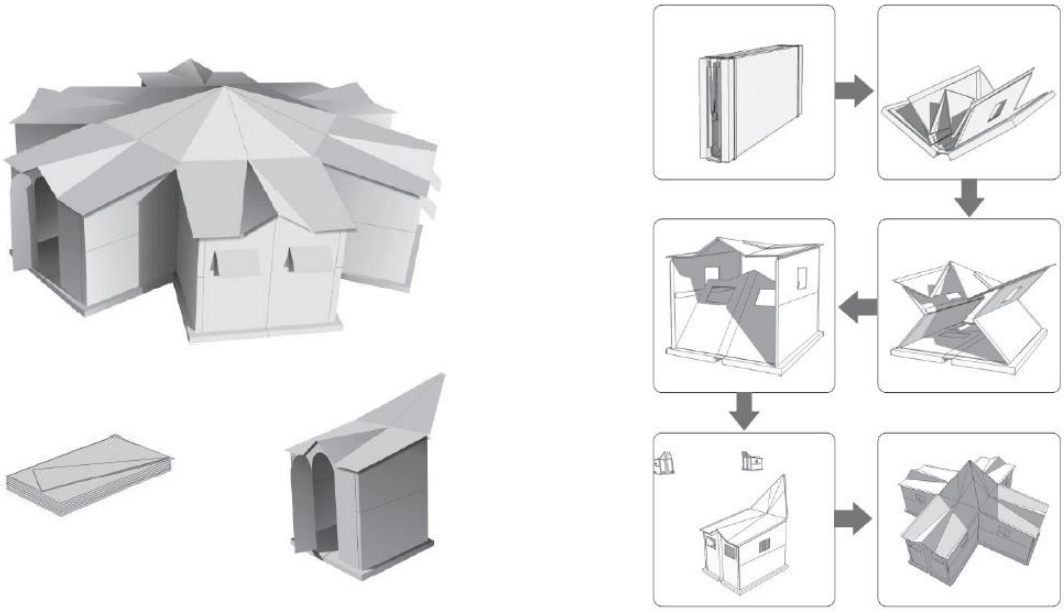


Figure 8 –Transitional shelter prototype by *Maddel International.* Images taken from [8]

The second proposal worth mentioning is the *TranShel* Prototype from World shelters. It is composed of frameless corrugated polypropylene panels, which enable further exterior and interior cladding adaptation with local materials. It has $18m^2$, and accommodates 5 people. The total package is 100kg in a volume of $8m^3$ and can be packed vertically onto a 120x80cm Euro pallet. It is said to be durable, re-usable, and recyclable. Figure 9 illustrates this transitional shelter proposal.

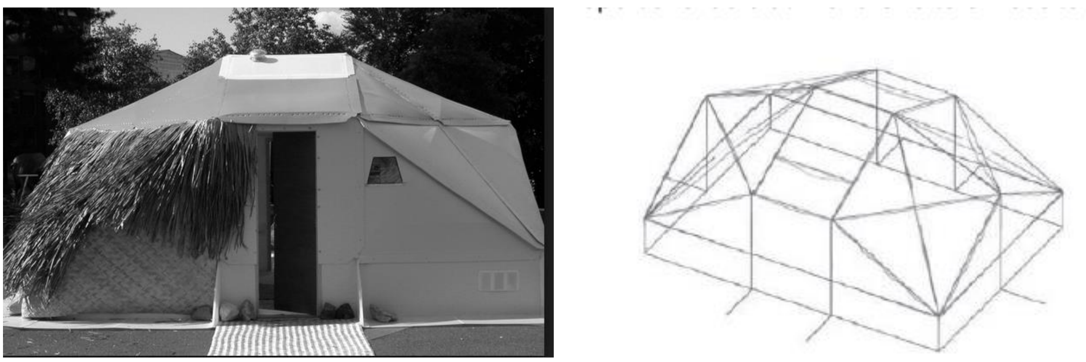


Figure 9 –Transitional shelter prototype by World Shelter. Images taken from [8]

Regardless the lack of more data to analyze the performance and appropriateness of these shelters, none of the above projects under the current definition for transitional shelter can be considered as such, given that they fail to be truly upgradable, not becoming part of a transitional shelter approach, or being versatile enough to be culturally adapted by its inhabitants.

That said we will now look at a selection of existing transitional shelter solutions. All the following seven projects are considered examples of transitional shelters successfully built across the world ranging 3 different climates[1]. Each of the examples were constructed in significant numbers, took less than 3 weeks to complete, proved to last the entire lifespan of the transitional period, show to be appropriate to the climate, culture, people and withstand local hazards, as well as demonstrated flexibility of use and efficiency of its design.[4]

This selection sought to incorporate geographically dispersed examples, so it could illustrate a greater range of different materials usage and its adaptation to different climates and cultures in the transitional shelter approach. Figure 10 illustrates the overlapping of the climate map and the selected examples of the transitional shelters.

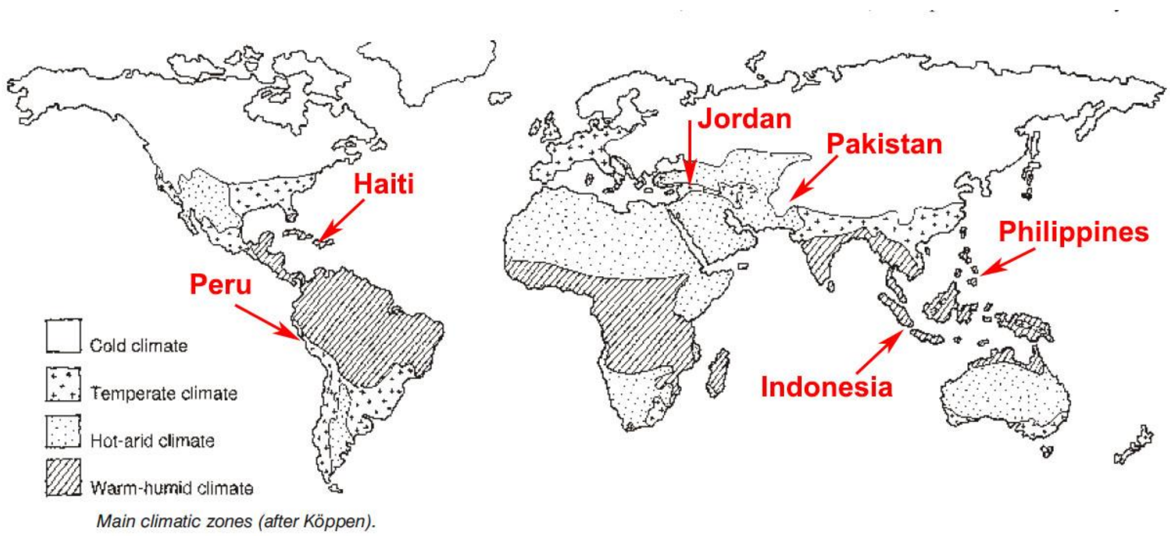


Figure 10 - Transitional shelter examples over the main climate map (after Koppen). Adapted image from [10]

[1] A climate is considered cold when its annual average temperatures are below 10ºC, hot when its annual average temperatures are above 25ºC [9] and temperate when its average temperatures are in between them [5].

The first example is from Indonesia. This transitional shelter represents a vernacular style of construction, being entirely made of locally procured materials, namely bamboo frame and bamboo matting walls. It has concrete foundations and terracotta roof tiles, which is worth mentioning that brings some security concerns in the event of an earthquake. This 4x6m transitional shelter was community-built by 3 to 4 people during 3 to 4 days, and has an anticipated lifespan of up to 5 years. 430 of them were built with an approximately cost per shelter of 315€. “It is easily moved by unpegging the frame from the foundations and the materials can be reused as part of a permanent housing reconstruction.”[4] **Erro! A origem da referência não foi encontrada.** illustrates this transitional shelter.

Figure 11– Indonesia’s transitional shelter (Earthquake, 2009) with bamboo frame solution. Images taken from [4] and [11]

The second example is from Peru. This transitional shelter is a lightweight braced box made of locally available palm mats and eucalyptus wood nailed into imported plastic sheeting. The foundation and floor consists of an unreinforced concrete slab with cast in wire ties. Its lifespan is short, around 1 year, and not upgradable, however its straw mats and frame can be reused. This 3x6m shelter is easily assembled in 2 days by 4 unskilled workers and easily relocated after cutting the wire ties from its foundation. It is worth mentioning that it lacks robustness to withstand wind or flood events. 3.000 of them were built with an approximately cost per shelter of 325€, which caused disruption in the local market capacity to supply bamboo mats.[11] Figure 12 illustrates this transitional shelter.

Figure 12– Peru’s transitional shelter (Earthquake, 2007) with timber frame solution. Images taken from [4] and [11]

The third example is from the Philippines. This transitional shelter represents an adaptation by local architects and engineers of the traditional *Amakan* - a house made from locally materials such as palm leaf weaves for walls, and coco lumber, for the structure. This $18m^{2}$ shelter can be built on 2 to 3 days; be easily repaired, rebuild, relocated by 20 people, and its materials can be reused. When on site it should be anchored to the ground by concrete reinforced foundations to prevent it of being upturned by wind or flood forces. Despite being properly anchored to the ground, some concerns regarding its resistance to wind loads remain. 1.823 shelters with an approximately cost per shelter of 500€ were built in 30 transitional settlement sites, demonstrating the importance and challenges of acquiring land for transitional settlements [12]. One truck could carry lumber for 28 shelters. Figure 13 illustrates this transitional shelter.

Figure 13 – Philippine's transitional shelter (Cyclone, 2012) with timber frame solution. Images taken from [12]

The fourth example is from Jordan. This transitional shelter was constructed in the *Azraq* camp planned for 67.000 refugees. Multiple contractors produced the kits with locally procured materials. They "were made up of steel structural pieces manufactured in a factory off-site, aluminum coated foam insulation, IBR metal sheet cladding, steel windows and doors, ventilation pieces, plastic sheeting for roof ceiling works, and steel wires and turnbuckles for temporary room partitioning." [2] A complete transitional shelter, including ground levelling, could be built by 4 people in 12 to16h.These shelters were designed to protect against severe weather conditions and maximize privacy. The 24m^2 shelter can be dismantled, transported, reassembled, and reused, "making re-siting possible", which turns possible to become a "part of a return package" [2]. At the end of September 2014, 7.000 out of the 13.500 planned units were already built, with an approximately cost per shelter of 2.100€, which caused a positive impact on local labor market. Figure 14 illustrates this transitional shelter.

Figure 14 - Jordan's transitional shelter, and settlement (Syria conflict, 2013) with steel structures. Image taken from [2]

The fifth example is from Pakistan. This transitional shelter is built with local and international procured materials: timber and bricks from local sources, and corrugated steel sheeting and plastic sheeting from international ones. It is easy to assemble, dismount for reuse of its materials, and is appropriate for cold climates. As it is, it fails to withstand wind and snow loads This 4,3 x 5,7m transitional shelter, which is built by a team of 4 non skilled workers in one day, has an anticipated lifespan of 2 years. 10.000 of them were built with an approximately cost per shelter of 475€. Figure 15 illustrates this transitional shelter.

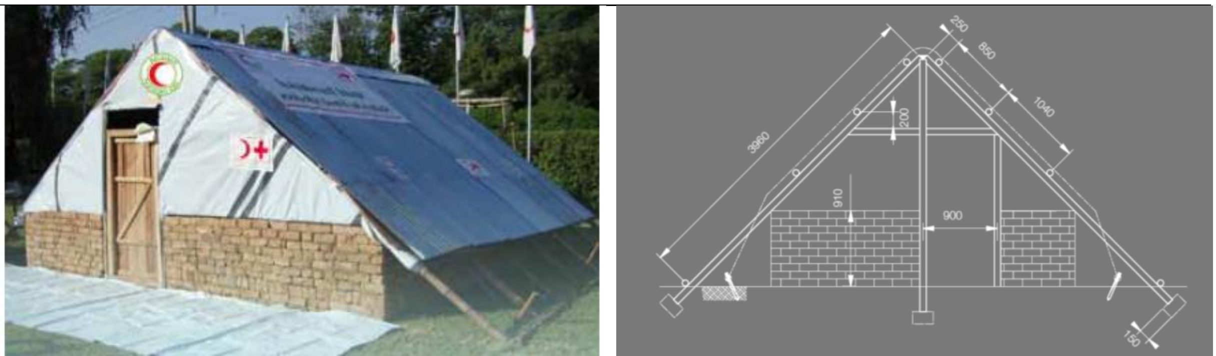


Figure 15 - Pakistan's transitional shelter (Flood, 2010) with timber frame solution. Images taken from [4].

The sixth example is from Haiti. This transitional shelter is built with internationally procured Galvanized steel frame, and locally procured materials, namely: plasting sheeting, corrugated steel sheeting, and concrete foundations. This 3 x 6m shelter is built within 2 days by a team of 2 carpenters plus 5 helpers, having an expected lifespan of 2 years [13]. It can be “demountable with foundation bolts that can be cut to reuse the frame” [4], being upgradable by replacing the plasting sheeting walls with other materials. As it is, it lacks lateral stability to withstand wind and seismic loading. 5.100 of them were built with an approximately cost per shelter of 4.085€. Figure 16 illustrates this transitional shelter placed in two different situations.

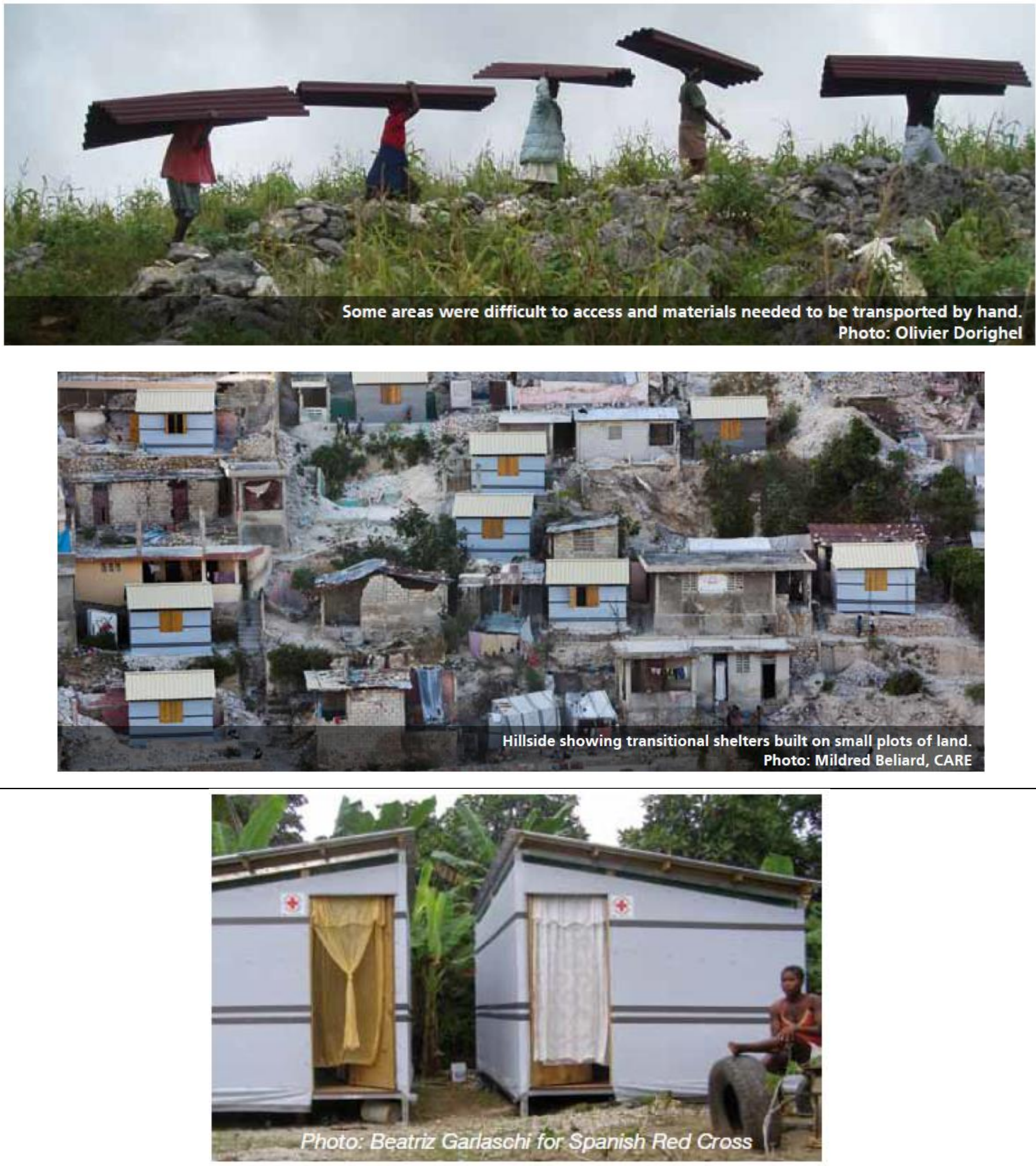


Figure 16 - Haiti’s transitional shelter (Earthquake, 2010) with steel frame solution. Images taken from [4] and [13].

The seventh and last example is from Indonesia. This transitional shelter has a similar design of the vernacular houses, but replaces the traditional framing material by galvanized steel. The frames were manufactured regionally, with the column base plates nailed directly into the ground, while the roof sheeting and timber imported internationally. It could be quickly scalable, but prone to cause delays in the implementation due to need of importing materials. The 25m^2 shelter is constructed in 3 days by a team of 4 to 5 people. Its lifespan expectancy is greater than 5 years and allowed to be reused, recycled, relocated and upgraded. However, some modifications were needed in order to improve its capacity to withstand wind loads, namely bracing the walls and roof, and replacing the foundations. It was sold as a dismountable kit, which included shelter frame, tools, timber planks, and studs, leaving the windows and gable materials to be procured in local markets. 20.000 of them were built with an approximately cost per shelter of 4.845€. Figure 17 illustrates this transitional shelter.

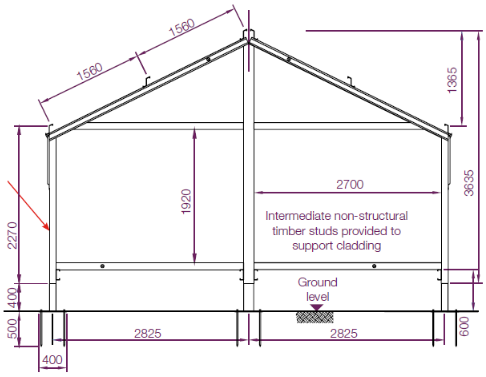


Figure 17 - Indonesia's transitional shelter (Tsunami, 2004) with steel frame solution. Images taken from [2]

From the UN shelter project reports [2], [12], [14] and IFRC transitional shelter selection [4], one can conclude that regardless the significant differences in number and cost of shelter solutions, on average the transitional shelter approach requires 5.000 transitional shelter per intervention, with an average cost of approximately 1.850€ each.

3. Guidelines and requirements for transitional shelter and settlements

3.1. The Sphere project handbook

The *Sphere project* was the result of a collective effort carried since 1997 from a group of NGO's, the Red Cross, and the Red Crescent Movement, to simultaneously improve the humanitarian response quality to disaster-affected people, and enhancing the accountability of the humanitarian system in this response.

This handbook, which was designed for action, was based on two simple core beliefs: "first, that those affected by disaster or conflict have a right to life with dignity and, therefore, a right to assistance; and second, that all possible steps should be taken to alleviate human suffering arising out of disaster or conflict." [16] **.** In order to put those ideals into action, 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. Although each technical chapter covers a specific subject, and once the scope of each subject often influences and overlaps with one other, the success of the response lies in the correct coordination among all the sectors.

It is worth to say that conforming with *Sphere* does not imply to meet each and all standard, as it is rather intended to set the goals and guidelines to enable progress monitoring and outcomes assessment, than to be a prescriptive law. These standards are qualitative in nature. Instead of reading the standards as normative rules, one should look up for it to acknowledge the gap between the sphere indicators and reality, understand its reasons, and assess its negative implications in order to be able to take the appropriate actions to mitigate those implications. In addition, one should bear in mind that it will probably be more important to reach out with basic help for a wider affected-population, than to meet all the standards just for a few of them.

While the handbook helped to set the program design for shelter and settlements, it also set several actions from disaster preparedness to early-recover that helps to mitigate the damages on the already affected-population.

The Humanitarian charter is composed of 11 principles, divided into beliefs, humanitarian role, rights and duties, and humanitarian commitment. The underlying premises of the humanitarian charter came from the universal declaration on human rights that: all human beings are born free and are equal in dignity and rights; have the right to a standard of adequate living, which includes food, clothing, housing and medical care; as well as the right to security. [17]

It is worth to state that dignity goes beyond the people's physical well-being. It encompasses the respect for the whole people's psychosocial well-being as well, meaning respect for their own values, beliefs, and freedom of conscience.

In order to fulfill the gaps between this humanitarian goals and the affected-population situation, the charter entitled them with the rights to receive humanitarian assistance as need it, and the right to seek protection and security, including refugees and IDPs.

The Protection principles reflect on affected-population's safety, dignity and rights. Humanitarian agents, above all, must confirm their actions with the four basic protection principles, namely:

1. Avoid exposing people to further harm as a result of humanitarian actions;
2. Ensure people's access to impartial assistance – in proportion to need and without discrimination;
3. Protect people from physical and psychological harm arising from violence and coercion;
4. Assist people to claim their rights, access available remedies and recover from the effects of abuse.

The six Core standards of the Sphere's handbook represent the single reference point to which all the different technical sectors ground their own standards.

The first Core standard acknowledges that "the People's capacity and strategies to survive with dignity" should be "integral to the design and approach of humanitarian response." [16] It means the affected-population should be supported to actively participate in the solution. Therefore, one should provide them with safe and accessible community spaces to gather, as well as to share information. Whenever sustainable, local economy should be promoted and cultural practice's needs addressed in the projects design. By engaging the population in the response, it will help them to restore some sense of control, while enhancing identity and resilience.

The second Core standard focus on the importance to coordinate the humanitarian response from all the parties involved namely humanitarian agencies, governmental authorities and any other civil society organization engaged in such cause, in order to take advantage of each own best contribution and achieve the most effective joint response.

The third Core standard focus on following a "systematic assessment of the context, risks to life with dignity and the capacity of the affected people and relevant authorities to respond." [16] Assessment must be seen as a process, meaning that phased in-depth and continuous assessments should be carried out in order to inform the relief needs from the onset event till the end of the humanitarian assistance.

The fourth Core standard introduces the role of design within the response. The goal is to close progressively the gap between the assessed existing conditions and the Sphere minimum standards, considering its particular context, risks, and opportunities to engage the population in its own recovery, while promoting community-based self-help networks and local economy sustainable revival. By closing the gap, one should understand first prioritizing live-saving actions, to later addressing all the other features of the individual and population's dignity. It requires program revision and adaptation. One should give special care in the response so that existing vulnerabilities are addressed and mitigated, and negative effects in the environment or in the wider/ host population avoided. Whenever attaining the sphere's minimum standards creates negative disparities to the wider or host population where the affected-population is settled, one should revise the scope of the response in order to include them also in the program.

The fifth Core standard relates with the humanitarian assistance's performance management, and with the importance that its performance "is continually examined and communicated to stakeholders" so "projects are adapted in response to performance." [16]

The sixth Core standard refers to the aid worker performance, assigning each humanitarian agency the responsibility to "provide appropriate management, supervisory and psychosocial support", which enables "aid workers to have the knowledge, skills, behavior and attitudes to plan and implement an effective humanitarian response with humanity and respect." [16] It makes agencies accountable for the effectiveness of its response while assures affected-population is aided by professionals.

In order to have a more comprehensive understanding of the overlapping implications and influences of the four life-saving technical chapters of this handbook to the architectural planning and design, a short briefing about each of them follows.

The four life-saving technical chapters:

3.1.1. Water supply, sanitation and hygiene promotion (WASH)

As water represents the basic support for human lives, also in disaster situations providing access to adequate water supply and sanitation, i.e. excreta disposal, vector control, solid waste disposal and drainage, makes the difference between life and death. As essential to prevent death from dehydration, and to minimize water-related diseases and the risk of public health issues, such as cholera, malaria, yellow fever, and dengue, it is also necessary to enable cooking and promote safe hygiene.

Therefore, to minimize public health issues, hygiene promotion's programs must be shortly undertaken. In camp scenarios, in order to instruct the population on the public health risks that poor hygiene behavior entails, there should be at least two hygiene promoters per 1000 affected-population members. Table 3 describes the packs of basic hygiene items to provide to the affected-population.

Table 3 - Basic hygiene items according to [16]

10–20 litre capacity water container for transportation	One per household
10–20 litre capacity water container for storage	One per household
250g bathing soap	One per person per month
200g laundry soap	One per person per month
Acceptable material for menstrual hygiene, e.g. washable cotton cloth	One per person

For survival sake, is then mandatory to provide access to sufficient and safe water supply for drinking, cooking, personal, and domestic hygiene. In order to ensure equitable assess to water points, one should plan the household's layout so that the maximum distance from each one to the closest water point is less than 500m, and its queueing time is shorter than 30minutes. Although the survival water needs of an individual is context based and therefore depends on several factors, such as climate, sanitation facilities, activity, and cultural habits - including clothing and food -, the standard to which the humanitarian water supply should attain is 15 liters per person per day. Table 4 illustrates the disaggregation of basic survival water needs for domestic purposes and Table 5 shows the minimum water quantities to consider for institutions and other purposes.

Table 4 - Basic survival water needs according to [16]

Survival needs: water intake (drinking and food)	2.5–3 litres per day	Depends on the climate and individual physiology
Basic hygiene practices	2–6 litres per day	Depends on social and cultural norms
Basic cooking needs	3–6 litres per day	Depends on food type and social and cultural norms
Total basic water needs	7.5–15 litres per day	

Table 5 – Minimum water quantities for institutions and other uses according to [16]

Health centres and hospitals	5 litres per outpatient 40–60 litres per inpatient per day Additional quantities may be needed for laundry equipment, flushing toilets, etc.
Cholera centres	60 litres per patient per day 15 litres per carer per day
Therapeutic feeding centres	30 litres per inpatient per day 15 litres per carer per day
Reception/transit centres	15 litres per person per day if stay is more than one day 3 litres per person per day if stay is limited to day-time
Schools	3 litres per pupil per day for drinking and hand washing (Use for toilets not included: see Public toilets below)
Mosques	2–5 litres per person per day for washing and drinking
Public toilets	1–2 litres per user per day for hand washing 2–8 litres per cubicle per day for toilet cleaning
All flushing toilets	20–40 litres per user per day for conventional flushing toilets connected to a sewer 3–5 litres per user per day for pour-flush toilets
Anal washing	1–2 litres per person per day
Livestock	20–30 litres per large or medium animal per day 5 litres per small animal per day

That said, the water sources capacity should inform and serve as an important guideline while planning the population distribution. **Table 6** shows how to compute such capacity.

Table 6 –Maximum number of people per water source according to [16]

250 people per tap	based on a flow of 7.5 litres/minute
500 people per hand pump	based on a flow of 17 litres/minute
400 people per single-user open well	based on a flow of 12.5 litres/minute

Furthermore, the affected-population will also require the provision of laundry and bathing facilities. Those facilities should be designed to be easily accessible by all, as well as to promote a safety sense of use.

As human feces represents one of the biggest sources of contamination and diseases transmittance, the provision of appropriate facilities and safe excreta disposal also becomes one of the first priorities to address in post-disaster scenarios. Besides health issues, providing such facilities will help the population to restore its sense of dignity, safety and well-being.

While planning for excretal disposal, one should ensure that “All excreta containment measures, i.e. trench latrines, pit latrines and soak away pits, are at least 30 meters away from any groundwater source” and “the bottom of any latrine or soak-away pit is at least 1,5 meters above the water table”.[16] They should be easy to use and clean, safe for the environment, and provide the necessary privacy to their users. In order to meet the population needs, the number of toilets should be such that no more than 20 people use each toilet, and that its distance from the dwellings is less than 50m. Additionally, its use should be organized by sex or households, and water for hand washing purposes should be provided too. Table 7 describes the short and long-term goals regarding toilets for public spaces.

Table 7 – Minimum numbers of toilets at public places and institutions in disaster situations according to [16]

Institution	Short term	Long term
Market areas	1 toilet to 50 stalls	1 toilet to 20 stalls
Hospitals/medical centres	1 toilet to 20 beds or 50 outpatients	1 toilet to 10 beds or 20 outpatients
Feeding centres	1 toilet to 50 adults 1 toilet to 20 children	1 toilet to 20 adults 1 toilet to 10 children
Reception/transit centres	1 toilet to 50 individuals; 3:1 female to male	
Schools	1 toilet to 30 girls 1 toilet to 60 boys	1 toilet to 30 girls 1 toilet to 60 boys
Offices		1 toilet to 20 staff

Refugees and IDPs represent vulnerable groups for epidemics bursts, which are an important cause of sickness and death after any disaster. Wherever mosquitos, flies, ticks, lice or rats become disease-carrying agents, they are called vectors. Often, vector-borne diseases are related to stagnant water, excretal contamination, and poor hygiene or solid waste management. Therefore, if appropriate vector control measures are taken, it can be minimized or at best avoided. Such measures should include:

- Camp site selection 1 to 2 Km upwind from large breeding sites such as swamps or lakes;
- Provision of insecticide-treated mosquitos nets for the population;
- Water drainage;
- Excretal and solid waste disposal;
- Provision of shelters with adequate water supply, waste disposal, and food storage; and
- Health services;

The correct solid waste management, i.e., "the process of handling and disposal of organic and hazardous solid waste" [16] is crucial to prevent the pollution of surface and ground water sources and the obstruction of water drainage. From the architectural point of view, it means that:

- At least one 100-litre refuse container is available per 10 households;
- The distance from households refuse containers to the communal refuse pit, where it should be buried or incinerated, is less than 100 meters;
- The refuse pits, bins or specified area pits, are appropriately marked and fenced; and
- The distribution of commodities that produce a large amount of solid waste from packaging or processing on-site should be avoided.

Once that surface water increases the vector breeding risks, as well as water supplies contamination, the design of the solution must address proper water drainage with special attention to drainage at water points and washing and bathing areas.

3.1.2. Food security and nutrition

As undernutrition constitutes a public health problem, and a great cause of direct and indirect deaths, providing food security and nutrition is a humanitarian duty. As a rule of thumb, the provided food "should not require long cooking time or large quantities of water" [16] as fuel and water consumption should be rationalized.

For food storage management, warehousing may be needed. They should be easily accessed, secured, and safe. In addition, as food distribution points may be provided, they should be positioned nearby other support facilities, such as potable water, toilets, medical services, and shade. Whenever households are responsible for their food preparation, they will need to be provided with appropriate transport recipients, including water containers, cooking utensils and fuel. If community kitchens are set up instead, one should address its site selection carefully so it is easily accessible for all; it lays on a hygienic and safe site and allows access to potable water.

3.1.3. Health action

Healthcare assistance must be a priority after the occurrence of any disaster situation so casualties can be reduced and further harm can be avoided. The hazardous event carries in itself direct but also indirect impacts for individual and public health - deaths, injury, infectious diseases, and malnutrition.

Indirect impacts can be prevented as they often come from inadequate water quantity and quality; inadequate sanitation; food security; inadequate living conditions such as overcrowding, inadequate shelter, including inadequate site choice nearby standing waters, inadequate settlement layout that blocks ventilation or lack of vector control measures.

Beyond prevention, providing access to health care system becomes determinant to increase the disaster-affected population survival rates. That said the post-disaster response [16] should be able to provide for:

- one basic health unit/10,000 population (basic health units are primary healthcare facilities where general health services are offered);
- one health center/50,000 people;
- one district or rural hospital/250,000 people; and
- more than 10 inpatient and maternity beds/10,000 people;

For that purpose both field hospitals or mobile clinics may be considered to deploy at the site, although whenever feasible it may be more efficient reinforcing existing hospitals capacity and resources.

3.1.4. Shelter, settlement and non-food items (NFI)

Among adequate water, food, and health care action, shelter is a critical factor for survival. It ensures personal safety and protection from the outside environment, promoting therefore resistance to illness and recovery. Vital for human dignity, it offers privacy to the disaster-affected population and the starting point for their self-management and self-sufficiency.

The “Minimum standards in shelter, settlement and non-food items” [16] is one of the technical chapters covered in the *Sphere* handbook that, for the purpose of this specific work, will be deeply further explained.

By NFIs, one should know it includes clothing, bedding, household, and shelter support items. From the architectural planning point of view, it is worth mentioning them once they will have to be present in the design solution, whatever that is.
The disaster-affected population will need access either to a “safe, fuel-efficient stove and an accessible supply of fuel or domestic energy, or to communal cooking facilities” [16]**.** Nevertheless, for safety purposes, it might be easy to manage adequate ventilation and fire safety in communal cooking facilities than in individual stoves provided for each household. Furthermore, and depending on the shelter solution, shelter support items, such as construction materials, tools and fixings as well as technical guidance, whenever required, should also be part of the relief assistance packages.

That said, the right to a standard of adequate living can be translated according to *Sphere* [16] into:

- 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.

For an informed and efficient response, several factors regarding the local context should be prior considered. That includes assessing the local climatic and environmental conditions, as well as whether it is in a rural or urban site, its security and political situation and their population capacity to cope in the construction of their shelters. Figure 18 illustrates the transitional settlement options for both non-displaced population and displaced population.

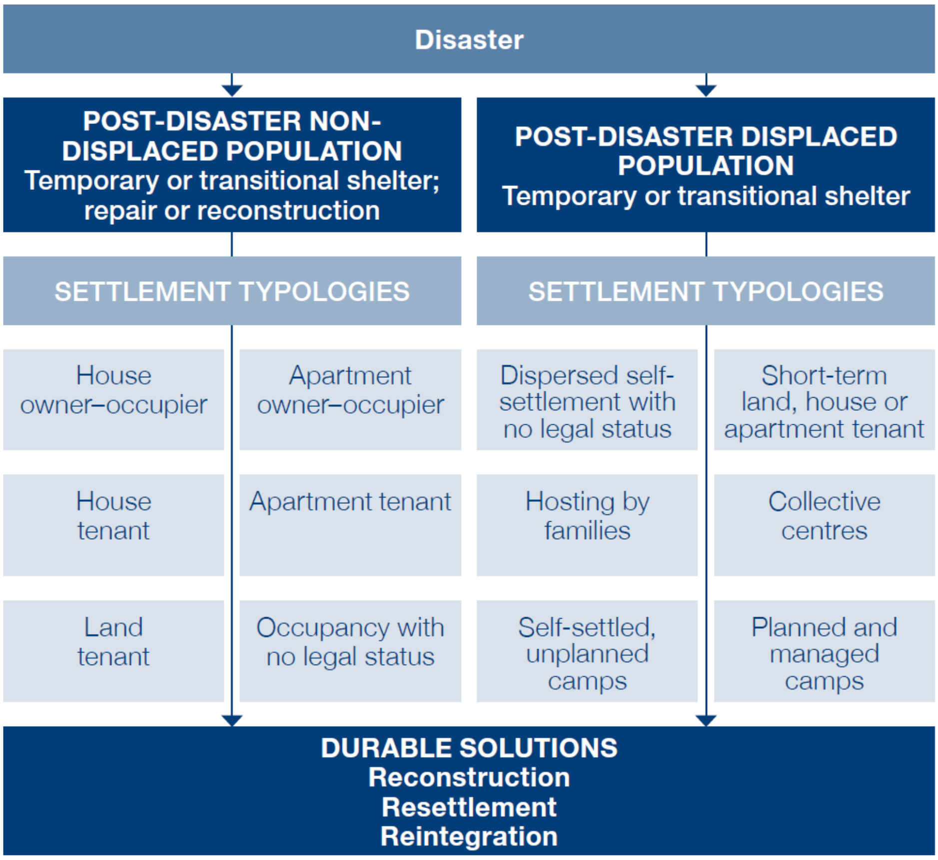


Figure 18 – Shelter and Settlement options and response scenarios [16]

In extreme weather conditions, displaced population will need a quick shelter solution. For that matter and depending on other factors they could either be settled in public buildings used as collective centers, being hosted by families or accommodated in existing planned camps. For that purpose, the transitional household shelters in use should allow expansion and upgrading.

However, wherever feasible, disaster-affected population should be assisted with transitional shelter as near of their original homes as possible. It will enable them to work not only on their homes reconstruction, as also to maintain their livelihoods and social connections. Thus, it may require contemplating the "provision of appropriate construction materials, tools and fixings, cash or vouchers, technical guidance and training or a combination of these" [16] as part of the humanitarian assistance.

Depending on the solution though, it may then be appropriate that shelter responses allows upgrading to the extent they turn into durable solutions.

3.1.4.1. Shelter and settlement standard 1 - Strategic planning:

"Shelter and settlement strategies contribute to the security, safety, health, and well-being of both displaced and non-displaced affected populations and promote recovery and reconstruction where possible." [16]

The strategic planning for an efficient post-disaster response starts with the appropriate assessment, consultation, and coordination of all relevant data to inform the programme design and implementation. Data being coordinated should include the affected-population needs and building skills, post-disasters risks, vulnerabilities and opportunities, weather patterns, security context, land or property rights, existing contingency plans, and environmental impact.

Once the post-disaster immediate relief ceases, the return of the displaced population should be supported and prioritized. However, due to several reasons that go from building safety, to social security or inability to reconstruct their own homes right away, people will need a transitional place to live in. On the other side, whenever population is unable or unwilling to return to their original homes, there will be a need for transitional sheltering as well. In either cases, being the affected-population hosted by its relatives or accommodated in collective camps or centers, there will be a need to support the upgrading/extension of the family shelters or centers.

In order to meet the affected-population's shelter needs, one should conduct an assessment to optimize the correct combination of the appropriate assistance methods to provide. It may include household and shelters NFIs such as clothing, bedding, stoves, fuel, tents, plasting-sheeting and toolkits, to building materials or transitional shelters. It may require providing manual work and or technical expertise, as well cash, vouchers, or loans to stimulate the local economies trough building materials supply. Information about all the above options should be given to them, as well as support in their self-management capacities. Transitional shelter must be understood as a response process rather than as a final solution, and therefore concerns regarding the need for disassembling, reuse, and relocation, or upgrading and extension should be taken into account from both displaced or non-displaced users.

Strategic planning includes minimizing the future settlements exposure to risk, vulnerability, and natural hazards. In order to do so, a thorough vulnerability assessment should be mapped including not only natural or man-made hazards and vector risks, but also any unhealthy relationships between affected population and host community.

Whenever the post-disaster response faces a natural hazard, debris removal must become a priority, as it will enable access for reconstruction and removal of any corpses and hazardous material. It will also allow separating materials for recycling, reuse, or disposal, and so provide work opportunities.

To finish with, the location of the settlement must be such that it allows the affected-population to have safe access to essential services such as water and sanitation services, as well to schools, health facilities, and communal meeting areas. It should allow that the population pursues their own livelihood activities.

3.1.4.2. Shelter and settlement standard 2 - Settlement planning:

"The planning of return, host, or temporary communal settlements enables the safe and secure use of accommodation and essential services by the affected population." [16]

The planning process of settlements should be informed based on the type of crisis, disasters, and impact on the affected population, considering the long-term implications of the transitional settlement site decision, namely: host families, collective centers or planned camps, as well as the rights of use of such properties. Appropriate site selection for planned camps includes mitigation of vector risks. The settlement should avoid being set at breeding grounds for pests such as low-lying areas, debris, excavations and so on.

Essential services and facilities, which include "appropriate water, sanitary facilities, fuel for cooking or communal cooking facilities, healthcare, solid waste disposal, schools, social facilities, places of worship, meeting points, recreational areas, including child-friendly spaces and space for livestock accommodation(…), administrative offices, warehousing and staff accommodation and quarantine areas in temporary communal settlements" [16] should be made available for disaster affected-population. Settlement, primary storage, or "food distribution points should be accessible by heavy trucks from an all-weather road" [16] and in order to provide safer pathways or roads, artificial lightening should be considered.

Existing social networks, such as family, should inform the neighborhood planning of the settlements so that resources such as water, sanitation facilities, and communal cooking can be shared. The settlement plot layout should “maintain the privacy and dignity of separate households by ensuring that each household shelter opens onto common space or a screened area for the use of the household instead of being opposite the entrance to another shelter”. [16]

Sufficient surface area in planned settlements for household plots, “roads, footpaths, external household cooking areas or communal cooking areas, educational facilities and recreational areas, sanitation, firebreaks, administration, water storage, distribution areas, markets, storage and limited kitchen gardens for individual households” [16] as well as adequate fire separation between the buildings must be provided. For that matter, $45m^2$ of usable surface area should be accounted for each person. However if the communal services are placed outside the settlement the minimum required per person drops to $30m^{2.}$ While planning for fire safety in the settlement one should consider designing a 30m firebreak for every 300m of built-up area, providing a minimum of 2m in between individual buildings, although doubling the overall height of any structure would be safer.

3.1.4.3. Shelter and settlement standard 3 - Covered living space:

“People have sufficient covered living space providing thermal comfort, fresh air and protection from the climate ensuring their privacy, safety and health and enabling essential household and livelihood activities to be undertaken.” [16]

Sufficient covered living space is a qualitative standard. It depends on how or what for it will be used and on the subject that will use it. This handbook proposes to quantify it to a minimum of $3{,}5m^2$ per person, recognizing thought that climate and context influences the space requirements inhabitants need. In cold climates for instance, people will require more covering area to do their household activities, while in warm climates where activities such as food preparation or cooking can happen outside to a shaded adjacent area, reduces the need for the interior covering area. Although for immediate and short-term shelter solutions, less than $3{,}5m^2$ per person can be lifesaving, for longer periods of time one should considered the adverse effects on health, privacy and dignity of it, bearing in mind that transitional shelter often turns into medium to long-term solutions. In addition, the floor-to ceiling height plays an important role in the thermal comfort of a building, being high ceilings appropriate for warmer and humid climates where it aids ventilation, and lower ceiling appropriate for colder climates, reducing the air volume required to heat.

The design should address privacy concerns, reflecting the privacy needs between different groups or families in collective accommodations, as well as within family members living in individual shelters. In order to do so, the design must allow for internal subdivision of its space.

The shelter design must optimize the use of the covered and exterior adjacent areas, so that 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” [16] can be undertaken.

Whenever local post-disaster shelter solutions are not easily available, one should supply shelter kits, packages of materials or prefabricated building to its immediate relief. However, participatory design must be pursued so that the solution can reflect the affected population's technical and financial capacities to maintain and repair it, as well as its cultural appropriateness.

The shelter design must assess the specific weather conditions where it will be erected, so it can optimize thermal comfort, ventilation, and environmental protection. Furthermore:

- "For warm, humid climates shelters should be oriented and designed to maximize ventilation and minimize entry of direct sunlight. The roof should have a reasonable slope for rainwater drainage with large overhangs except in locations vulnerable to high winds. The construction of the shelter should be lightweight, as low thermal capacity is required. Adequate surface water drainage should be ensured around the shelter together with the use of raised floors to minimize the risk of water entering the covered area."; [16]
- "In hot, dry climates construction should be heavyweight to ensure high thermal capacity, allowing changes in night and day temperatures to alternately cool and heat the interior, or lightweight with adequate insulation. Care should be taken in the structural design of heavyweight construction in areas with seismic risks. If only plastic sheeting or tents are available, a double-skinned roof should be provided with ventilation between the layers to reduce radiant heat gain. Door and window openings positioned away from the direction of the prevailing wind will minimize heating by hot winds and heat radiation from the surrounding ground. Flooring that meets the external walling without gaps should be provided to minimize dust and vector penetration."; [16]
- "In cold climates: Heavyweight construction with high thermal capacity is required for shelters that are occupied throughout the day(…) Minimize air flow, particularly around door and window openings, to ensure personal comfort while also providing adequate ventilation for space heaters or cooking stoves. Stoves or other forms of space heaters are essential and must be appropriate to the shelter. Assess and mitigate potential fire risks from the use of stoves and heaters.(…) Surface-water drainage should be provided around the shelter and raised floors should be used to minimize the risk of water due to rain or snow melt from entering the covered area."; [16]
- "Ventilation and vector control: Adequate ventilation should be provided within individual household shelters and public buildings such as schools and healthcare facilities to maintain a healthy internal environment(…)".[16]

3.1.4.4. Shelter and settlement standard 4 - Construction:

"Local safe building practices, materials, expertise and capacities are used where appropriate, maximizing the involvement of the affected population and local livelihood opportunities." [16]

After any disaster, the re-construction phase can offer a relevant mean for local economies to rebuild themselves. Therefore, and before deciding on the solution, the availability of human and material resources should be properly assessed. While one can support the local livelihoods by local procurement of building materials, one can also employ the affected population in the construction process of building back their homes, empowering them with new skills. Nevertheless, technical expertise should not be neglected so that the agreed construction standards on safety and accessibility can be met and procurement and construction management becomes transparent. The shelter solution must be such that allow its inhabitants to maintain, adapt, or upgrade it through locally available tools and materials.

3.1.4.5. Shelter and settlement standard 5 - Environmental impact

“Shelter and settlement solutions and the material sourcing and construction techniques used minimize adverse impact on the local natural environment.” [16]

Natural disasters, often landslides and floods, can be due the result of prior poor settlement decisions. Therefore, it is essential to conduct a thorough assessment of the site’s environmental risks, vulnerabilities, and opportunities in order to plan for the adequate response. The sudden demand for construction materials should not result in an unsustainable demand on local natural resources. Moreover, retaining vegetation and trees helps to protect soil from erosion minimizing surface runoff while providing shade and climate protection.

That said management the long-term environmental impact might then require external procurement of materials, and the introduction of some mitigation measures, as replanting, in order to avoid local natural depletion. Additionally, it is worth to state that it may be more environmentally sustainable to concentrate the affected population in large managed settlements, than having them disperse among several smaller ones.

To conclude with, whenever the settlement aims to be transitory, it should leave no environmental footprint when dismantled, being any materials, or waste with negative impact removed.

3.2. Planned camps for transitional shelter

Transitional shelter and settlements are intricately linked together and should not be treated as separate entities. The settlement is responsible for the establishment of the physical and social framework that will enable shelters to have access to infrastructure and essential services, as well as enable support for the livelihoods of its inhabitants. Although transitional shelter can be placed anywhere, once one of its five characteristics is exactly that it can be relocated, it should take part of a broader transitional settlement programme. For simplicity sake, we will think of the transitional shelter approach as part of the planned camp settlement option, which, because it is often placed some distance from the original homes, limiting access to income-generator activities for the disaster-affected people, delaying reconstruction, creating livelihood dependency and protracting displacement, should only be considered as the last possible solution. The planned camp is a purpose-built settlement, which aims to provide a full-range of services to displaced people. For that purpose, the UNHCR set in its Handbook for emergencies [15] the quantitative standards to comply with when designing for such settlements.

In such blank canvas scenarios, the master plan should not only be able to respond to the immediate needs of its inhabitants, but also plan ahead for the provision of their longer-term needs, as often these temporary solutions last longer than expected. Having that in mind the master plan of a planned camp must comply with the following figures described in Table 8.

Table 8 - Site planning figures for emergencies from [15]

RESOURCE	HOW MUCH YOU WILL NEED
Land	30 - 45 m² per person
Sheltered space (tents, or other structures)	3.5 m² per person
Fire break space	A clear area between shelters 50 m wide should be provided for every 300 m of built-up area. A minimum of 1-1.5 m should be provided between guy-ropes of neighboring tents on all sides
Roads and walkways	20-25% of entire site
Open space and public facilities	15-20% of entire site
Environmental sanitation	1 latrine seat per 20 people or ideally 1 per family sited not farther than 50 m from user accommodations and not nearer than 6 m. 1 x 100 liter refuse bin per 50 people 1 wheelbarrow per 500 people 1 communal refuse pit (2 m x 5 m x 2 m) per 500 people
Water	15 - 20 liters per person per day of clean water
Tap stands	1 tap per 200 persons sited not farther than 100 m from user accommodations
Warehouse space	For food grains in bags, stacked 6 m high allow 1.2 m² of floor space per tonne
Food	2,100 kcal/person/day This will require approximately 36 metric tonnes/10,000 people/ week of food assuming the following daily ration: 350-400 g/person/day of staple cereal 20-40 g/person/day of an energy rich food (oil/fat) 50 g/person/day of a protein rich food (legumes)

Calculating the total land required, also depends on whether its inhabitants will plant their own vegetable garden space, and cook their own meals in which case 45m^2 /person is required instead of 30m^2 /person.

This handbook for planned camps defines that the physical organization of the camp should be approached from a bottom-up modular perspective, starting from its smallest component, in this case the family unit, and building up successively larger social units until the overall design of the site be complete. Although the modules dimension should be adjusted according to each particular situation, the camp modular planning, as shown in Table 9, should be built on the addition of 4 successively larger modules, namely family, community, block, and sector.

Table 9 - Modular planning from [15]

Module	Consisting of	Aprox. No. of persons
Family	1 family	4 - 6 persons
1 community	16 families	80 persons
1 block	16 communities	1,250 persons
1 sector	4 blocks	5,000 persons
1 camp module	4 sectors	20,000 persons

That said, a planned camp, which should not accommodate more than 20.000 people, is composed of 4 sectors, each in turn composed of 4 blocks, which are composed of 16 communities, which in turn are composed of 16 families.

Nevertheless, the overall layout should avoid following a rigid grid design, but instead reflect the social organization and culture background of its inhabitants. The settlement design should be such that it promotes community interaction and neighborhoods identification in order to develop a sense of ownership among its inhabitants. For that matter, each community, a 16 families module, should be planned to include its own services, such as water supply, sanitation, and garbage collection, so that it promotes accountability for its own maintenance and protection. Figure 19 illustrates the modular design concept of a community sub-block, where despite all family modules being open to a shared common area, due to a 45 degree twist in the shelter orientation, their privacy remain somehow protected.

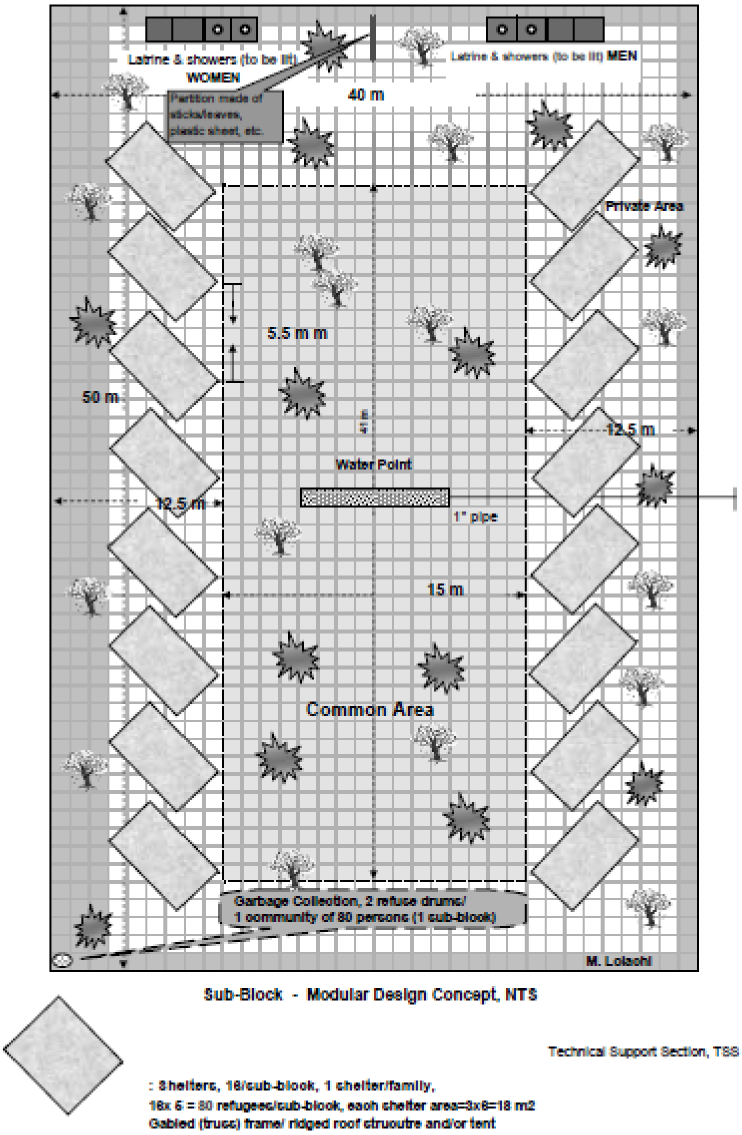


Figure 19 - Self-contained community plan from [15]

To finish with this handbook defines the minimum infrastructure and services to be provided for each level of the modular planning, starting from the family unit until the camp unit. Table 10 describes those requirements.

Table 10 – Typical services and infrastructure requirements for refugee camps from [10]

1 latrine	per	1 family (6 - 10 persons)
1 water tap	per	1 community (80 - 100 persons)
1 health centre	per	1 camp (of 20,000 persons)
1 hospital	per	up to 200,000 persons
1 school	per	1 sector (5,000 persons)
4 commodity distribution sites	per	1 camp module (20,000 persons)
1 market	per	1 camp module (20,000 persons)
2 refuse drums	per	1 community (80 - 100 persons)

3.3. UNHCR Request for Proposal standards

In order to suppress the affected population's needs, the UNHCR, as the UN agency mandated to lead and coordinate international actions for safeguarding the rights and well-being of refugees and stateless people, purchases goods and services all around the world. In 2013 and for that matter, it opened a request for proposals (RFP) for the establishment of a frame of agreement for the provision of shelter solutions for different climates [18]. This RFP sent to qualified suppliers (in which no result could be found during the writing of this thesis) not only helped to establish the shelter requirements, as also served to set some standards on how to address the design for different climates, namely cold weather, hot weather, and all weather conditions[2].

Generically, the common considerations that the shelter should address are that:

- It should 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;
- It should be versatile enough to allow for living areas extensions and to climate adaptation;
- It should be flexible in use so it could became adaptable to different local cultures and traditional practices;
- It should be easily assembled and disassembled for relocation purposes leaving no significant ecological footprint into the environment;
- Its materials should be environmentally friendly, should come from a sustainable source and be prone for recycling;

[2] Designing for all weather conditions means that the shelter should be able to withstand a great range of climatic extremes from cold nights and winters to hot days and summer [18]

- It should consider the possibility to evolve, by the inclusion capacity of its materials and/or structure, into long-term solutions;
- It should be light and packed for cost-effective transport using a standard 20-foot shipping container, thus limiting cost of transport and storage.

Specifically, the considerations on the shelter's components are:

- Footings - should be able to anchor the shelter to the floor so that it can withstand wind uplift forces;
- Roof shape - being flat, single-slope, or gable roof, should, in accordance with the weather, minimize water entrance and maximize rainwater drainage. It should be securely fixed to the shelter structure so it can withstand strong winds and storms;
- Walls - must provide lateral stability in all directions and transfer the wind uplift forces of the roof to the ground while allowing it to be easily disassembled;
- Floor - should minimize dust and vector penetration, while contributing to the shelter stability;
- Partition walls - should be lightweight but able to provide privacy for its inhabitants;
- Exterior door - should be insulated and have a simple lock for security. Its size should be greater than 90cm x 190cm and it should open out.
- Windows - should have a simple lock for security. Its size should be greater than 60cm x 60 cm and it should open out.

Last, the shelter standards for the criteria regarding design, stability, and logistic are the ones illustrated in Table 11.

Table 11 – adaptation of Terms of reference for the provision of shelter solutions for different climates [18]

	Standard	Description	Addressing climacteric differences		
Design criteria			**Cold weather**	**All weather**	**Hot weather**
1	**Setting-up**	Should be quickly transported and easy to setup with minimal application of construction tools.	Easy		
2	**Time per unit**	1-2 days (maximum).	≤ 48 hours	≤ 6 hours	≤ 24 hours
3	**Manpower**	2-3 persons (maximum). However, increase the number of manpower should reduce the required set up time.	2-3 persons		
4	**Skill**	Should be assembled on-site with only basic tools (Nonpowered portable hand tools).	unskilled labours with some technical support	unskilled labours	unskilled labours with some technical support

4	**Shape**	Square / Circular / Rectangular (L/B)<2 or any acceptable equivalent shapes.	N/A		
5	**Size**	Should have a minimum living space based on 5 persons x 3.5 m^2 or 4.5 m^2 (minimum shelter space per person on Sphere Standards depending on the weather conditions).	20m2 < A < 24m2	17.5m2 < A < 20m2	17.5m2 < A < 20m2
6	**Height**	The internal floor-to-ceiling height should be not less than a minimum of 2.0 meters from floor to the ceiling/eave level (greater height being preferable in hot and humid climates to aid air circulation and lower height preferable in cold climates to minimize the internal volume that requires heating).	2.0 m < H < 2.5 m	2.0 m < H < 2.5 m	2.1 m < H < 2.7 m
7	**Life Span**	Should be designed to last approximately for 1-5 years.	1 to 5 years	1 to 2 years	1 to 5 years
8	**Ventilation**	Should be designed to optimize entry of direct sunlight as well as optimize efficient indoor air exchange according to weather conditions. Proposed shelter design must accommodate ventilation systems (windows and ventilation openings) suitable to the issues of air quality. Indoor air speed should not be more than 0.2 m/s. Exhaust fumes and gases should be also eliminated through flue pipe/opening	≤ 2 openings (excluding the window opening)	≥ 2 openings	≥ 2 openings (excluding window openings)
9	**vectors control**	Should prevent or aim to be resisting to vectors such as mosquitoes, fleas, ticks and small animals like rats, birds and monkeys.	Mesh/Net fixed in ventilation openings/window		
10	**Maintenance**	Should ensure a certain degree of sustainability, especially in term of longevity, resistance to adverse weather conditions, and comfort for the users, with efficient cost implications. A serious consideration shall be given to maintenance requirements within the shelter life-cycle. It should be easily maintained by the family, easy cleaning, repairing and fixing missing or broken parts from simple materials available in local markets.	Easy		

11	**Thermal Resistance**	The proposed shelter components (roof, wall and floor, if any) should be lightweight of low thermal capacity with adequate insulation or possible to upgrade with suitable insulation for extreme climate conditions. It should have also an appropriate resistant to the effects of UV sunlight through the proposed lifespan	UV ≥ 6,500 Hours	UV ≥ 3,500 Hours	UV ≥ 7,500 Hours
12	**Fire Resistance**	The property of proposed shelter materials or their assemblies should prevent or retard the passage of excessive heat, hot gases or flames under condition or normal use. Therefore, the proposed shelter shall have sufficient structure stability under fire conditions with minimum fire-resistance rating not less than the referenced time.	F.R. ≥ 30 minutes		F.R. ≥ 60 minutes
13	**Water Proof**	Shelter materials should remain waterproof for the heavy rains and high humidity.	N/A		
Stability and Hazards criteria			**Cold weather**	**All weather**	**Hot weather**
14	**Dead and Live Loads**	Depends on the shape and material components of the proposed shelter, the dead loads required for the design should be minimum as the lightweight materials used in the shelter. However, the proposed shelter should be designed to carry a live load on the roof of 100 kg/m2. If the proposed shelter has a structural element floor, the design live load of 160 kg/m2 on the floor should be used.	L.L. ≥ 100 kg/m2		
15	**Winds Load**	Proposed shelter must have a shape that minimizes horizontal and vertical wind loads. Depends on the shape and type of support/footing of the proposed lightweight emergency shelter, the combined wind load pressure required for the design should follow this table minimum s with special design measure of wind uplift forces.	≥ 80 km/hr ≥ 70 kg/m2	≥ 70 km/hr ≥ 60 kg/m2	≥ 110 km/hr ≥ 90 kg/m2

16	**Snow Load**	Depends on the shape and type of roofing material components of the proposed shelter, the dead loads required for the design should be minimum as the lightweight materials used in the shelter. the roof snow load required for design should follow this table minimum s (based on minimum snow load) for flat, mono-slope or gable roof (15 degree).	≥ 120 kg/m2	≥ 100 kg/m2	N/A
17	**Earthquake**	The proposed shelter structure should withstand earthquake with low risk to human life in the event of shelter failure due to the earthquake effects.	N/A		
18	**Flood**	It is not expected that the proposed shelter will be subjected to high-velocity wave action.	N/A		
19	**Rain/Storm**	Should be designed for the rainfall event as "design storm" to ensure safe and economical design. (It may be also possible to upgrade and use rainwater harvesting system for the family).	≥ 70mm/hr (15 min. period)		
Logistic Criteria			**Cold weather**	**All weather**	**Hot weather**
19	**Weight**	Should be light, compactly packed for cost-effective transport, be possible to store for prolonged periods of time and be disposed at the end of its useful life in an environmentally friendly manner.	160kg ≤ w ≤ 250kg	80 kg ≤ w ≤ 160 kg	120kg ≤ w ≤ 200kg
20	**Packed Volume**	Should be designed for easy transportation. It may deploy in a flat packed unit/s where no more than two people can quickly assemble the shelter without the need of tools or equipment's.	0.25m3 ≤ V ≤ 0.35m3	0.15m3 ≤ V ≤ 0.25m3	0.18m3 ≤ V ≤ 0.30m3

3.4. Portuguese standards (DL 177/2001, DL 163/2006 and DL 64/90)

Once there is no legislation regarding transitional shelter and this project aims not only to be able to deliver a quick response concerning shelter needs, but also offer a solution versatile enough to adapt to different circumstances, i.e. different typologies, different user's needs, and different climates, we will confront it against the Portuguese standards regarding building dwellings. Portuguese law in force, namely, the general regulation of urban buildings - DL 177/2001 -, the accessibility regulations for public building, housing, and community facilities - DL 163/2006 -, and the fire protection regulations for residential buildings - DL 64/90 - will then be consulted to serve as guidelines, and not strict requirements to comply with.

Knowing that the number of bedrooms defines the dwelling typology, and their identification is used by the symbol "Tx", where x is the number of bedrooms, one can see from Table 12 which compartments, in number and area, are required to comply within each typology. It is worth saying that WC compartment is not included in it and that the add-in in the last row cannot give rise to an autonomous or enclosed space, but should be distributed through the kitchen and living room, as a space to be allocated for clothing treatment. For the purpose of this project, it will be dismissed.

Table 12 - dwelling typology and compartment minimum areas from [19]

	número de compartimentos por fogo							
	2 T0	3 T1	4 T2	5 T3	6 T4	7 T5	8 T6	Mais de 8 Tx>6
	áreas em metros quadrados							
Quarto casal	—	10,5	10,5	10,5	10,5	10,5	10,5	10,5
Quarto duplo	—	—	9	9	9	9	9	
Quarto duplo	—	—	—	9	9	9	9	
Quarto duplo	—	—	—	—	—	9	9	restantes quartos 9m2
Quarto simples	—	—	—	—	6,5	6,5	6,5	6,5
Quarto simples	—	—	—	—	—	—	6,5	6,5
Sala	10	10	12	12	12	16	16	16
Cozinha	6	6	6	6	6	6	6	6
Suplemento de área obrigatório......................	6	4	6	8	8	8	10	(x + 4)m2 (x= n.º de quartos)

As shown in Table 12, one can see that for instance a T0 dwelling is composed of two compartments, namely living room and kitchen, plus the toilet.

The dwellings typology described above give origin to gross floor areas with the minimum values illustrated in Table 13, which as one can see are obviously bigger than the clear compartments areas.

Table 13 – Dwellings Typology gross floor area from [19]

	Tipo de fogo							
	T0	T1	T2	T3	T4	T5	T6	Tx>6
área bruta em metros quadrados	35	52	72	91	105	122	134	1,6 x Ah

(in Table 13 "*Ah"* goes for Living area, which means the sum of the areas of the housing compartments, except lobbies, interior circulation, toilets, storage and other similar function compartments. It is measured from the inside perimeter of the walls that limit the dwelling, discounting, generically, interior walls, partitions and ducts.)

Regarding circulation, general regulation [20] sets the corridors widths to 1,10m, allowing its reduction for 0,90m whenever it is a secondary corridor no longer than 1,5m long. Fire protection regulation [21] sets passage widths, i.e. doorways, to have at least 0,80m wide, as well as its doors to open into the exit direction**.** However, accessibility regulation [20] is more prescriptive and sets exterior building doors to have a clear width greater than 0,87m, allowing though for the interior doors to have a clear width no less than 0,77m. The bottom line here is to achieve the complete maneuver of a regular wheel chair as shown in Figure 20. For that matter doorways should have unobstructed maneuvering and leveled areas as shown in Figure 21.

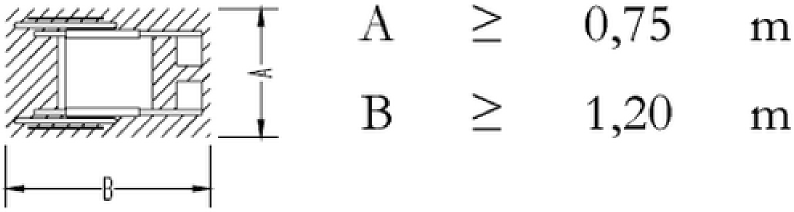


Figure 20 - Clear area for a regular wheel chair. Image taken from [20]

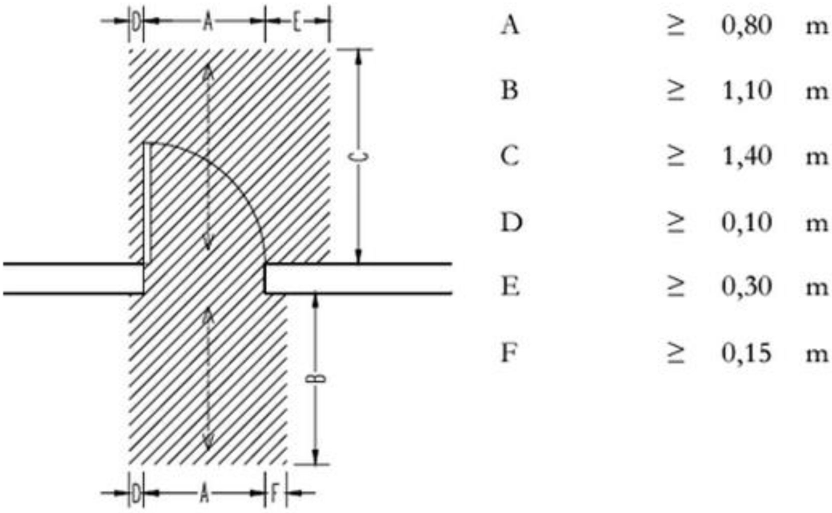


Figure 21 - Unobstructed maneuvering areas for regular wheel chairs. Image taken from [20]

Special attention is given, regarding the interior air quality of the building. For that matter, all compartments should be lit and ventilated by one or more openings practiced in the walls. Those openings should be in direct communication with the outside and its total area should be not less than one-tenth of the area compartment. Dwelling’s cross-ventilation should be promoted, generally by means of windows arrangement in two opposite walls.

4. Construction restrictions and Architectural constraints

4.1. GFRP materials and ALTO’s technology

The architectural project, which normally comes first, was in this particular project restricted and subordinated to the previous choice of the project´s materiality and construction process. The aim of this project was to test GFRP application in being capable of delivering a new final product such as a prefabricated shelter to a potential growing market. Therefore, the shelter should be made out of GFRP profiles and panels according to the available technology at “*ALTO – perfis pultrudidos, Lda”* [22], the Portuguese leading enterprise in such pultruded profiles. (For more information regarding ALTO’s commercial profiles, see Figure 72 at the Appendix I)

Figure 22 illustrates the pultrusion process of GFRP profiles at ALTO´s facilities. Numbers 1, 2, and 3 refer to the three different glass fibers used, number 4 to the polymeric matrix (resin), and number 5 to the metal preform and pultrusion table. After glass fibers 1 and 2 have been embed in the resin (4), they are pulled together with glass fiber 3 into the metal preform that will shape the section of the profile as shown in 5. Thus, this industrialized process allows producing constant section profiles with little manual work.

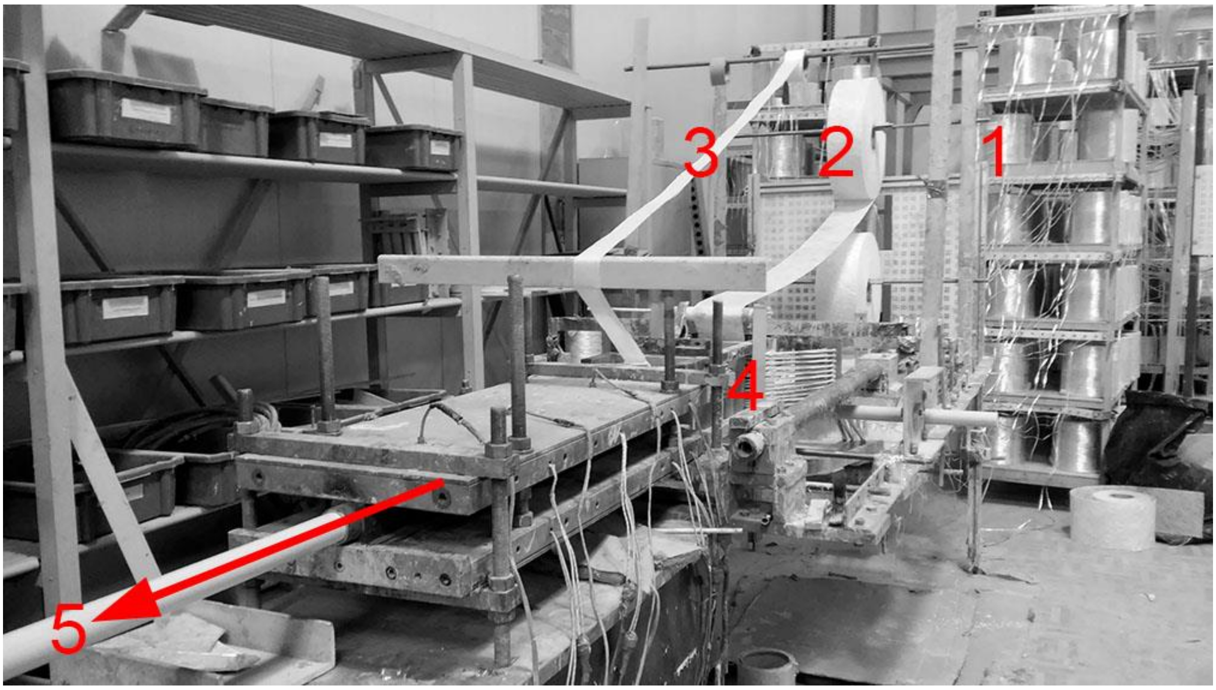


Figure 22 – Pultrusion process of the GFRP profiles. Image taken at ALTO’s facilities.

Besides the GFRP pultrusion process, GFRP products can also be manufactured differently as in the case of molded gratings or the manual hand lay-up process, which enables creating adaptable panels to different shapes. Figure 23 illustrates a sample of ALTO’s products, namely gratings, sandwich panels and pultruded profiles.

Figure 23 - Sample materials produced at ALTO. Image taken at ALTO's facilities.

The structure of this transitional shelter had already been set. Each module was composed of a frame of beams and columns, made of pultruded GFRP tubular profiles, as showed in Figure 24, with a square section of 12 cm. The connections between beams and columns, as well as columns and its foundations, were invisible. They were accomplished by stainless steel bolts and steel plates positioned within the tubular cavity as shown in Figure 25.

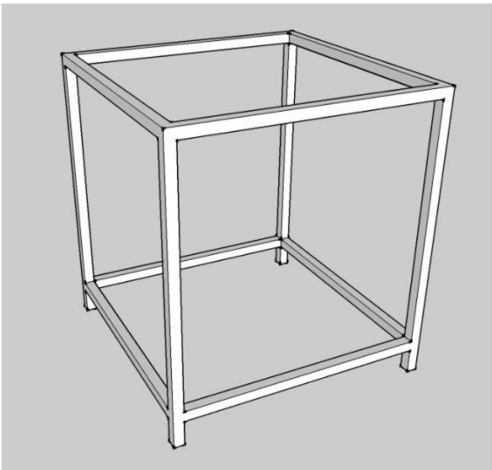


Figure 24 – Structural frame of beams and columns for the Single module

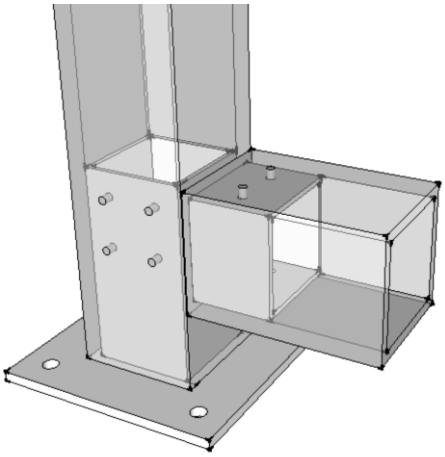


Figure 25– stainless steel connectors within the GFRP structural profile [23]

4.2. Geometry, components, connections and floor arrangement

The Clickhouse project was thought to be a modular project that, by means of cells aggregation, could offer the possibility to build different and larger compositions according to its inhabitant's needs. The transitional shelter prototype was thought to be the combination of several modules of 2,4m^3 where it could be possible to include sanitation and kitchen facilities as required.

For structural reasons the floor panels have to be arranged alternately as shown in Figure 26. By doing so, and because the load path distribution follows the biggest panel span, each floor beam only has to support one module floor [23].

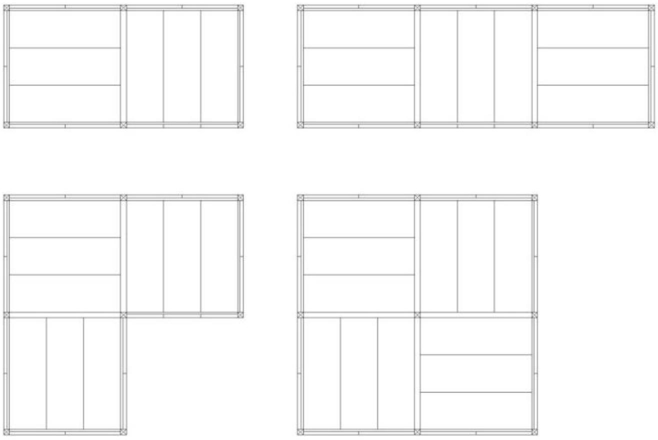


Figure 26 - arrangement of the floor panels

The walls, floor, and roof were made of sandwich panels composed by an insulation material in its core - rigid polyurethane foam – lined by two outer sheets of GFRP. These panels were thought to be able to incorporate water, sewage, and electricity networks [24]. The connections, between the structure and the panels and between the panels themselves, were accomplished by a female-male connection (through fitting, by click, a 5cm wide GFRP square profile into a 6cm U-shape GFRP profile), and thus originating the name of the project to Clickhouse. This male connection profile – square - was to be adhesively bonded to the beams and columns at the production facilities, to make the beam/column-to-panel connection, as shown in Figure 27, and was to be adhesively bonded between them to make the panel-to-panel connection as shown in Figure 28. Figure 29 shows how all this components go/click together to form the single module as shown in Figure 30.

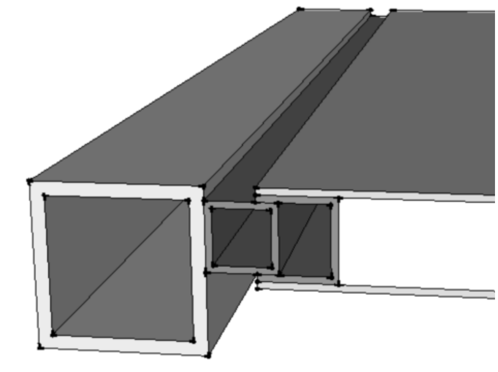


Figure 27 - Beam/column-to-panel connection [23]

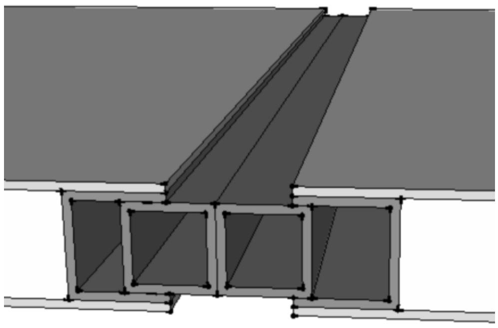


Figure 28 - Panel-to-panel connection [23]

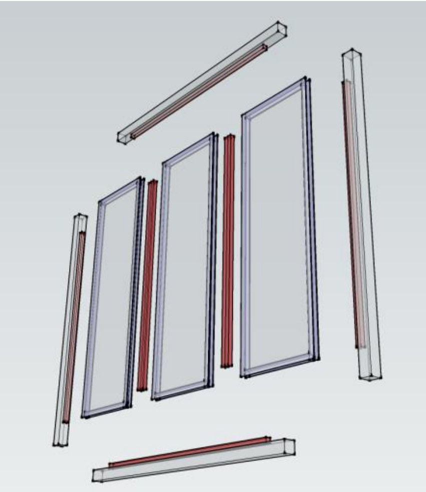


Figure 29 - Construction process: exploded wall showing Beam/column-to-panel connection and panel-to-panel connections

Figure 30 - X-ray of a single module

Besides the roof assembly, which was foreseen to follow a similar design approach as the walls and floors, all the construction process had already been fully developed. Therefore, the architectural design input to the project was limited to optimizing 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.

5. Architectural input

5.1. Passive design lessons to address thermal comfort

One of the big issues this project faced was how to optimize the shelter components so that the module could comfortably respond to a range of different weather conditions, namely temperature, humidity, and wind.

As the module's components were to be standardized, i.e. the same materials with the same geometry, thermal insulation and therefore thermal inertia, regardless the geographically circumstance where the module would be placed, the climacteric response's capability of the shelter had to be sought simply by the application of passive design techniques and that proposed a great challenge.

Nevertheless, there were still a few lessons one could take from passive design techniques into the module's components design, so the thermal response of the shelter could be somehow optimized to its inhabitants needs.

Orientation factors: Taking outside conditions into design consideration

To start with, and before going on into the shelter's design conditioning factors that influences the building thermal behavior, per se, one should carefully consider the choice of the location and orientation where the shelter would be set up. Sun and wind orientation can play important roles on the building's envelope thermal capacity, leading thus to a great transmission range of temperature to the interior of the shelter even within the same climatic zone [9]**.** Figure 31 illustrates two examples of street's orientation in relation to prevailing winds. On the left, an example on how the houses block the prevailing winds. On the right, an example on how the street orientation according to the dominant winds enables ventilation to reach all the houses.

Figure 31 - Street's orientation in relation to prevailing winds. Images taken from [26]

Figure 32 illustrates how the design of the main streets enables the correct settlement ventilation. The main streets should be designed in the direction of prevailing winds so it cools down and clean the street. Its enlargement at the corners will cause wind speed changes that will help to suck the wind out of side streets where the wind is stopped. [26]

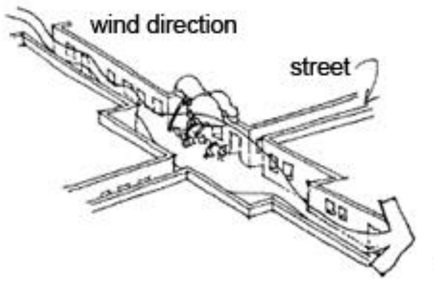


Figure 32 - Settlement design in relation with prevailing winds. Image adapted from [26]

Figure 33 illustrates the wind protection effect on the cooling of the buildings. On the left, the settlement has no wind protection and the temperature in between the buildings cools down 5º C [26]. On the right, the vegetation barrier prevents that the wind cools down the convectional thermal gains of the walls of the buildings.

Figure 33 - Wind protection effect on the cooling of the buildings. Images taken from [26]

The street's design should also consider its solar orientation. Figure 34 illustrates the shadowing effect during the day of a street facing North/South, where the side ways of the streets become partially at shadow during the rising and setting of the sun.

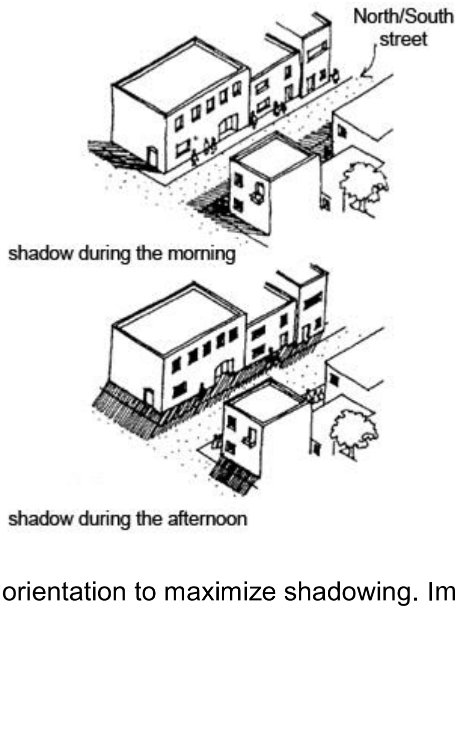


Figure 34 - Street's orientation to maximize shadowing. Images taken from [26]

In the Clickhouse particular project where one knows its panels have small thermal inertia [25] and therefore high temperature transmittance between outside and inside temperatures, special care should be given in its placement so it can be at the most favorable conditions that contribute to avoid heating in the already warm situations and cooling in the already cold ones. Therefore, one should give careful plan to surfaces shading, being opaque, transparent, or translucent, once it can work either for or against the desired effect, i.e., it can avoid overheating but it can also prevent solar gains.

Volume factors

Regarding the shelter´s shape design, the height of the ceiling can help, to some extent, to regulate its interior temperature. Because air's temperature affects its density, being the colder air temperature, the heavier, when designing to address different climates, one should play with the height of the ceiling, together with ventilation if need it, in order to generate beneficial airflows in its interior. To sum up with, when addressing exterior warm temperatures one will want to have high ceilings so that the colder air can drop and turn the air layer next to its inhabitants the most comfortable it can. On the other hand, when addressing for exterior cold climates one will want to have lower ceilings, so that it can bring the warmer air layer next to its inhabitants and simultaneously minimize the internal air volume that requires heating.

Fenestration size, disposition, and ventilation

Fenestration size, disposition, and functioning can also play an important role in the control and improvement of the shelter's interior temperature and in its inhabitant's well-being. The glazing of the windows not only allows the natural light to come inside and the inhabitant's field of view to increase by looking outside, but also allows solar heat gains, or losses, to the shelter interior, depending on its solar incidence and its thermal transmittance [9]and [25]. That said, when addressing to design for different weather conditions, one should consider the windows size - glazing dimensions -, position - solar orientation and its height from the floor -, and functioning - fixed or ventilated glazing - so that solar gains and thermal losses can be optimized. In warm climates is good practice to maximize the cooling of the interior space through cross- ventilation, and for that means, to position the windows next to the ceiling, where the warmer air lays. However, there are significant differences that one should take into consideration when addressing hot and dry climates versus warm and humid ones. In the hot and dry climates, where there are significantly temperature changes during a 24-hour period, the glazing should be kept to the minimums that enable ventilation at night and so thermal gains through it during the day can be mostly avoided. On the other hand, in warm and humid climates where the temperature remains stable over night and day, ventilation should be maximized and therefore the more opened windows there are the better. In cold climates, the windows approach is different. The glazing should be positioned to maximize the solar gains while ventilation should be restricted to the inhabitant's air renovation needs.

Shape factors

Besides all mentioned above, there are still some factors concerning the plan development of the shelter that can positively contribute to its climate adaptation. If it is truth when addressing the design for warm and humid climates, one will want to maximize ventilation and for that instance the fact there are 6 exterior surfaces, including the shelter's elevated floor, directly exposed to the outside environment is desirable, the same just not apply to the hot and dry climates. In such cases, one will want to minimize the interior temperature's fluctuations alongside with the exterior environment, and in order to do that, minimize the amount of surfaces in direct contact with the outside air. Once that in the Clickhouse project, due to the elevated floor construction process, the earth thermal mass cannot be taken as an advantage, the only possibility to minimize the amount of exterior elements in contact with the exterior is through module aggregation and shelters compactness. In doing this, it will allow not only to reduce thermal gains through walls convection, but also, to provide extra shading to the adjacent shelter.

5.2. Standardization and Functionality

Designing for a standardized module that aims to be able to respond to different uses, sites, and weather conditions requires a strong negotiation between the overall plan and the detailing of its components, so that with the minimum number of them, one can generate as many customizable solutions as possible. While the standardization of its components will facilitate mass production (reducing operation costs and speeding manufacturing), the interchangeability possibilities of its components and module arrangements will allow building different, adaptable and larger compositions.

Once that the Clickhouse aim was to offer a shelter universal solution, the yardstick used to measure the space were the standardized dimensions of household appliances and furniture and not any cultural differences in the use of space that might arise among different peoples. That said the basic furniture considered for the bedroom and living room design, were single and doubled beds, wardrobe closet, bedside, desktop, side chairs, dining table and sofas. For the bathroom, the sanitary equipment considered was toilet basin, shower base, and washbasin and for the kitchen, standard base modules, which could enable embedding sink, hotplate, oven, and refrigerator.

Starting from the shelter structure's pre-sizing, the base module was a cube with approximately 2,4m of interior side. Each surface was originally composed of two sandwich panels measuring 2,4 x 1,2m. The sanitation facilities were not included in this structure, but thought to work as an independent and smaller module, an appendix, that would be attachable to the main modules instead and whenever needed.

In this panel's constructive process, all fenestrations, i.e., doors and windows would have to fit into the panel frame. Therefore, it became clear that being the wall composed of just two panels, it strongly conditioned the use of the module, as the door panel would have to take either one of its sides and never be at the center. If 2,40m is both divisible by 2 and 3, generating respectively 1,20m and 0,80m width panels, and the exterior door was initially requested to have 0,90m width, then the solution might be to simultaneously produce 2 and 3 panels surfaces. There were two advantages in such hypothesis. Firstly, it would allow positioning the door at the center of the wall, which would open possibilities for the layout of the bedroom, as shown in Figure 35, and secondly, by reducing the width of each panel, the door operating space would diminished, which would be of good use for interior partitions whatever the module uses would be.

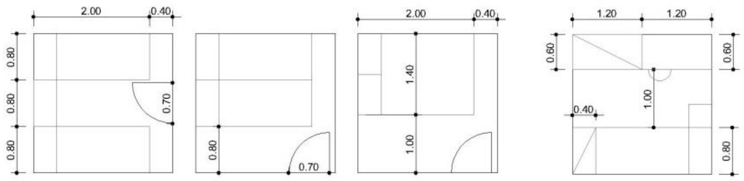


Figure 35 – Bedroom layout study for a 2,4m^3 module

In order to assess the use potentialities offered by these dimensional constraints, a thorough study of the interior layout was followed. Figure 36 shows the sanitation facilities layout preliminary study either for single-family or communal use. Figure 37 and Figure 38 shows the layout preliminary studies conducted for the bedroom, kitchen, and living room, respectively.

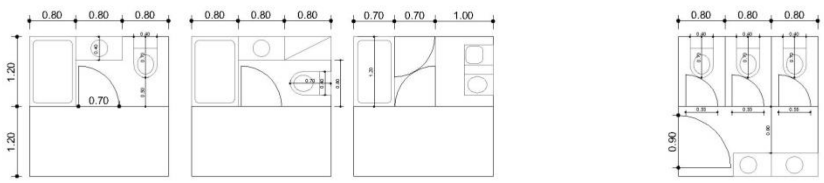


Figure 36– Sanitation facilities layout study for a 2,4m^3 module

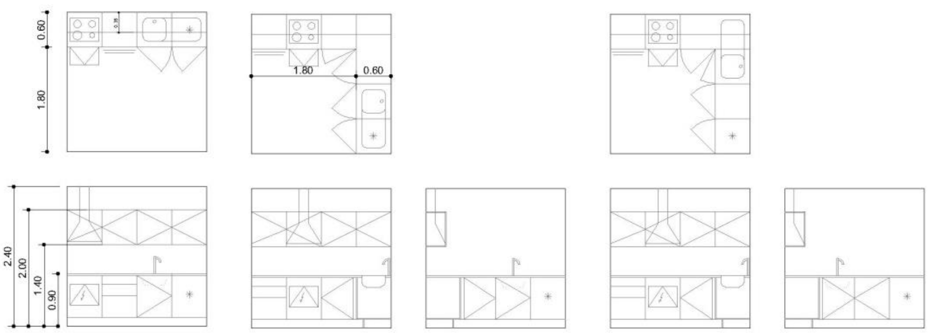


Figure 37 – kitchen layout study for a 2,4m^3 module. Plan at the top; Elevation at the bottom

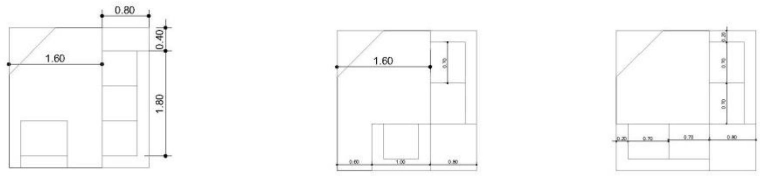


Figure 38 – living-room layout study for a 2,4m^3 module

After the interior layout of the base module, or cell, had been assessed in its potential uses, namely sleeping, cooking and being, a study concerning module aggregations to generate different dwellings typologies was carried out. Soon it was concluded that, for such a small module, it would be of more efficiency to incorporate the sanitation facilities in part of a standardized module, as it would enable to introduce space for circulation and distribution for the other modules in the overall plan, as shown in Figure 39 and Figure 40.

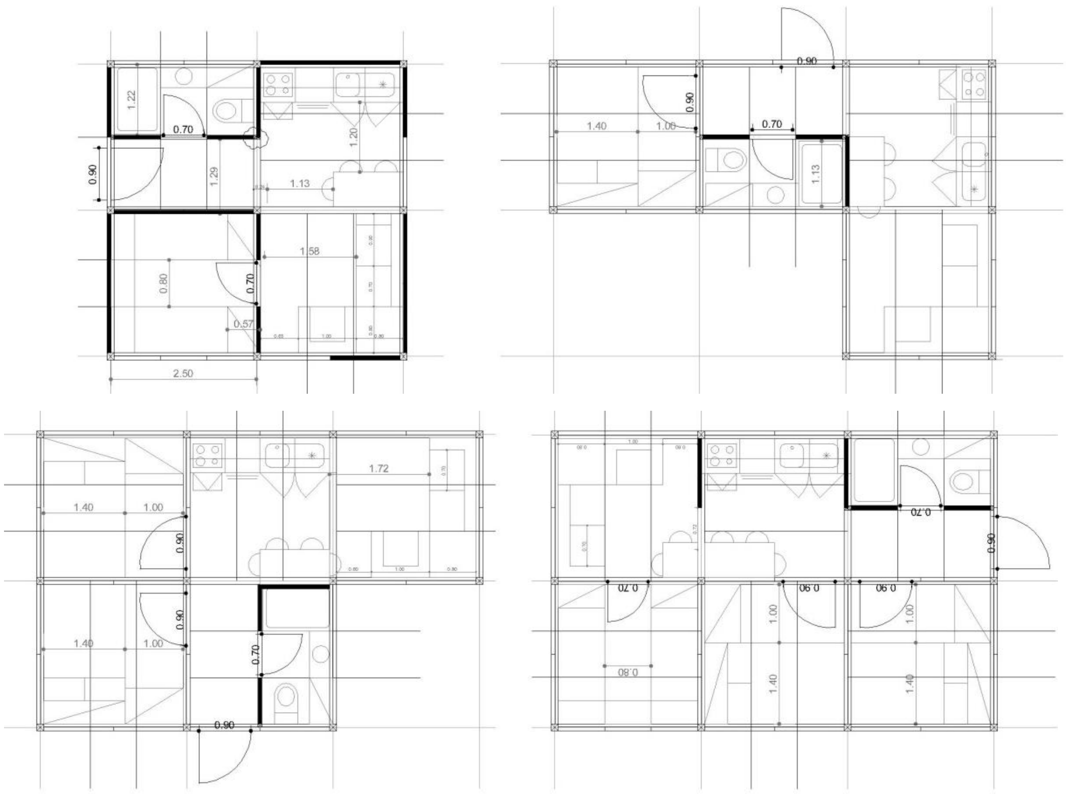


Figure 39 - T1,T2 and T3 typologies study: circulation and distribution through the WC module

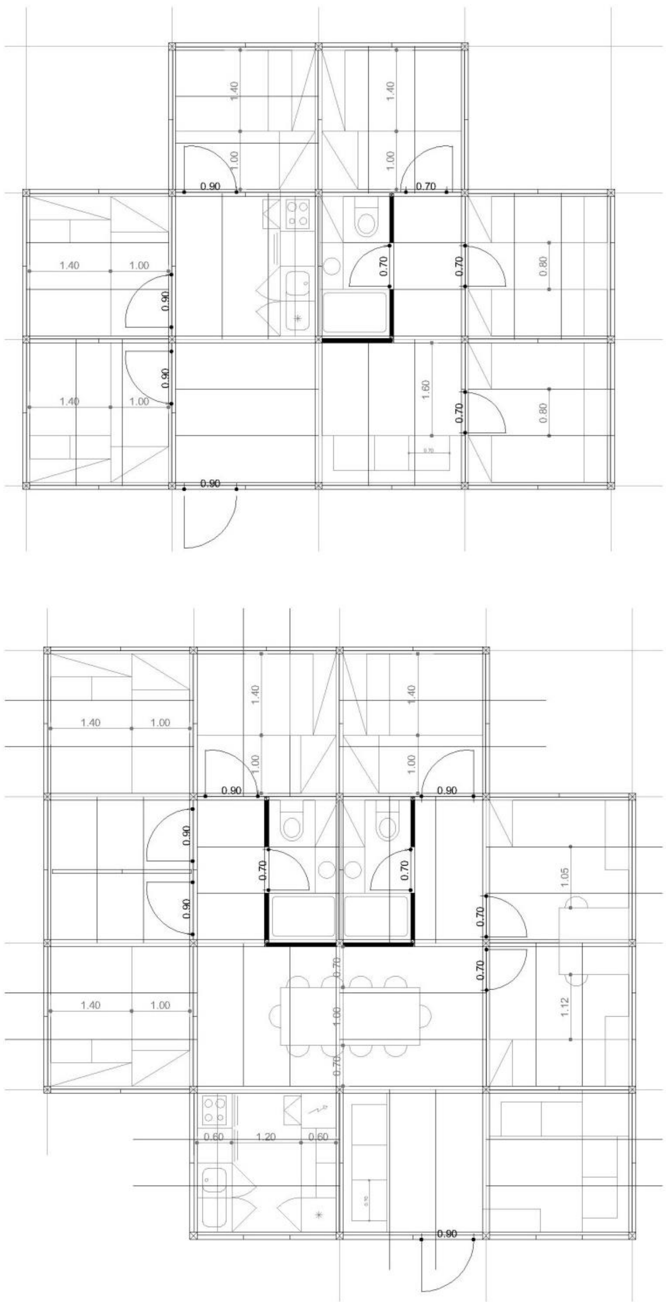


Figure 40 - T6 typologies study: circulation and distribution through the WC module

Besides distributions concerns, by incorporating the sanitation facilities inside the regular module, there would not be any need for introducing a new different construction solution for that appendix and no need to disrupt construction standardization.

Another issue regarding standardization emerged from those module's aggregation exercises. The existing wall panels flushed with the outside surface of the structural frames, even they reproduced the beam-to-panel alignment connection, were when enclosed by a wall, generating different floor areas in adjacent modules. This asymmetrical solution was conditioning the versatility of the shelter expansion.

The solution found to enable modular repetition, whatever situation the module was - standing by or grouped together - was to reposition the walls connections to the axis of the frame so they could become symmetrical. Figure 41 captures all the 6 columns possibilities. (Each one of these different columns are adhesively bonded to the auxiliary tubular connector of the walls at the production facilities.)

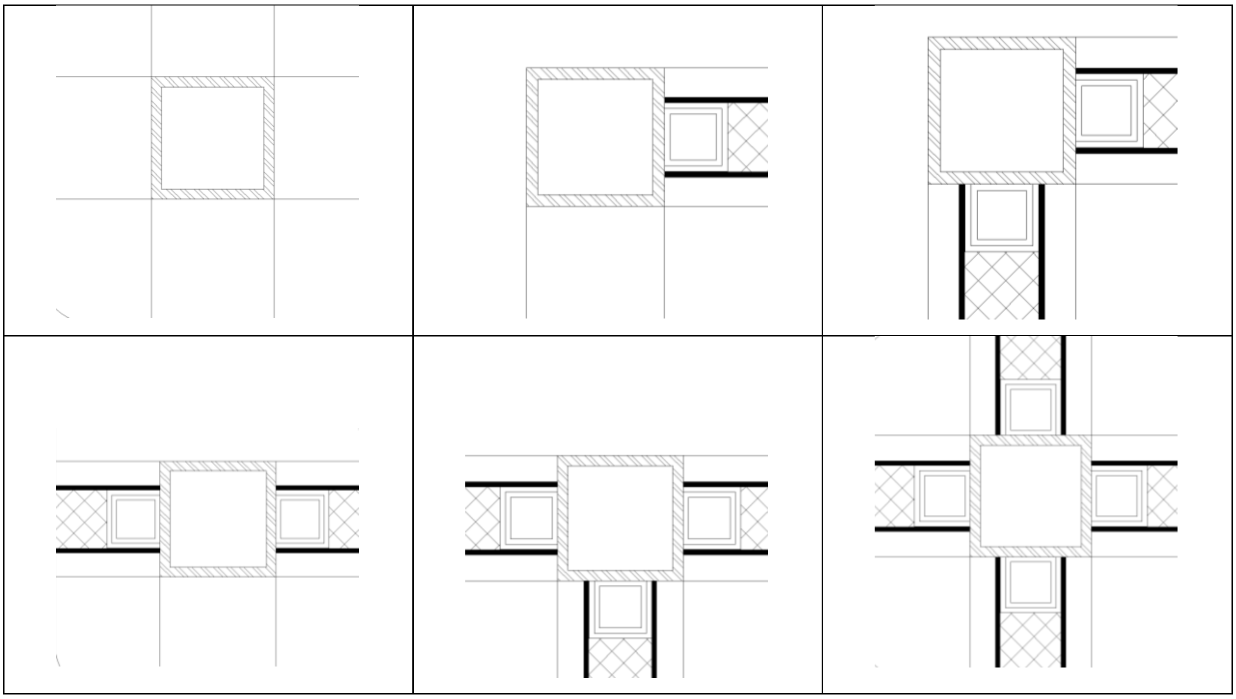


Figure 41 - Plan of the 6 types of columns.

5.3. Geometrical iterations: from the initial 2,40m^3's base module up to 2,88m^3

After tackling the big picture and integrating its conclusions within the project, - modularity, and versatility - one of the main issues the module's design faced was how to optimize the space so that a family could live comfortable in it for a transitional period that could go up to 5 years. In order to test the layout potentialities of the module, the study followed several geometrical iterations as described below.

The initial 2,40m^3 base module, as referred above, presented itself already with a problem: the door panel width. While fenestrations guidelines for the construction of an emergency shelter [18] predicts the outside door to be 0,90m wide, the Portuguese legislation[19]and [20], regarding interior doors, lowers the bar to nearly 0,80m, which is just wide enough for a wheel chair to pass. That said, the 3 panels wall of 2,40m could not comply with the least demanding regulation concerning fenestration, once the 0,80m wide panel when replaced by a door, would necessarily have to include a door frame which would reduce its nominal width and for that reason that geometry had to be dismissed.

After this first trial, it was tested a 2,70m^3 base module with 3 panels walls of 0,90m each, as shown in Figure 42. The conclusion was that the panels were still not wide enough to incorporate the GFRP doorframe that meanwhile started to be developed, as shown in Figure 43. Furthermore, the bedroom optimization of such base module, dictated beds to be 1,90m long, instead of the more unanimous 2,00m that the project aimed to pursue, and so this attempt was also promptly discarded.

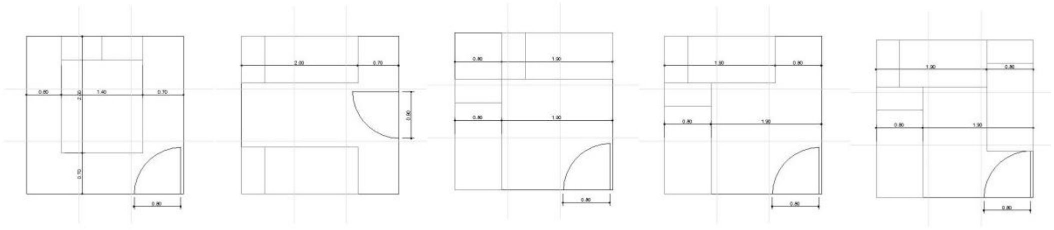


Figure 42 - 2,70m x 2,70m base module study

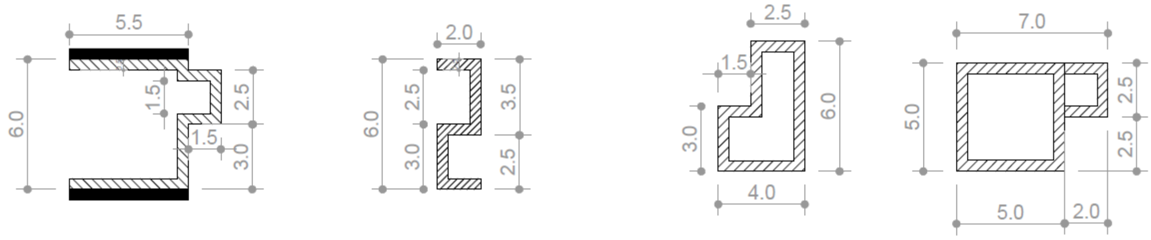


Figure 43 - GFRP design development for doorframes, doorjamb and transom bar or panel

Alongside, it was tested a rectangular base module measuring 2,4m x 3,6m, as shown in Figure 44. Its surfaces were composed of 1,2m wide panels and the solution had the merit of simultaneously address the issue of providing 3 panels walls, while providing door panels apertures wide enough to meet with the most demanding guidelines. Nevertheless, this solution would bring different issues to the project. On one hand, the same door, when working in partition walls would simply become oversized, and on the other hand, the asymmetry of the plan would challenge typological aggregation and the structure´s capability.

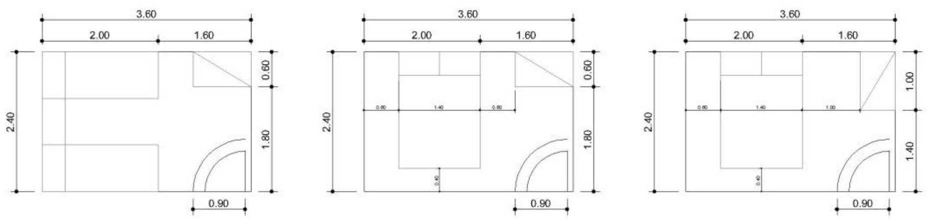


Figure 44 – 2,40m x 3,60m base module study

After quitting a non-cubic solution, it was tested a $3,00m^3$ base module, as shown in Figure 45, in which finally the 1m wide panels allowed, not only meeting the minimum door clearance as prescribed in the Portuguese regulations [19] [20] but also, meeting the guidelines for the construction of a shelter [18]. Figure 46 shows the door assemblage in a 1m width panel. Nevertheless, the 3x3m base module felt somehow oversized and not optimized for the emergency scenario that the project aimed to respond, being then also discarded.

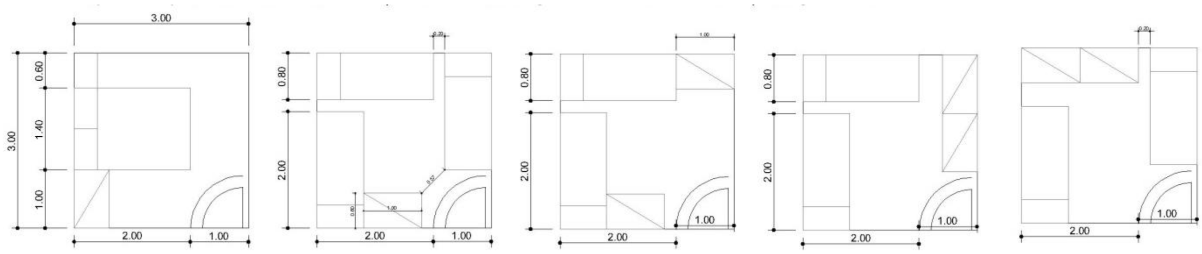
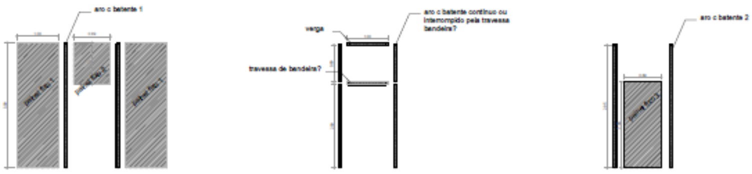
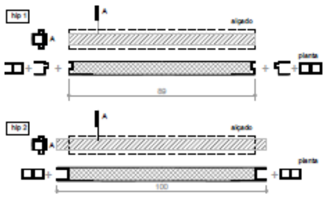


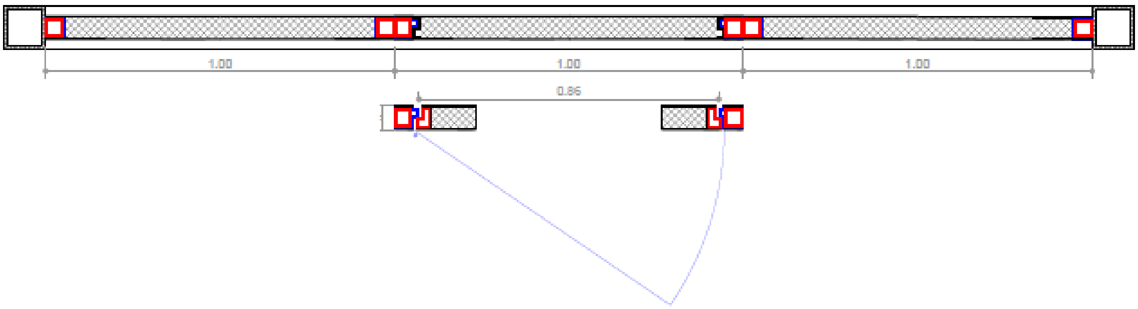
Figure 45– 3,00m x 3,00m base module study



Constructive elevation



Transom bar hypothesis



Plans of a wall at different heights. At the top transom panel, at the bottom door panel.

Figure 46 – Door's assemblage study: wall panels, doorframe, doorjamb, and transom bar or panel.

After some trial and error design exercises, one could finally grasp the dimensional requirements and constraints of the project, finally fixing the wall surface to 2,88m x 2,88m, which is to say, and easily remembered 3m in-between structural axes. In this final module solution, as shown in Figure 47, each surface is composed of 3 panels, having the wall and floor panels the same 0,96m width.

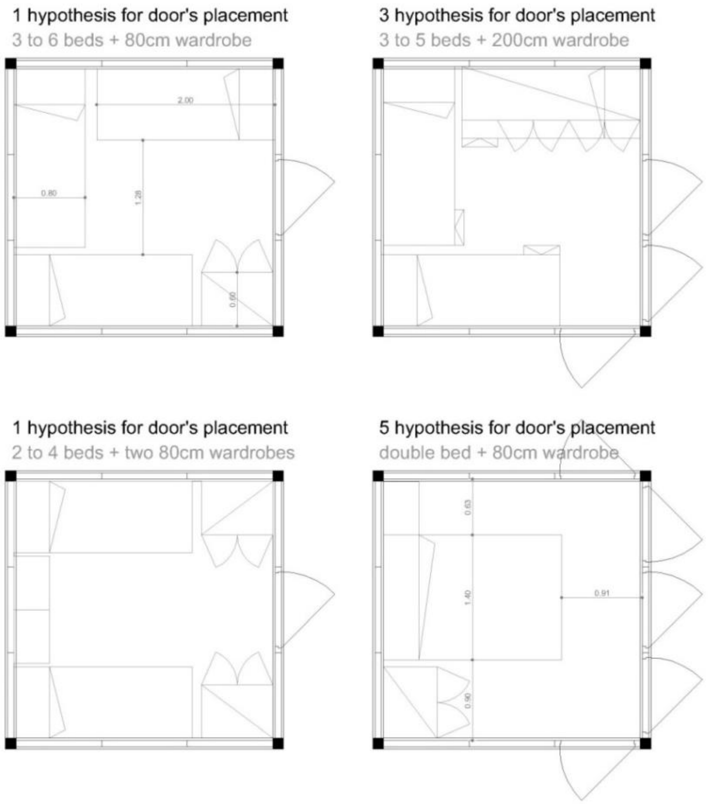


Figure 47 - 2,88m x 2,88m base module study for bedroom functioning

It is worth mentioning that the development of the fenestration study followed the design iterations. The underlying idea of this study was that the panel, being evenly subdivided, would originate smaller standard panels, which could become doors, windows, or both, as illustrated in Figure 49.

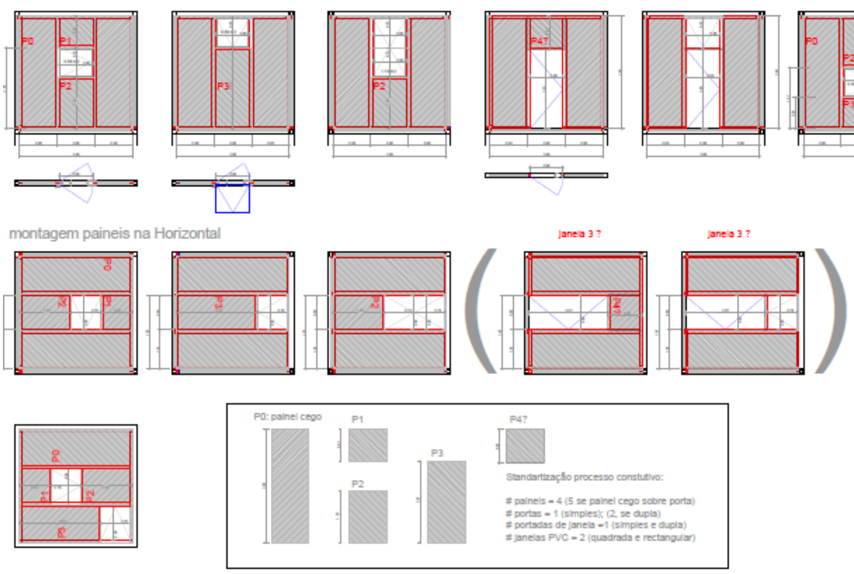
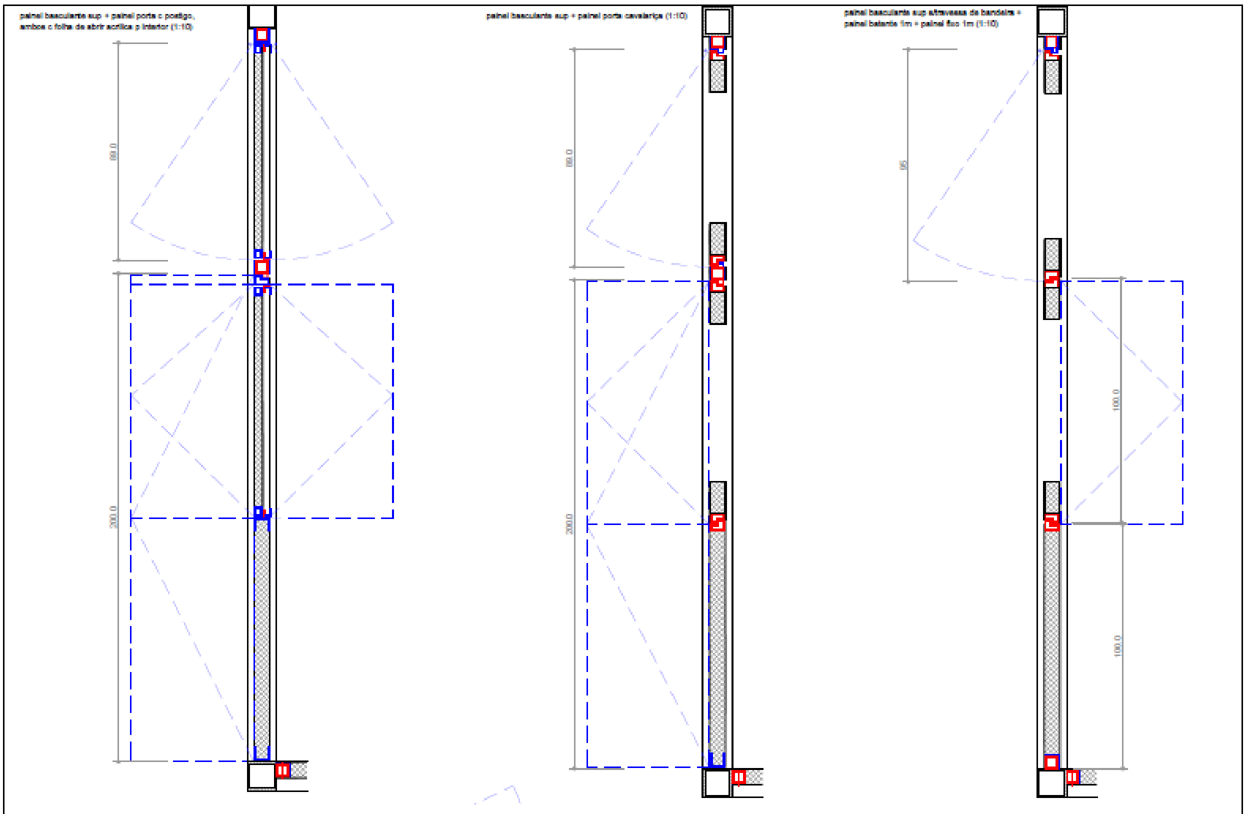
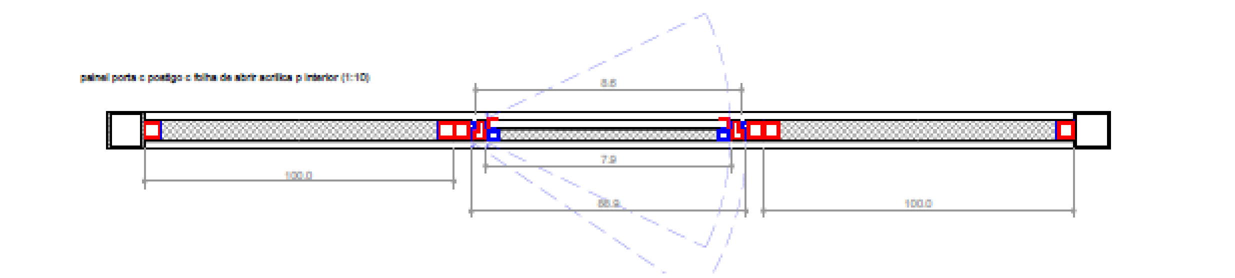


Figure 48 - Fenestration development study for a standard 0,96 x 2,88m panel.

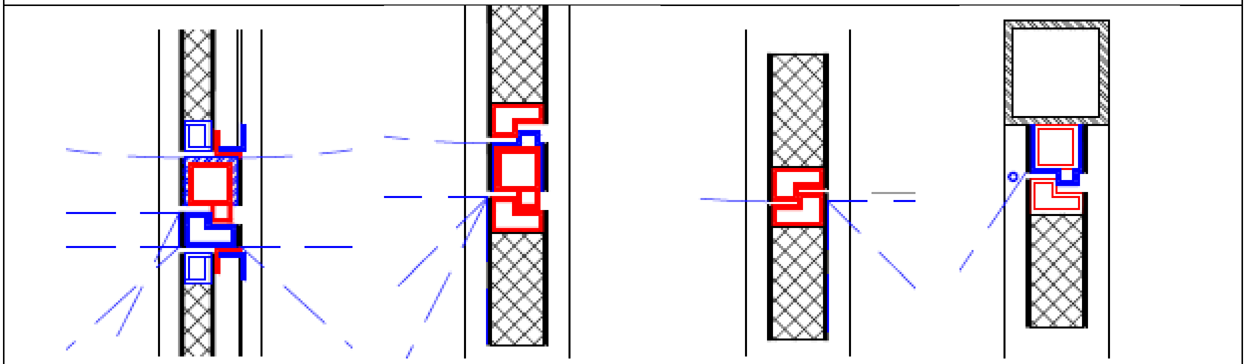
Initially and for thermal comfort issues, all windows were thought to be able to be protected by shutter panels, similar with the door panels. While the shutters would open outside, creating windows shading at day, the windows would open inside. It meant that each time there were consecutive openings, there was a need to incorporate a transom bar between them as shown in Figure 49.



Door's and Windows's Sections



Door's and Window's Plan



GFRP frame details for different situations

Figure 49 - Study for consecutive openings in panels. Windows with shutters, door and transom bar.

The fact that the window alone could be arranged in various heights together with the fact that each panel could be arranged into 3 different positions, and that the panel frame could be horizontally assembled whenever there were no door, would result into several possible elevation combinations, enabling customization of the elevations simply by panels arrangement.

Regardless the design effort to develop such GFRP’s profiles (Figure 43 and Figure 49), after closer consultation with ALTO´s manufacturer, and due to economic constraints in purchasing the metal preform for the pultrusion process, the idea of a door and window frame in GFRP had to be finally discarded. Additionally, ALTO’s technology was not able to produce nor a water tightness window nor a certified one, and so it was decided that it should be procured thought outsourcing instead.

Several request for quotation were then sent to aluminum and PVC window’s suppliers, and after analyses and comparison, it was decided to incorporate PVC windows with a 16mm polycarbonate working as the glazing [25] (for more information regarding the PVC framing, see **Figure 74** at the Appendix I). Due to the depth of the PVC frame, being the same 70mm of the wall panels, there was no spare space to include the flushed shutter with the wall, and so the incorporation in the design of a window shading system, which simultaneously promoted visual privacy during the night, was also discarded.

To finish with, and because the window design was required to incorporate a mosquito net, it was decided that all windows should open inside, instead of what was requested in the terms of reference for the provision of shelter solutions [18], as described before in the chapter 3.3.

6. Results and discussion

6.1. T0/1's dwelling shelter

After setting the module and panel dimensions, the project focused on the development of a 19sqm T0/1 shelter, i.e., a single bedroom dwelling that could accommodate a family of 4 to 5 members for a warm but dry climate.

The proposed T0/1 shelter is composed of two coupled modules divided into 3 different spaces, namely bathroom, kitchen, and bedroom, as shown in Figure 50**.** 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 [24]. 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**.**

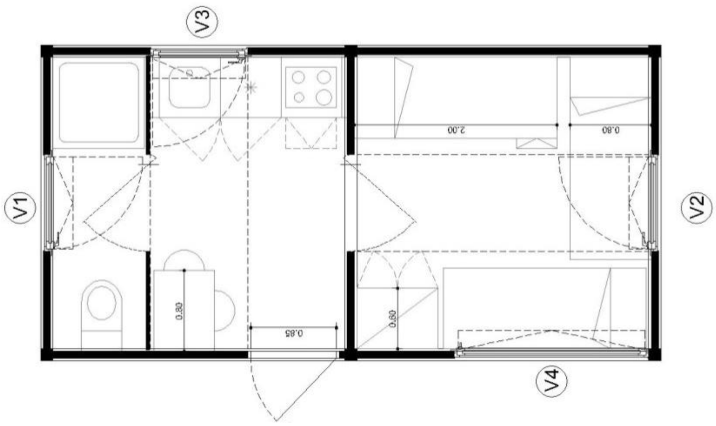


Figure 50 - Plan:T0/1 transitional shelter for a detached dwelling using two 2,88m^3 base module.

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 [16], this T0

/1, 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 51. 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, as said before, was replaced by a 16mm translucent polycarbonate with 60% of light transmissibility but good energy performance [25], and the window frame was equipped with a mosquito net from the outside for health issues.

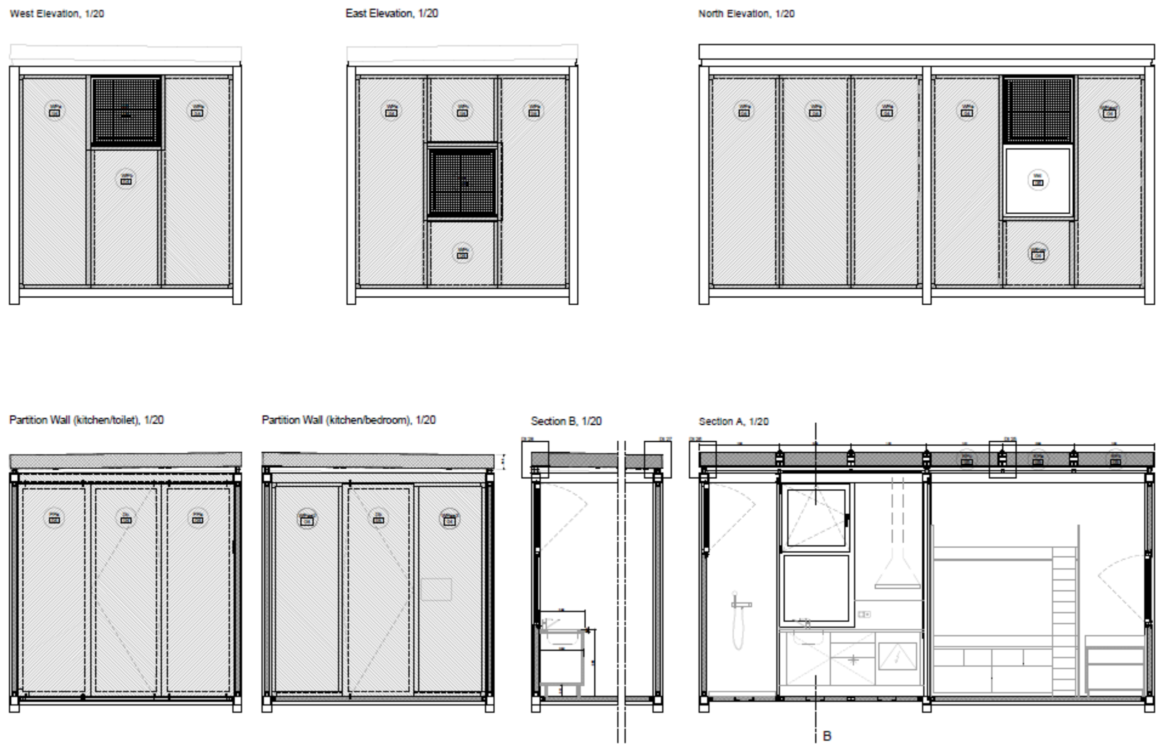


Figure 51 – Elevations and Section: Windows's arrangement in the T0/1 shelter

There are two sizes of window frames, occupying one or two-thirds of a panel, but three types of windows: the inward-stop's square window positioned at the smaller sides of the dwelling; the horizontal tilting's window at the bedroom; and the vertical casement's window at the kitchen, where one of the glazing is fixed. 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 52 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).

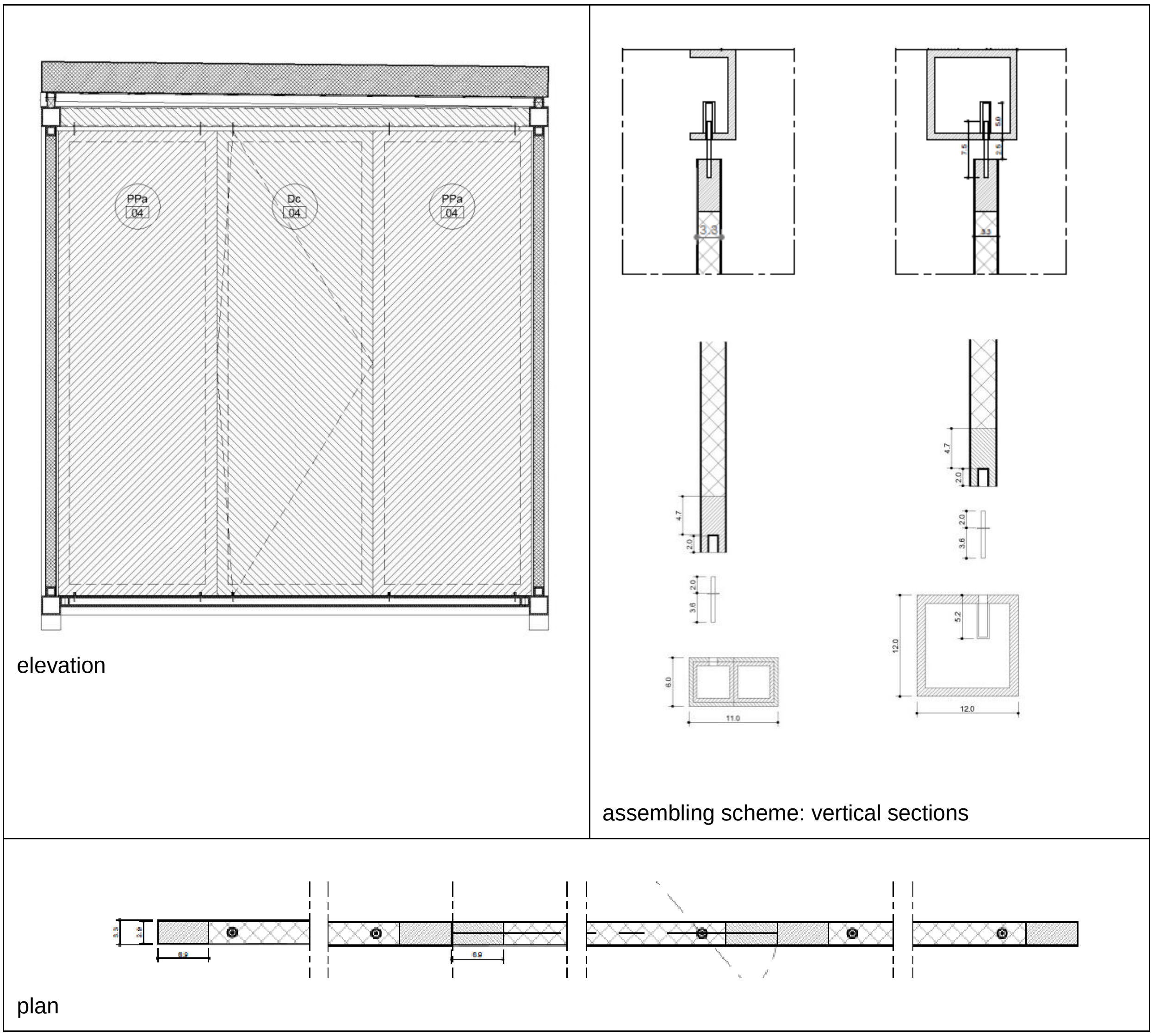


Figure 52 - Partition wall and door construction system

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 53, and depending on the module's working independently or in aggregation, there will be a need for 2 to 3 different panels, respectively.

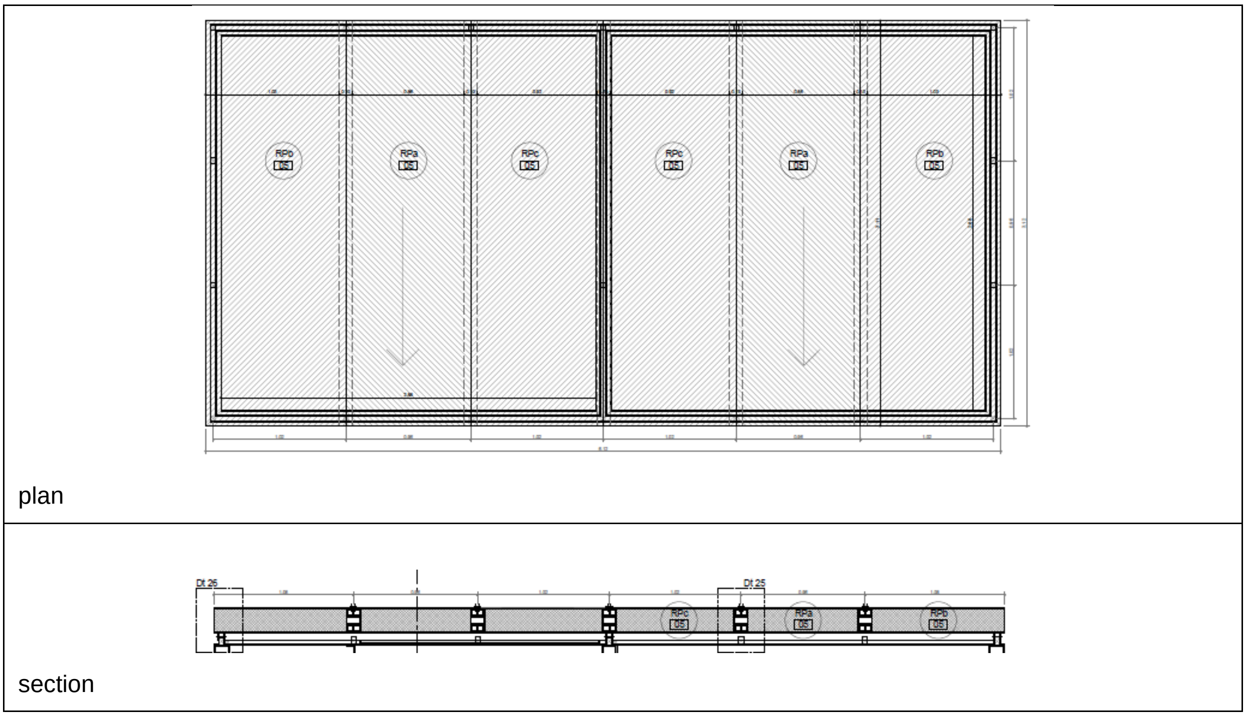


Figure 53 - Flat roof solution

The roof connection to the structural frame is accomplished by the fitting of the adhesively bounded U-shape profile of the roof panel into the L-shape profile adhesively bounded to the beam below, as shown in Figure 54. The roof slope is only of 1% due to the GFRP commercial profiles availability.

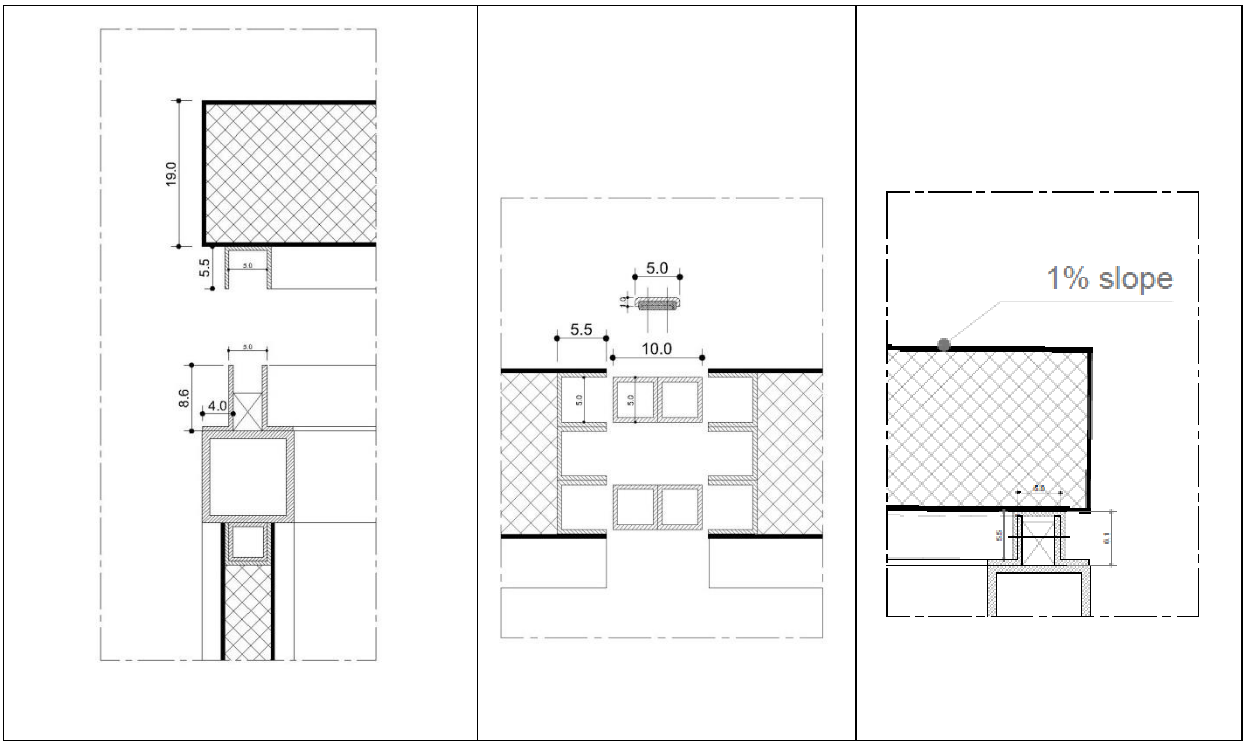


Figure 54– Sections: Roof assembly for a flat roof solution

6.2. Climate customization: the need for special components and module's aggregation

As referred in the previous chapter, the orientation, volume, fenestration and plan shape factors play important roles in the thermal comfort of the building.

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. 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. Figure 55 illustrates the GFRP molded grating panel as a possible component to address the tropical climate requirements. Its manufacturing is similar with the one of the partition walls already described above (Figure 52), with the particularity of having a ventilated molded grating instead of an opaque sandwich panel. It can be assembled either vertical or horizontally, and depending on the number of metal pivots, it can become either a fixed panel or a single or double door.

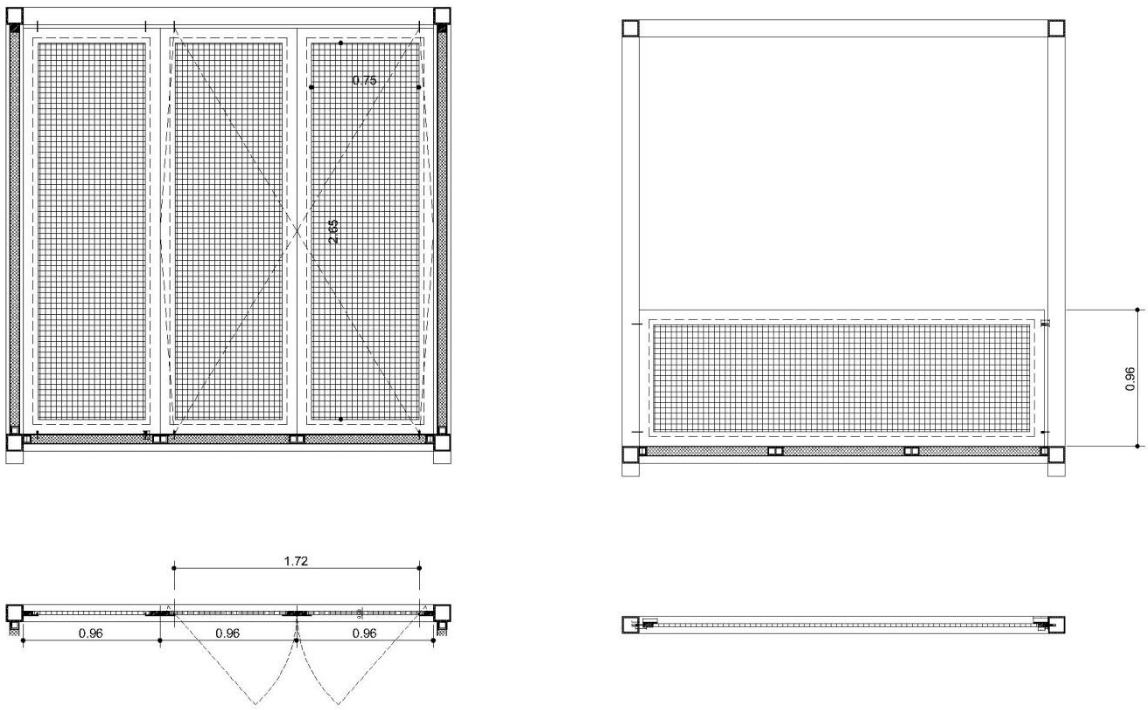


Figure 55 - Component's customization for tropical climate: molded gratings partition panels, doors, and railings

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.

Having overcome the volume adaptation limitation, several aggregation studies were conducted in order to test the potential of the plan shape in addressing different climates.

Figure 56 to Figure 57 illustrate some of the carried studies concerning dwellings aggregation. Figure 56 illustrates plan studies for semi-detached T0/1's dwellings. It is worth mentioning that the more compact the dwelling is, the less exposed its surfaces will be, and therefore lesser thermal fluctuations the dwelling will suffer, meaning that building's compactness can act as a natural thermal insulation, per se. On the other side, one should keep in mind that there would be a loss of available surfaces to ventilate, meaning that none of these solutions is adequate for tropical climates.

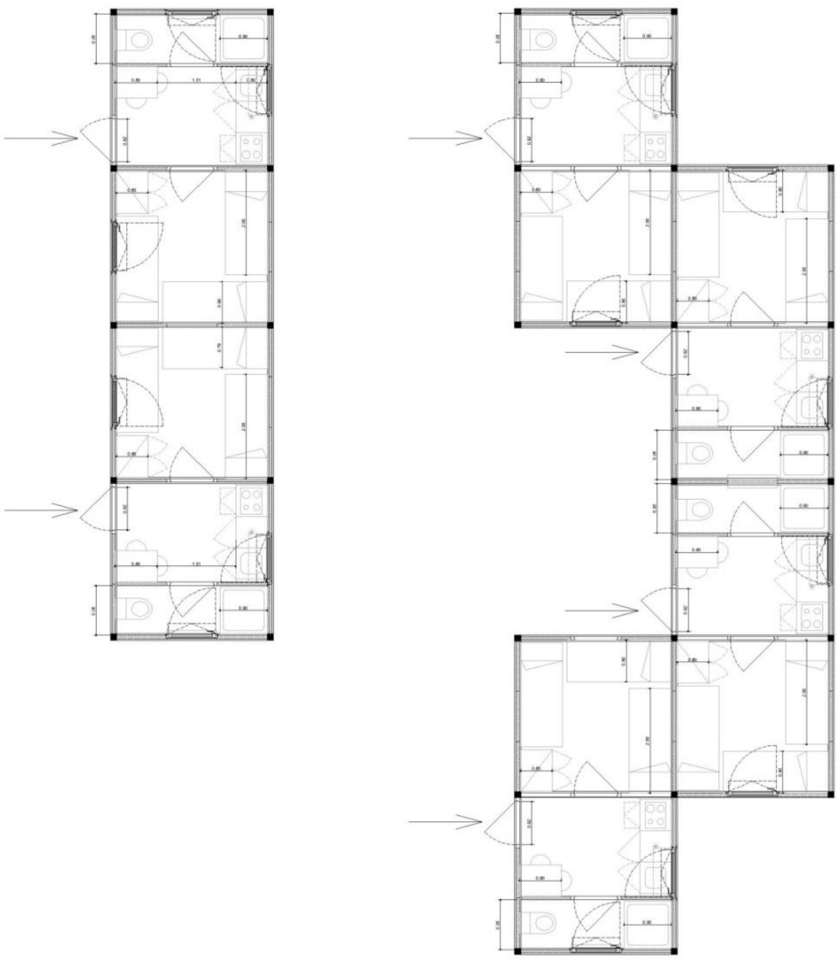


Figure 56 – Transitional shelter study for semi-detached T0/1's dwellings using a 2,88m^3 base module.

For hot and dry climates, the optimal design approach will require to combine building's compactness, with shaded patios that can promote beneficial airflows with the inside [9] and [26]. The underlying idea is to reduce convection thermal gains through the walls and promote the creation of more pleasant microclimates in the patios. Figure 57 illustrates a semi-detached patio-house study to address a warmer and dry climate. The patio-house is a T1 dwelling, composed of three modules, being the fourth the result of the leftover of the aggregation. Although the patio could either receive, or not, the floor panels, for microclimate's efficiency is better if the floor panels are left off. Without the floor panels, it will not only promote ventilation below the raised floor, but also prevent extra thermal gains through sunlight reflections in the floor panel.

Figure 57 – Transitional shelter study for semi-detached patio-houses using a 2,88m^3 base module: plans and schematic section

The semi-detached patio-houses form a block that is the result of the aggregation of two patio-houses facing opposite sides, i.e., two symmetrical dwellings accessed by two parallel roads. The modules with the water and sanitation infrastructure - the bathroom and kitchen - are positioned to be in direct contact with the exterior, so the water supply of each dwelling is facilitated. On the opposite, the patio is positioned to be at the center of the building block so it promotes dwelling's cross-ventilation.

Needless to say that in order to conduct the module aggregations in more than one direction, as in these aggregation studies, special roof panels would have to be developed to solve the different roof connections that it entails. Additionally, because the panel's connectors have to be adhesively bounded to the beams or columns at the manufacturing facilities, the shelter's customization has to be forecast in advance, which is a great drawback.

6.3. Structural restrictions in module aggregation: topography and development of communal facilities

From a merely theoretical point of view, the module's aggregation possibilities are endless. The structure could be expanded in both directions and simultaneously. The module's aggregation rule is that wherever different modules shares the same column, there is a floor's direction change in adjacent modules, as shown in Figure 58, and deeply explained in chapter 4.2. This direction change in the floor panels affects the interior subdivision of the modules, once that the partition walls placement is placed either in between the structural frame or on the panel-to-panel connection inside the floor.

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 [23], it strongly conditions the manual assemblage of such bigger structures. On one hand, it might be already hard enough assembling the shelter, which only has 2 contiguous modules and six footings, in a leveled ground with basic tools, and on the other hand the bigger the structure is, the more difficult it becomes to ensure the correct positioning and levelling of each footing in relation with the others. Not to mention the likelihood need for expansion joints in such structures. The fact that there is only 60 mm adjustment, means 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.

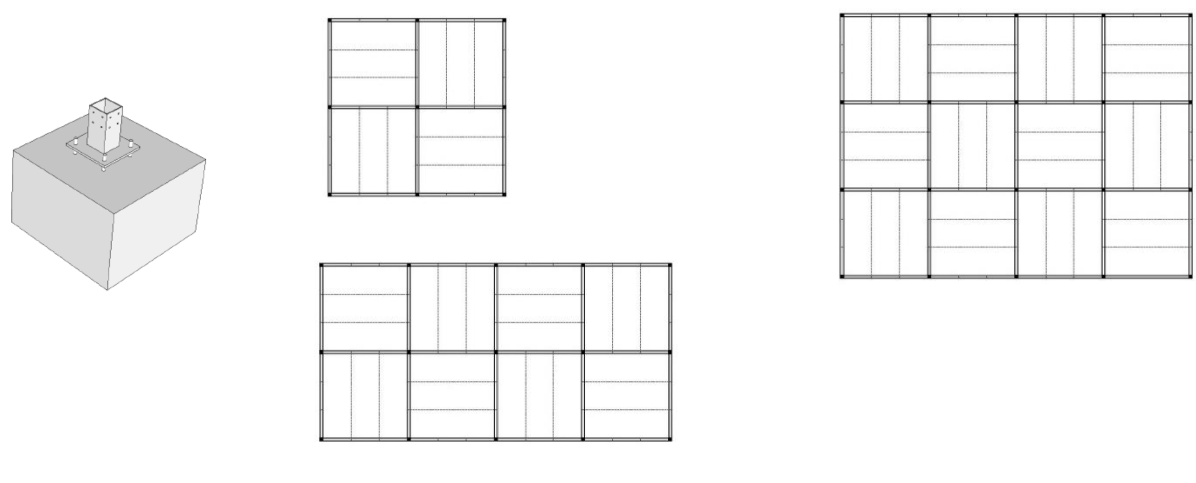


Figure 58 – Reinforced concrete footing [23] and module aggregation structure

Before going on into the restrictions this structure presents in the development of communal facilities, it is worth to recall that accessibility regulation [20] requires that exterior building doors have a clearance greater than 0,87m, which means that for that matter a double door must be manufactured. Figure 59 illustrates the design proposal for a double door, where one of the folded panels is the regular single door, being the other folded panel a new component required to be manufactured.

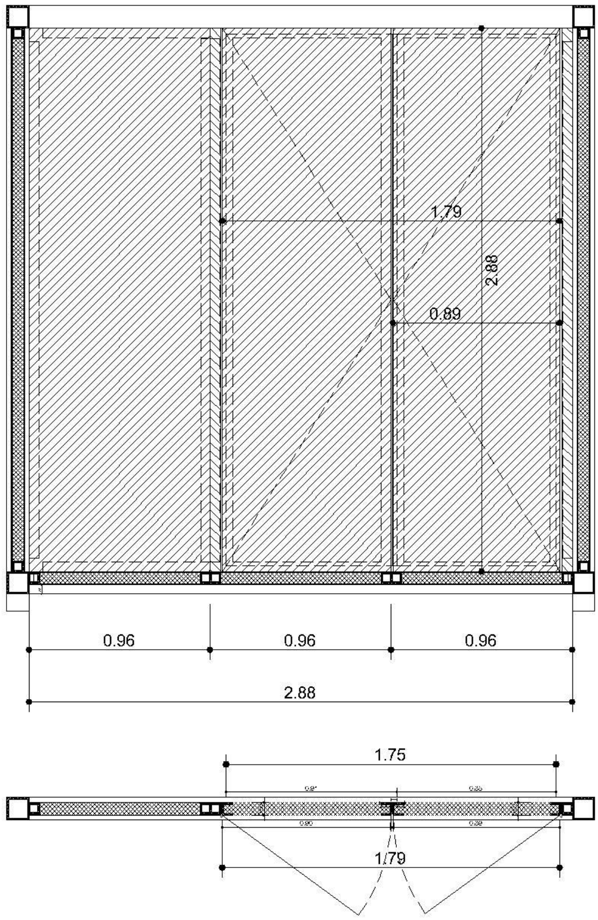


Figure 59 – Double door equals two different folded panels

Figure 60 illustrates the design exercises conducted for the development of a communal dormitory, by module's aggregation forming one row and two rows. As one can see the restrictions imposed by the structural frame and the construction process, strongly conditions the positioning of the walls and partition walls across the interior space. In such constructive system, because the corridors have to be integrated in the structural network of the module, the space optimization and the privacy of each module conflicts with each other.

Figure 60 – Communal facilities: Dormitory

Figure 61 illustrates the plan studies carried for the communal bathrooms and laundry. For water supply distribution and sanitation network reasons, each panel can only connect to one single sanitary equipment.[24] For privacy issues, the partition walls of the individual toilet basins would require further design development.

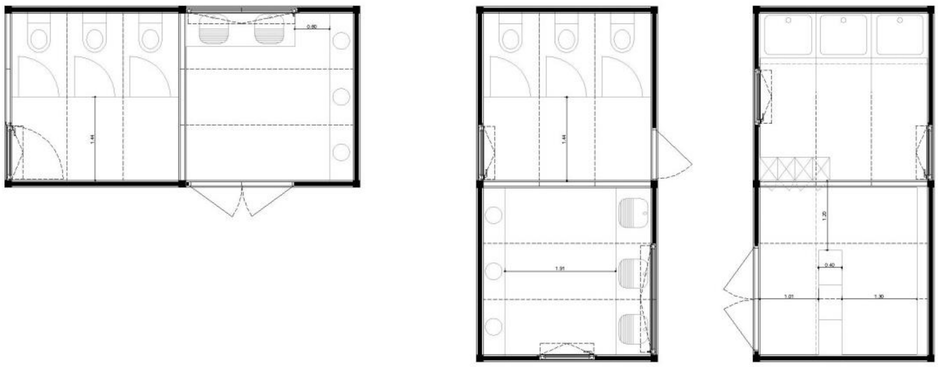


Figure 61 - Communal facilities: WC with laundry

For dry climates only, the dormitory's bedroom privacy could be solved by making the access to each room directly through an external patio. It can be achieved by combining the previous WC cells with the dormitory cell, generating thus a variation of the patio-house, as shown in Figure 62 and Figure 63.

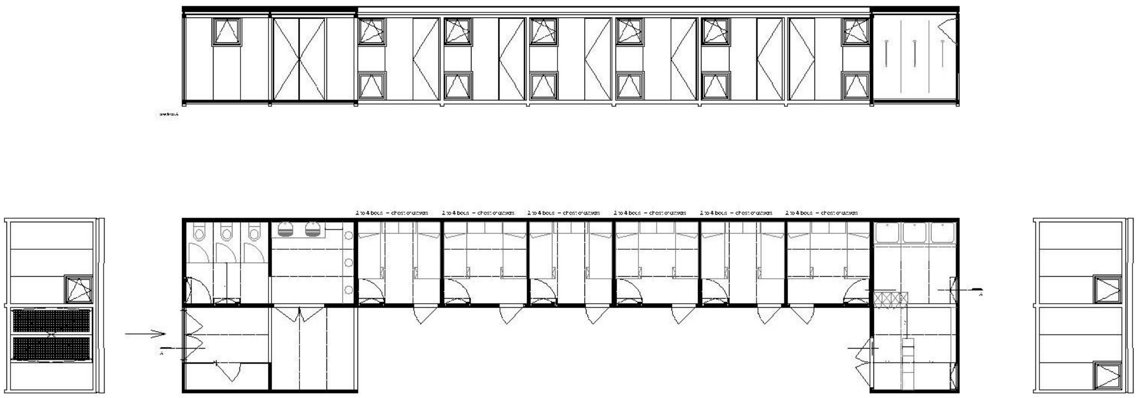


Figure 62 - patio dormitory for dry climates (feminine or masculine dorm).

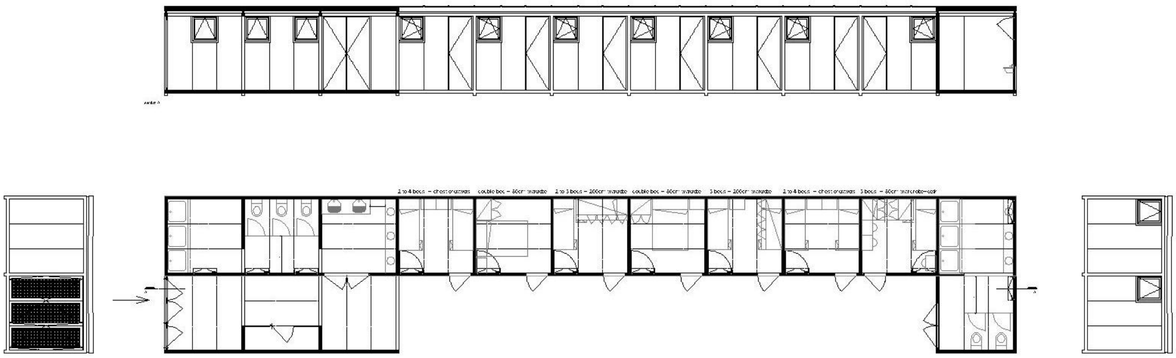


Figure 63 - patio dormitory for dry climates (mixed dorm).

Figure 64 illustrates the design study conducted for a health clinic. The same issues regarding the rigidity of the structural network emerge, with the aggravating circumstance of, for this particular function, the circulation spaces should allow fairer use of mobility aids, such as wheelchairs, crutches, or the repositioning of the hospital-type beds and stretchers.

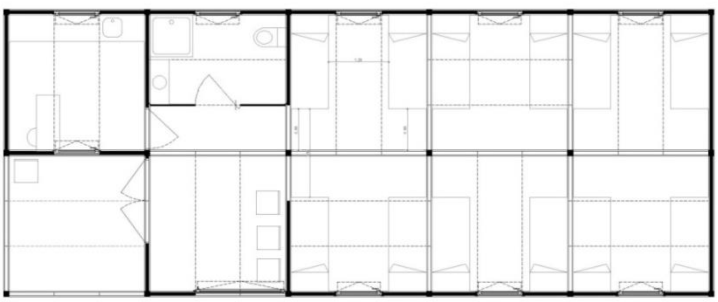


Figure 64 – Communal facilities: Health clinic

Figure 65 illustrates the design study for a canteen, where we could not find any special restriction.

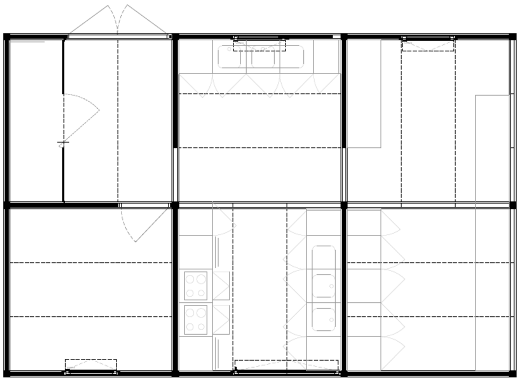


Figure 65 - Communal facilities: Canteen

Figure 66 illustrates the study carried for designing a school. In this typology, we found that the grid's dimensions strongly restricted the size and capacity of a classroom to the point that it could not allow seating more than 9 students and did not allow many possibilities in the seating arrangement of a classroom.

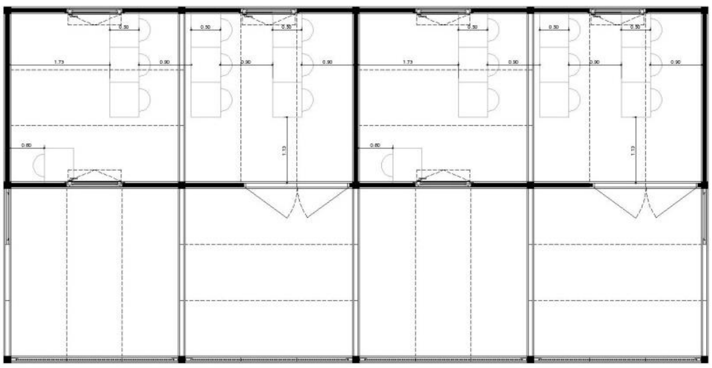


Figure 66 - Communal facilities: School (9 student's class)

Further communal typologies such as worships places, local information centers, warehouses, market places, commercial facilities, or shops, are also required for offer in emergency scenarios to displaced people that settle in transitional camps, sometimes for years. The greatest architectural constraints for these communal facilities relates to the already mentioned grid rigidity that imposes too close columns and places several restrictions in the partition wall positioning.

6.4. Shelter clusters development

Infinite compositions of shelter clusters can be achieved through a variety of different combinations enabled by the Clickhouse modular system. By module's aggregation, bigger enclosed spaces can be easily generated, offering opportunities to a variety of uses as shown in the previous chapter.

In order to illustrate its potentialities in generating urban areas, thus contributing for the reinforcement sense of community, 3 quick exercises were conducted.

The first one concerns an abstract construction site. The scenario for this settlement is a construction site situated in a warm but dry climate. It is expected to accommodate between 10 to 50 resident workers, and a floatable number of technical and administrative staff, that could go up to 60 people, working on the site. This work site is composed of a large office building at the center, a small administration office and reception near the entrance and facing the construction site work, 2 different size warehouses, 2 sets of public toilets at the opposite corners, a canteen opened for the main square, and 4 dwellings placed facing outside the construction site. All the modules embedded with water supply and sanitation networks are positioned to be in direct contact with the exterior, for easy supply and maintenance of the infrastructure. Figure 67 illustrates this settlement study exercise.

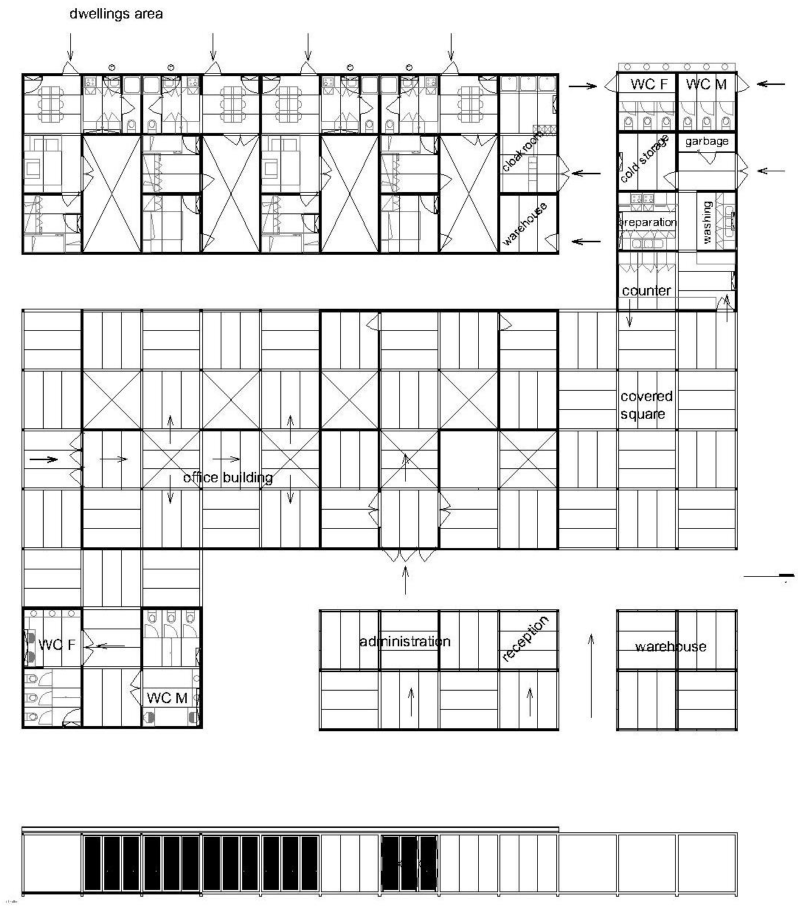


Figure 67 - Settlement layout study for a construction site in a warm and dry climate. (Plan and section)

The second and third exercises concern the development of the bedrooms arrangement in a hotel-like situation. Figure 68 illustrates the settlement layout study for a "S-shaped cell" dorm, where each 2 independent bedrooms share a semi-private bathroom, given place, when aggregated in series, to a bigger building block subtracted by patios.

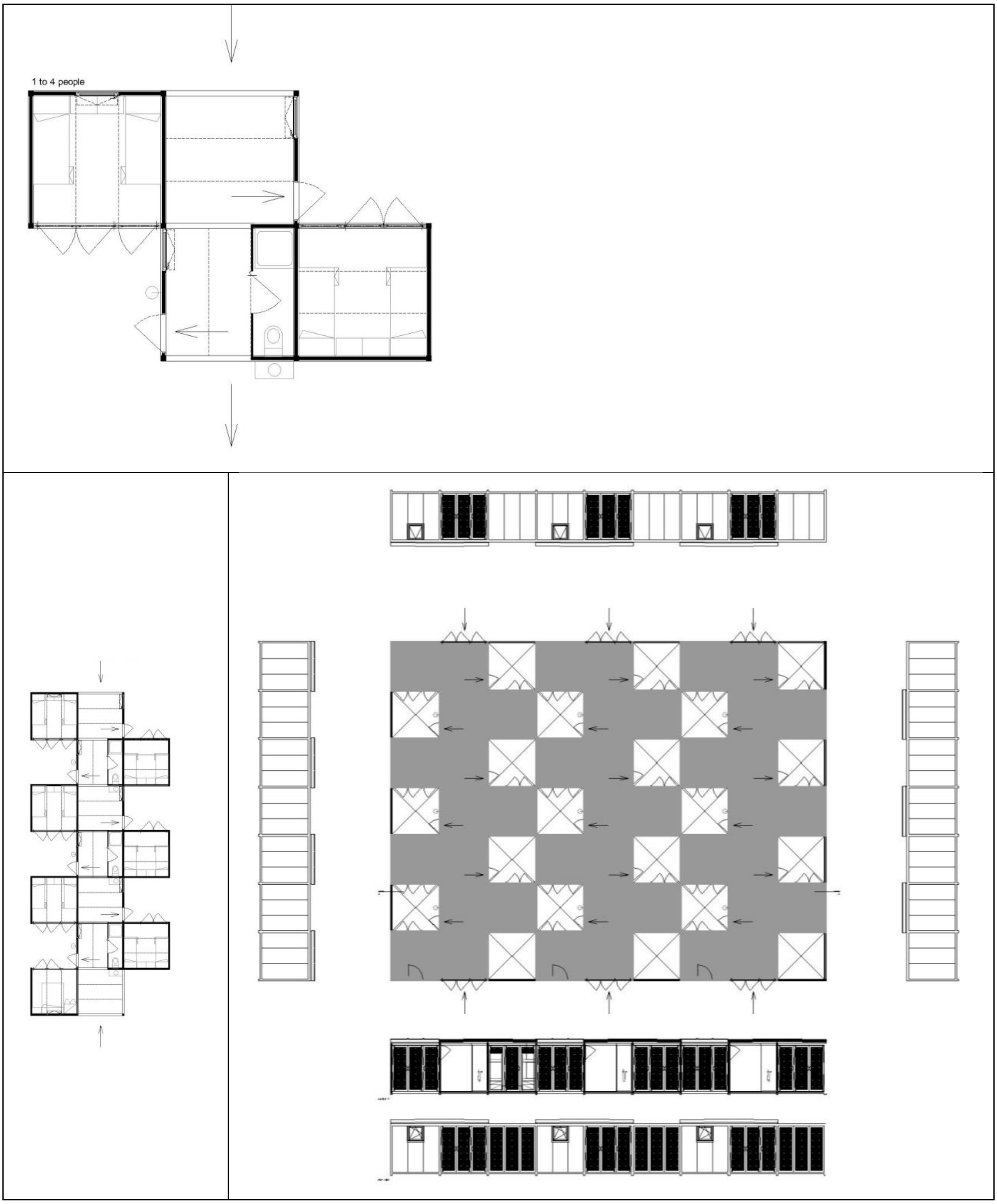


Figure 68 – Settlement layout study for a "S –shaped cell" dorm. (Plan, section and elevations)

Figure 69 and Figure 70 illustrates the settlement layout study for the “L-shaped cell” dorm, where each 2 dependent bedrooms share a private bathroom. Being this cell possible to combine either in parallel or with rotation, gives rise to different settlement's layout development.

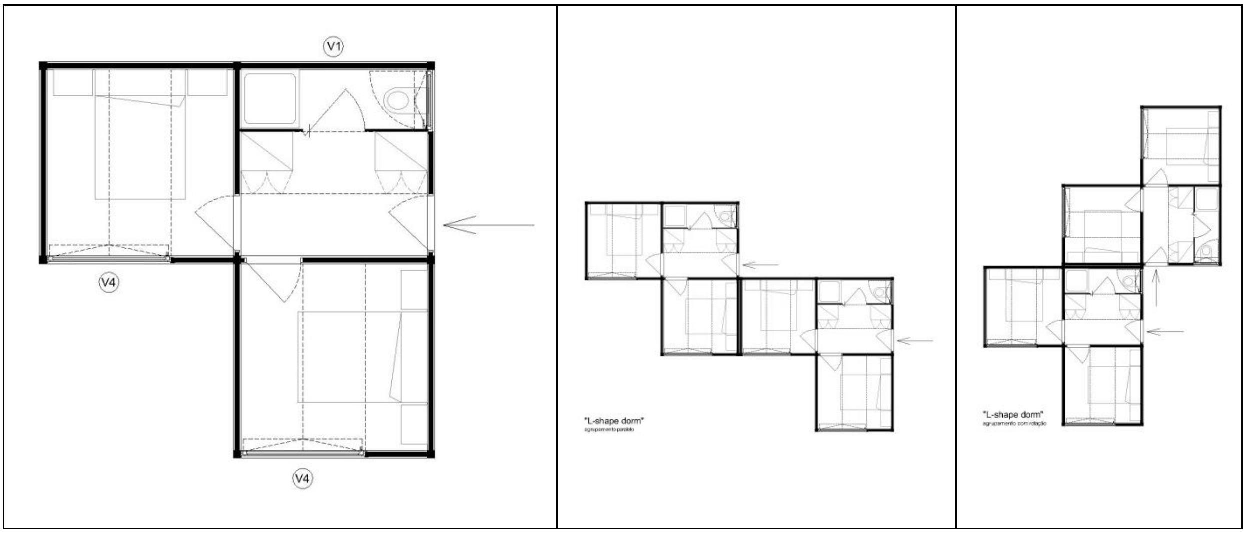


Figure 69 – Study of aggregations for a “L –shaped cell” dorm

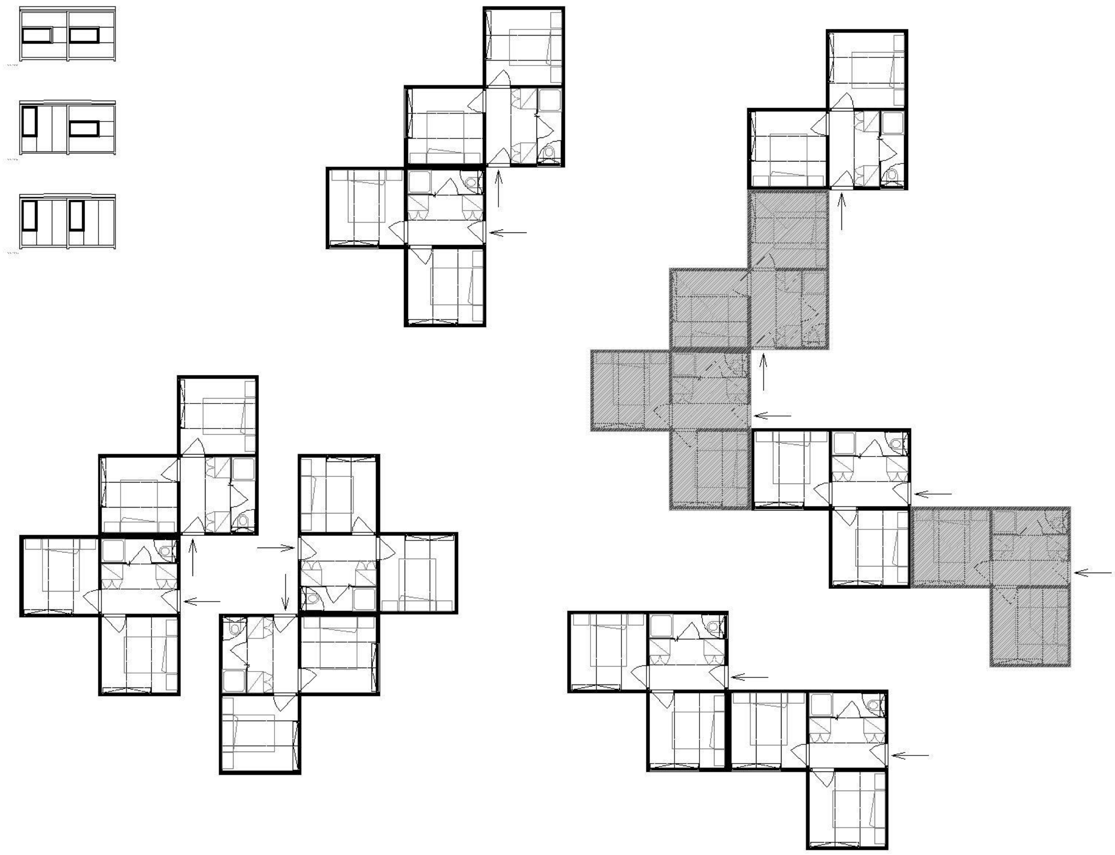


Figure 70 – Settlement layout study for the “L-shaped cell” dorm

6.5. Logistical issues: production, storage and delivery capacity

The complete T0/1´s production capacity of ALTO's manufacturing is estimated in one week for shelter. However, for pultrusion process preparation, one extra week will be required every time a new order sets up a new manufacturing process. If the shelter is manufactured in mass production, it is expected that the production time decreases for 1,5 shelters per week. Although the pultrusion manufacturing capacity is estimated in150m a day, which is enough for the structure of two T0/1, the manual hand lay-up process of the panels, which is only 4 panels a day, delays the complete manufacturing of the product.

Additionally, the manufacturer has a current storage capacity of 20 T0/1's, i.e., 40 modules packed in volumes of 330 x 230 x 230 meters, approximately, weighting each nearly 2.2 tons. It is worth mentioning that this package does not include any sanitary and kitchen equipment nor furniture or household items. Figure 71 illustrates a disassembled T0/1 inside a 20 ft.'s container. Due to the length of the columns and roof panels, the T0/1's full package occupies slightly more than half of the available space of the 20 ft. container, however if two T0/1s are packed in a staggered way there will be place to accommodate two shelters per 20 ft. container, and four shelters in the 40ft container.

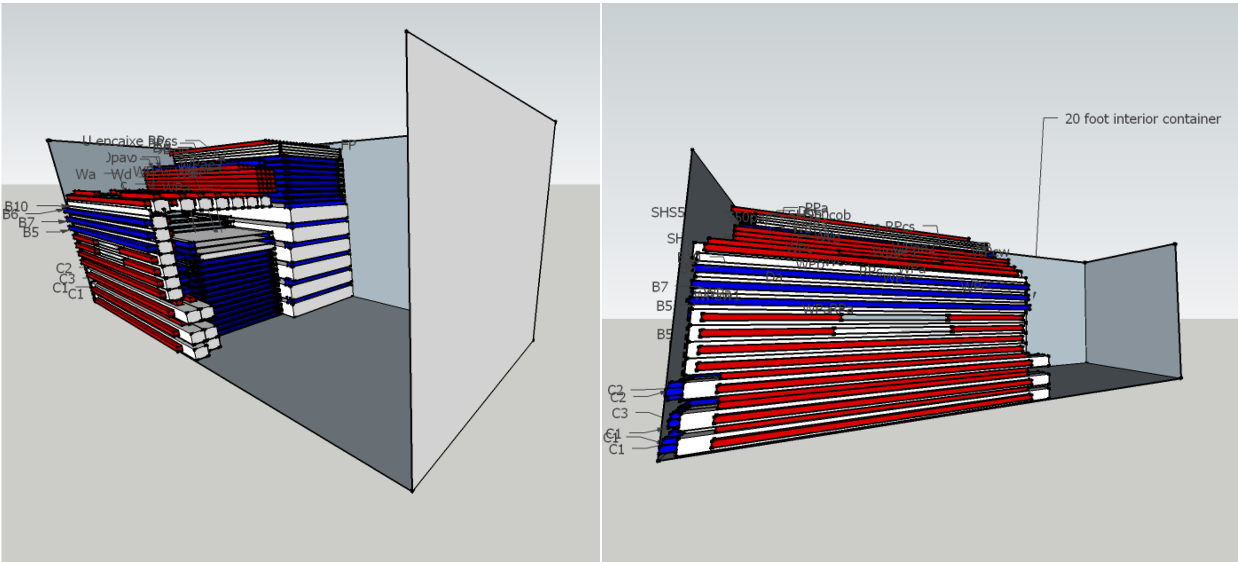


Figure 71 – Volume required for a complete T0/1´s shelter packing in a 20ft container

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 T0/1's kits. However, 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.

Besides the lead time, for international procurement purposes, the shipment time should also be accounted, varying significantly depending on its destination. The estimated shipment time, for instance, from Portugal to Morocco is 3/4 days, to Angola and Pakistan is 18/19 days, to Venezuela, Colombia and Syria is 26 days, and to Mozambique 35 days.

It means that due to these logistical constraints, starting from ALTO mass production's capacity -11 transitional shelter kits per 2,5 weeks-, to the long shipment time – up to one month in most of the potential destinations-, to the large storage capacity required for stockpiling purposes, it makes it difficult to conceive the transitional shelter kit as part of a transitional shelter approach.

Additionally, due to its volume and weight, its disassembling for relocation purposes might as well be jeopardized.

Nevertheless, if by any means there are local pultruded GFRP manufacturers and suppliers that can replicate the Clickhouse system, then both delivery time and final cost may decrease, while stockpiling's capacities may increase, which would turn this solution much more appropriate for transitional shelter purposes.

6.6. Transitional shelter's economic and environmental sustainability: final cost, impact on local economies, transitional lifespan and environmental footprint

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. [4][14][12][2]. In addition to production cost, and despite any economy of scale that might arise, the transport and customs costs would also have to be considered, representing an estimated increase between 2% to 15% in the final cost of the product, depending on whether the 20 ft. container carries 11 transitional shelter kits or only 2, but complete, T0/1's kits.

Furthermore, by importing the shelter solution, local economy is not being supported in its own capacity to sustain and promote local livelihoods, which is essential for its economical re-establishment and to become autonomous and self-sufficient [27]. In addition, importing the materials brings increased risks for future repairs or shelter maintenance, once original materials may not be easily available when they are needed.

On the other hand, and depending on the context, providing deployable shelter kits might be the optimal solution when preventing depletion of local natural resources is a major concern, or when it is predictable that the market will suffer negative effects from this sudden demand for construction materials, tools, and services. [27]

Similarly, the 50 years lifespan expectancy of the pultruded GFRP profiles may prove to be a more cost-effective solution in the long run than the commonly used materials in these solutions. The GFRP is easy to maintain, is not susceptible to rust as metal, and is not as susceptible to climatic and biologic agents as wood.

Regarding the environmental impact, and regardless of the potential negative impacts of importing, although GFRP does not require much energy to be manufactured, nor to be maintained, it is composed of resins, with unknown environmental assessment so far, and without record of being prone to recycling.

To finish with, and similarly with most of the existing transitional shelter solutions, the disassembling and relocation of Clickhouse’s system will leave at least the concrete footings as environmental footprints.

7. 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 increasingly number of disaster-affected people and its geographically dispersed occurrence, requires strong engagement and coordination between all different levels of stakeholders ranging from the local governments, to national and international humanitarian organizations and NGOs. 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, and once that the design of the shelter and settlement can contribute to mitigate the physical and psychosocial distress of the affected population, we think that architectural professionals should become more engaged in this thematic so they can contribute for the design of a better 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 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.

8. References

[1] UNHCR's site accessed on 26th May 2015 (http://www.unhcr.org/)

[2] IFRC, UN-HABITAT and UNHCR (2014) *Shelter projects 2013-2014,* IFRC, UN-HABITAT and UNHCR

[3] Global Shelter Cluster's site accessed on 3rd June 2015 (http://www.sheltercluster.org/)

[4] IFRC (2011), *Transitional shelters – Eight designs*, Geneva,

[5] Castelo, A. (2014) Masters Dissertation in Civil Engineering *Emergency constructions in catastrophe affected regions. Development of a constructive solution in advanced composite materials. (In Portuguese),* Lisboa: Instituto Superior Técnico

[6] ALTO-UM-IST (2013) Application text *Projeto SI I&DT – Co-Promoção (In Portuguese)*, Lisboa

[7] IOM (2012) *Transitional shelter guidelines,* Geneva: Shelter Center

[8] DFID (2009) *Transitional Shelter Prototypes Project,* Shelter Center

[9] Chaves,D. (2012) Masters dissertation in Architecture *Dwell hostile Places (In Portuguese)*, Lisboa: Instituto Superior Técnico

[10] Hans Rosenlund (2010) *Climatic Design of building using passive techniques,* Building Issues 2000, Volume 10 , Number 1, from http://www.sheltercentre.org/

[11] UN-HABITAT (2008) *Shelter projects 2008,* IASC Emergency Shelter projects

[12] IFRC, UN-HABITAT and UNHCR (2013) *Shelter projects 2011-2012,* IFRC, UN-HABITAT and UNHCR

[13] IFRC, UN-HABITAT (2010) *Shelter projects 2009,* 2nd edition: IFRC, UN-HABITAT

[14] IFRC, UN-HABITAT and UNHCR (2012) *Shelter projects 2010,* IFRC, UN-HABITAT and UNHCR

[15] UNHCR (2007), *Handbook for emergencies*; Geneva, Third Edition

[16] The Sphere Project (2011) *Humanitarian Charter and Minimum Standards in Humanitary Response.;* Belmont Press Ltd, United Kingdom;

[17] UN (1948), *The Universal Declaration of Human Rights*

[18] UNHCR (2013) *Request For Proposal For The Establishment Of A Frame Agreement For The Provision Of Shelter Solutions For Different Climates*;

[19] RGEU, DL - 177/2001

[20] DL -163/2003

[21] DL 64/90

[22] http://alto.pt/

[23] Martins,D; Correia,João Ramôa (2014) *Clikchouse: Task 2.1.1,* ICIST Report DTC nº /2015 Lisboa: Instituto Superior Técnico

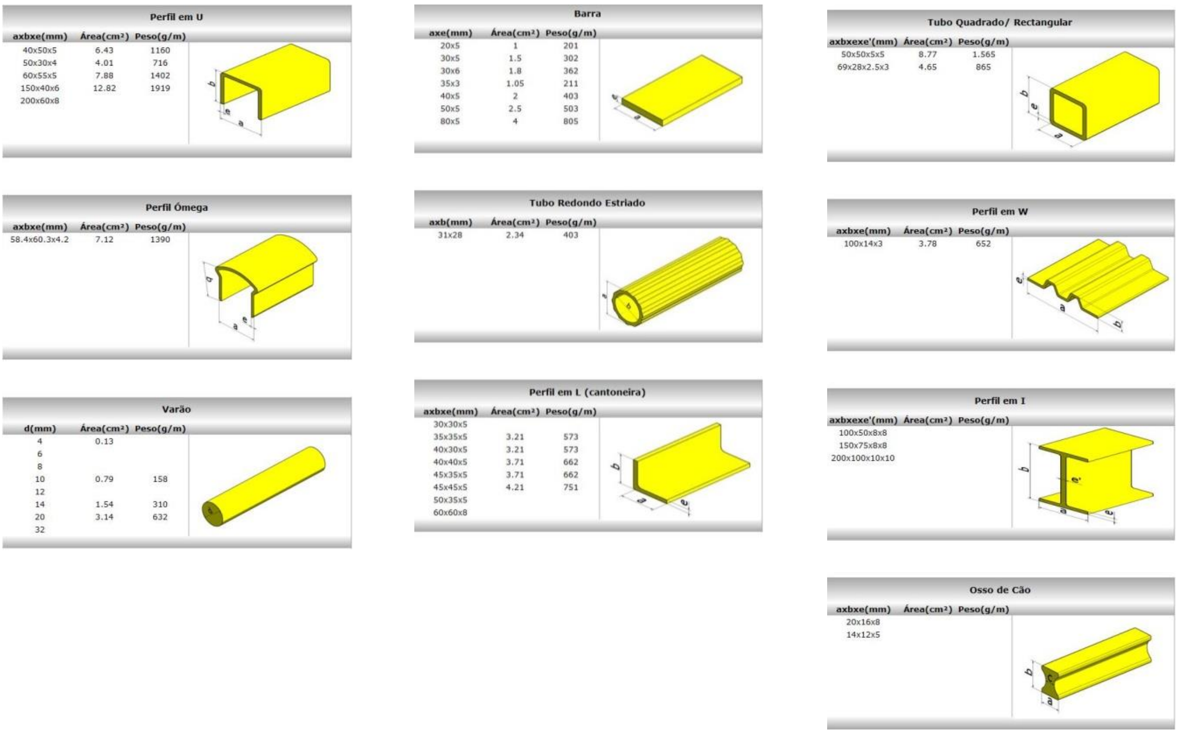
[24] Afonso, A.; Neves e Sousa, A. (2015) *Clickhouse Task 2.5*. *Design of Water Supply and Sewerage Systems* ICIST Report DTC nº20/2015,Lisboa: Instituto Superior Técnico

[25] Fernandes P.; Gomes M. Glória (2015) *Clikchouse: Task 3.4 - Numerical evaluation of the thermal behavior,* ICIST Report DTC n.º 4/2015, Lisboa: Instituto Superior Técnico

[26] Van Lengen, J. (2008) *The Barefoot Architect: A Handbook for Green Building*, California, Shelter Publications, Inc.

[27] Shelter Center (2008) *Transitional Settlement and reconstruction after natural disasters,* Field edition ; Shelter Center and UN/OCHA

Appendix I



Perfil em U

axbxe(mm)	Área(cm²)	Peso(g/m)
40x50x5	6.43	1160
50x30x4	4.01	716
60x55x5	7.88	1402
150x40x6	12.82	1919
200x60x8		

Barra

axe(mm)	Área(cm²)	Peso(g/m)
20x5	1	201
30x5	1.5	302
30x6	1.8	362
35x3	1.05	211
40x5	2	403
50x5	2.5	503
80x5	4	805

Tubo Quadrado/ Rectangular

axbxexe'(mm)	Área(cm²)	Peso(g/m)
50x50x5x5	8.77	1.565
69x28x2.5x3	4.65	865

Perfil Ómega

axbxe(mm)	Área(cm²)	Peso(g/m)
58.4x60.3x4.2	7.12	1390

Tubo Redondo Estriado

axb(mm)	Área(cm²)	Peso(g/m)
31x28	2.34	403

Perfil em W

axbxe(mm)	Área(cm²)	Peso(g/m)
100x14x3	3.78	652

Varão

d(mm)	Área(cm²)	Peso(g/m)
4	0.13	
6		
8		
10	0.79	158
12		
14	1.54	310
20	3.14	632
32		

Perfil em L (cantoneira)

axbxe(mm)	Área(cm²)	Peso(g/m)
30x30x5		
35x35x5	3.21	573
40x30x5	3.21	573
40x40x5	3.71	662
45x35x5	3.71	662
45x45x5	4.21	751
50x35x5		
60x60x8		

Perfil em I

axbxexe'(mm)	Área(cm²)	Peso(g/m)
100x50x8x8		
150x75x8x8		
200x100x10x10		

Osso de Cão

axbxe(mm)	Área(cm²)	Peso(g/m)
20x16x8		
14x12x5		

Figure 72 – ALTO´s industrialized pultruded profiles. Images taken from [22]

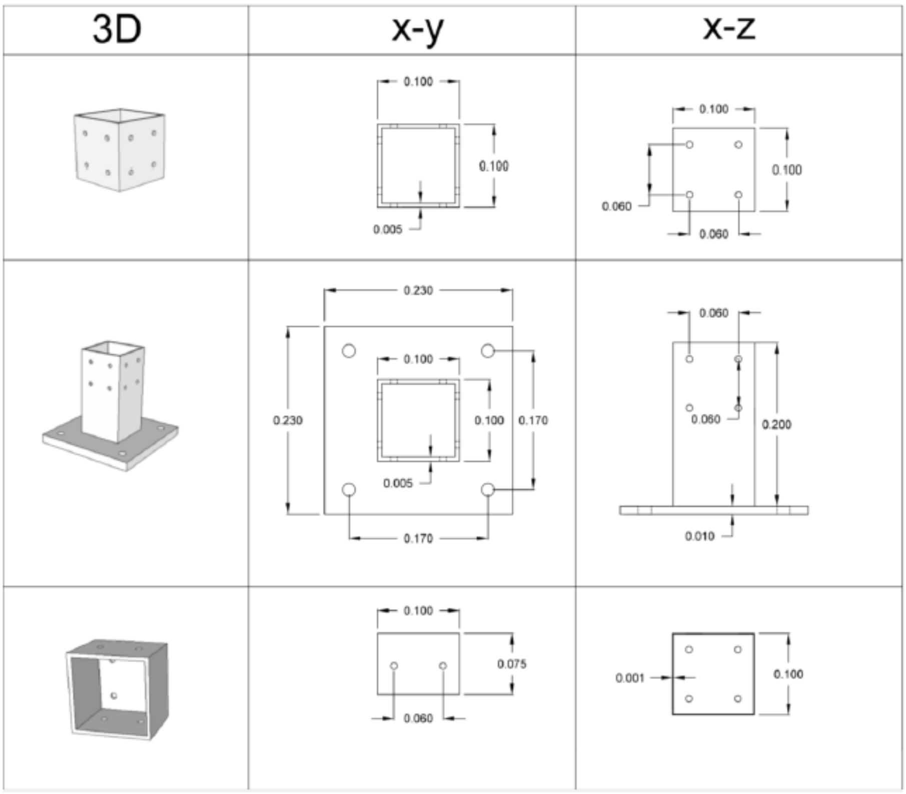


Figure 73 - Clickhouse's metal connections. Images taken from [23]

Table 14 - Clickhouse's bill of quantities

# components	Wall panels	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
1	**Wpa**	10	2,88	0,96	0,07			**319,01**	
	U Profile _Long.	2	2,88	---	---	0,0011	957	6,06	
	U Profile _Trans.	2	0,96	---	---	0,0011	957	2,02	
	Foam	1	2,77	0,85	0,066	---	48	7,46	
	GFRP skins	2	2,88	0,96	0,002	---	1500	16,59	
	U Profile _overlap	4	0,055			-0,0011	957	-0,23	
						total weight each panel		**31,90**	
2	***Wpa w1**	1	2,88	0,96	0,07			**31,90**	
3	***Wpa w2**	1	2,88	0,96	0,07			**31,90**	
4	***Wpa e1**	1	2,88	0,96	0,07			**33,71**	
5	***Wpa e2**	1	2,88	0,96	0,07			**32,34**	
6	***Wpa e3**	1	2,88	0,96	0,07			**32,34**	
7	****Da**	1	2,88	0,96	0,07			**33,67**	
8	****Da's doorjamb**	1	2,88	0,055	0,07			**7,34**	
9	****Db/c**	2	2,855	0,96	0,033			**67,26**	
10	****Ppa**	2	2,855	0,97	0,033			**33,63**	
11	**Wpb**	1	1,92	0,96	0,07			**21,90**	
12	**Wpc**	3	0,96	0,96	0,07			**35,29**	
13	***Wpcw**	1	0,96	0,96	0,07			**11,76**	
	total Wall panels	**26**						**692,05**	**Kg**

# components	Floor panels	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
14	**Fpa**	4	2,88	0,96	0,07			**232,82**	
	U Profile _Long.	4	2,88	---	---	0,0008	957	8,82	
	U Profile _Tran.	2	0,96	---	---	0,0008	957	1,47	
	Foam	1	2,77	0,85	0,060	---	48	6,78	
	GFRP skins	2	2,88	0,96	0,005	---	1500	41,47	
	U Profile _Tran.	8	0,055			-0,0008	957	-0,34	
						total weight each panel		**58,21**	
15	***Fpb**	1	2,88	0,96	0,07			**58,21**	
16	***Fpc**	1	2,88	0,96	0,07			**58,21**	
	total Floor panels	**6**						**349,23**	**Kg**

# components	Roof panels	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
17	**RP a**	2	3,12	0,96	0,19			**172,52**	
	U Profile _Long.	6	3,11	---	---	0,0008	957	14,29	
	Foam	1	3,11	0,85	0,180	---	48	22,84	
	GFRP skins	2	3,12	0,96	0,005	---	1500	44,93	
	GFRP side skins_ Trar	2	0,96	0,19	0,005	---	1500	2,74	
	U connetor Beam_Tran.	2	0,96			0,0008	957	1,47	
						total weight each panel		**86,26**	
18	**RP b**	2	3,12	1,08	0,19			**192,97**	
19	**RP c**	2	3,12	1,02	0,19			**181,89**	
	total Roof panels	**6**						**547,38**	**Kg**

# components	**Columns SHS 120+ SHS 50**	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
20	column type1_C1_H	2	3,21	0,12				**37,12**	
	SHS 120	1	3,21	---	---	0,0044	957	13,52	
	SHS 50	2	2,88	---	---	0,0009	957	4,96	
	L roof connector	1	0,12	---	---	0,0007	957	0,08	
						total weight each column		**18,56**	
21	column type1_C1_S	1	3,21	0,12				**18,54**	
22	column type2_C2H	1	3,21	0,12				**21,04**	
22	column type2_C2S	1	3,21	0,12				**21,02**	
23	column type2_C3	1	3,21	0,12				**17,62**	
	total Columns	**6**						**115,33**	**Kg**

	Beams SHS 120 + SHS 50	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
24	Beam type1_B1	5	2,88	0,12				**84,24**	
	SHS 120	1	2,88	---	---	0,0044	957	12,13	
	SHS 50	2	2,74	---	---	0,0009	957	4,72	
						total weight each column		**16,85**	
25	Beam type2_B2	1	2,88	0,12				**16,08**	
26	Beam type3_B3	1	2,88	0,12				**18,38**	
27	Beam type4_B4	1	2,88	0,12				**20,15**	
28	Beam type5_B5	2	2,88	0,12				**33,94**	
29	Beam type6_B6	1	2,88	0,12				**19,60**	
30	Beam type7_B7	1	2,88	0,12				**16,48**	
31	Beam type8_B8	1	2,88	0,12				**18,35**	
32	Beam type9_B9	1	2,88	0,12				**17,52**	
33	Beam type10_B10	1	2,88	0,12				**7,60**	
	total Beams	**15**						**252,33**	**Kg**

	male connectors	Quantity	Length	Width	Thickness	Cross section	Density	Weight	
			(m)	(m)	(m)	(m^2)	(Kg/m^3)	(Kg)	
	Roof	20	3,11					**56,56**	
	Walls	25						**45,24**	
	Floor	8						**19,09**	
	total male connectors	**26,5**						**120,88**	**Kg**

	Windows	Quantity	Length	Width			4	Weight	
			(m)	(m)			(Kg/ml)	(Kg)	
	Wa	1	1,04	1,04				16,64	
Rehau	Wb	1	1	1,04				16,32	
	Wc	1	1,96	1,04				24	
	Wd	1	1,04	1,04				16,64	
	total PVC windows	**4**						**73,6**	**Kg**
					total weight (excluding metal connetors, networks)			**2150,79**	

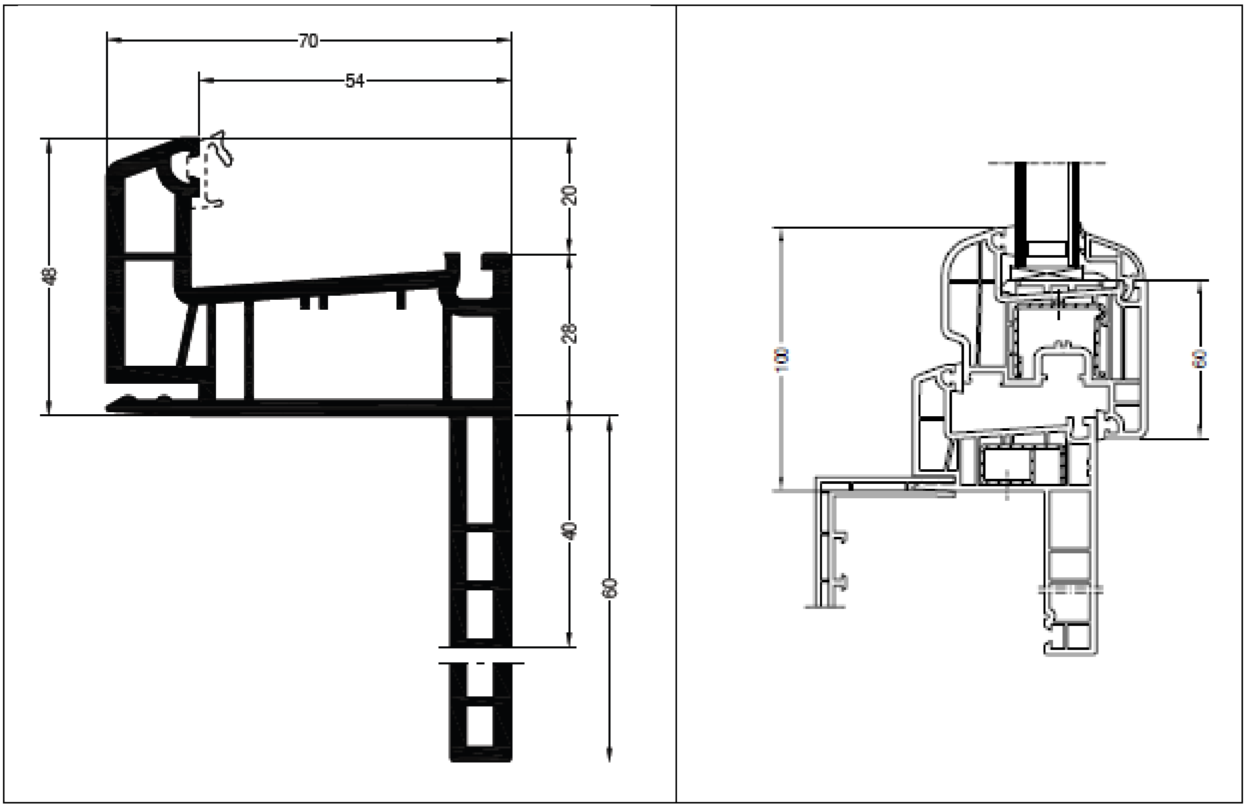
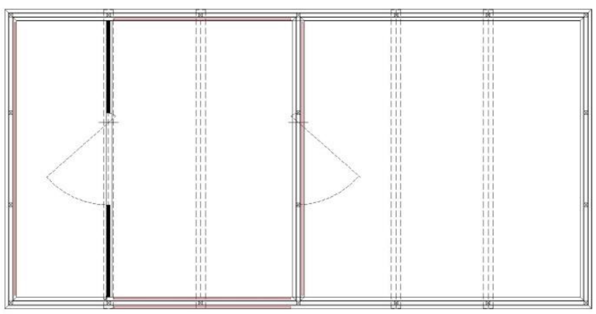
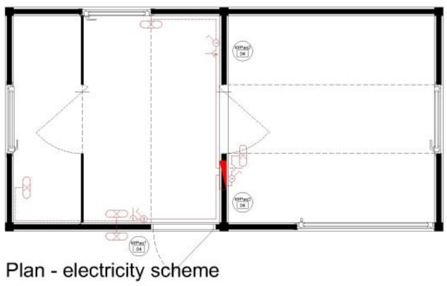


Figure 74 – PVC Window frames from *Rehau* (series Euro Design 70). Glazing replaced by a 16mm polycarbonate.





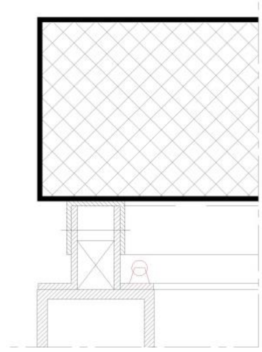
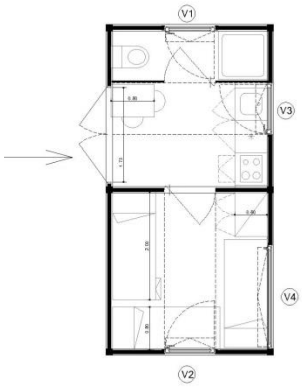
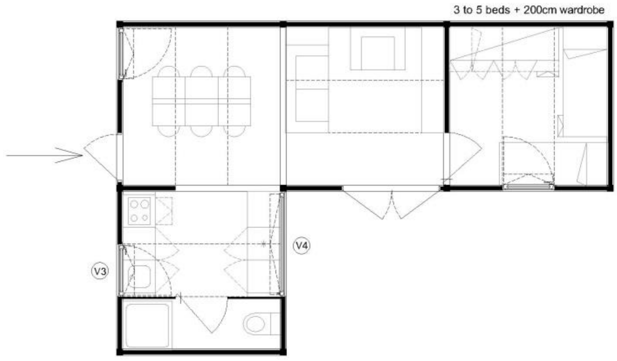
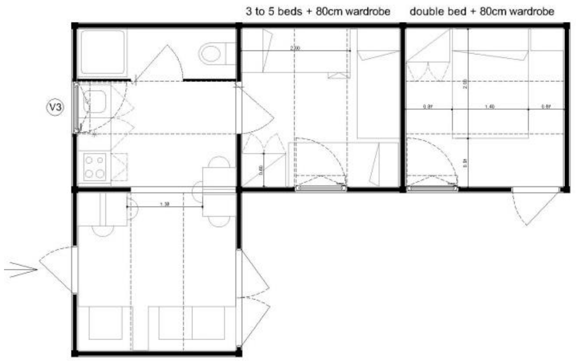
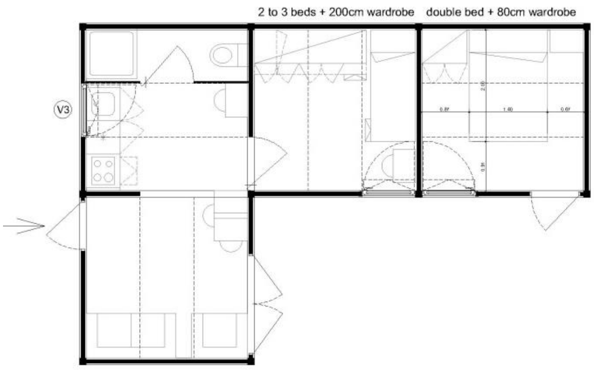
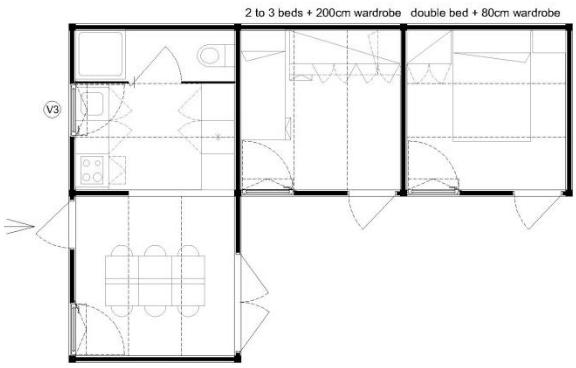
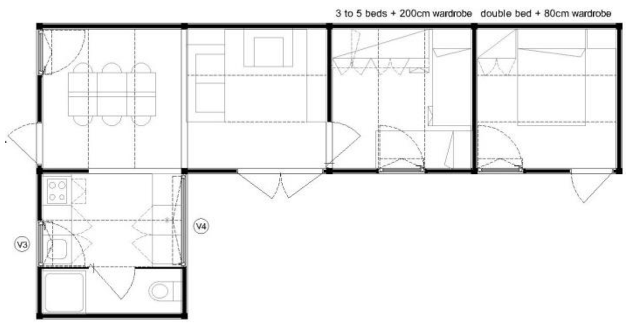
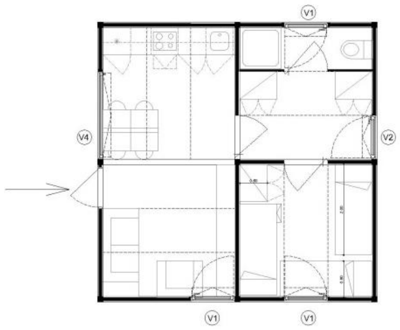
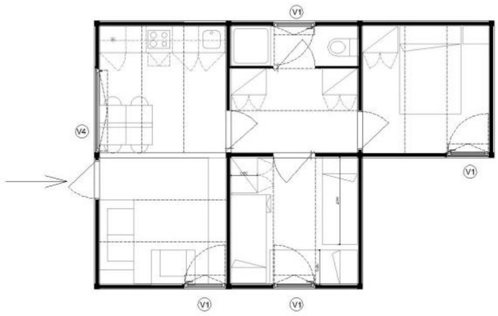


Figure 75 – lighting study for a T0/1 dwelling shelter

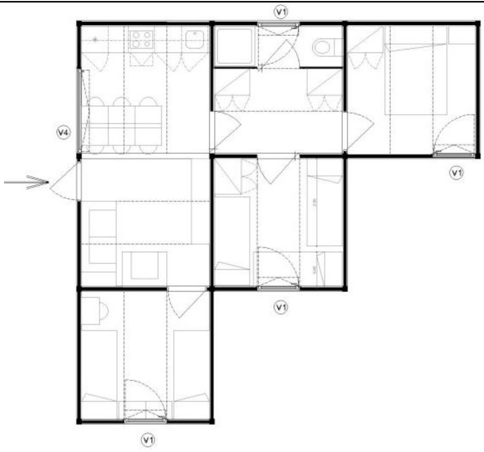
 T0/1 – 2 modules, variation 1	 T1 – 4 modules semi-detached patio house
 T2 – 4 modules semi-detached patio house	 T2 – 4 modules semi-detached patio house , var.1
 T2 – 4 modules semi-detached patio house , var.2	 T2 – 5 modules semi-detached patio house



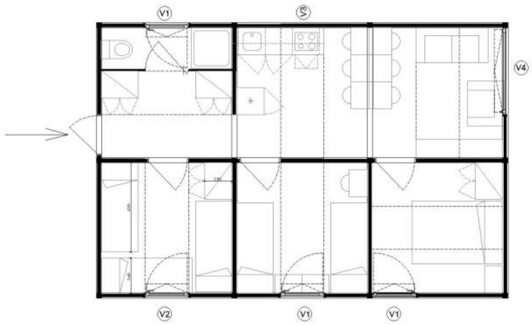
T1 – 4 modules house



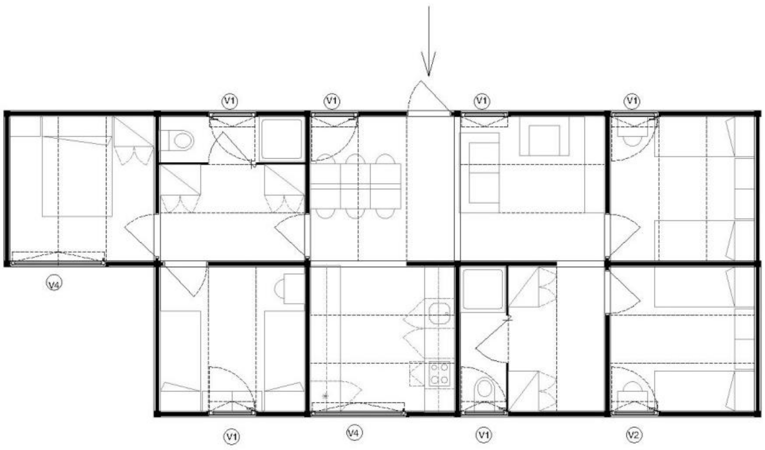
T2 – 5 modules house



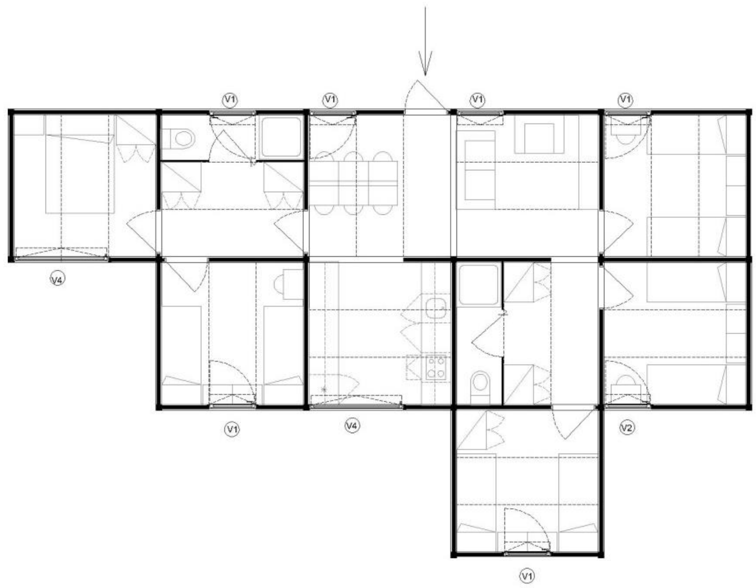
T3 – 6 modules house



T3 – 6 modules house, var. 1



T4 – 9 modules house



T5 – 10 modules house

Figure 76 –study for dwelling typologies

Appendix II – Clickhouse's drawings (A1 sheets)

01 - Architectural general drawings, scale 1/50

02 - Constructive drawings - plans and elevation, scale 1/20

03 - Constructive drawings - elevations and sections, scale 1/20

04 - Elevation schedule – scale 1/20

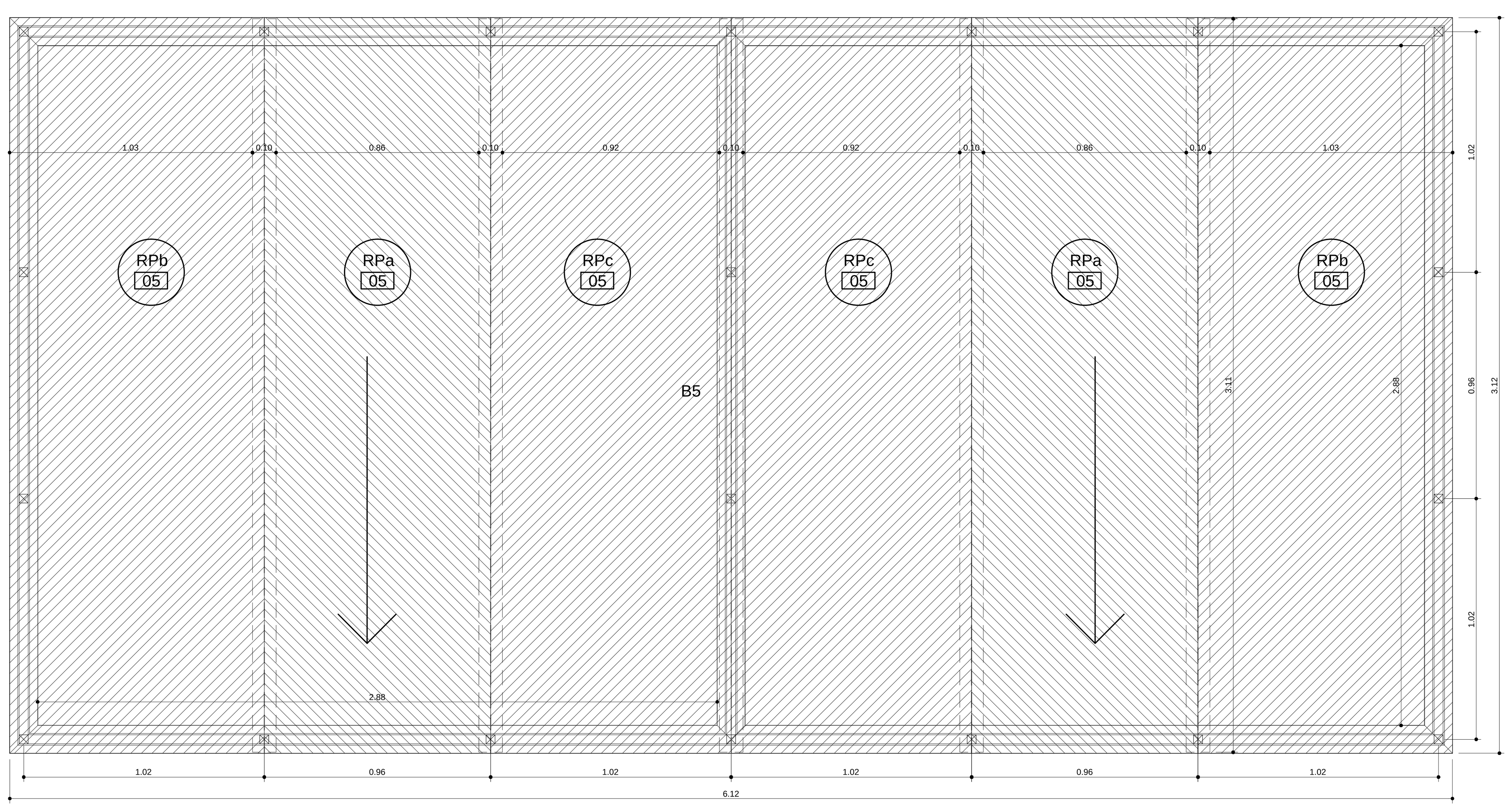
05 - Roof and floor schedules with details, scale 1/20 and 1/5

06 - Window schedule and details, scale 1/20 and 1/5

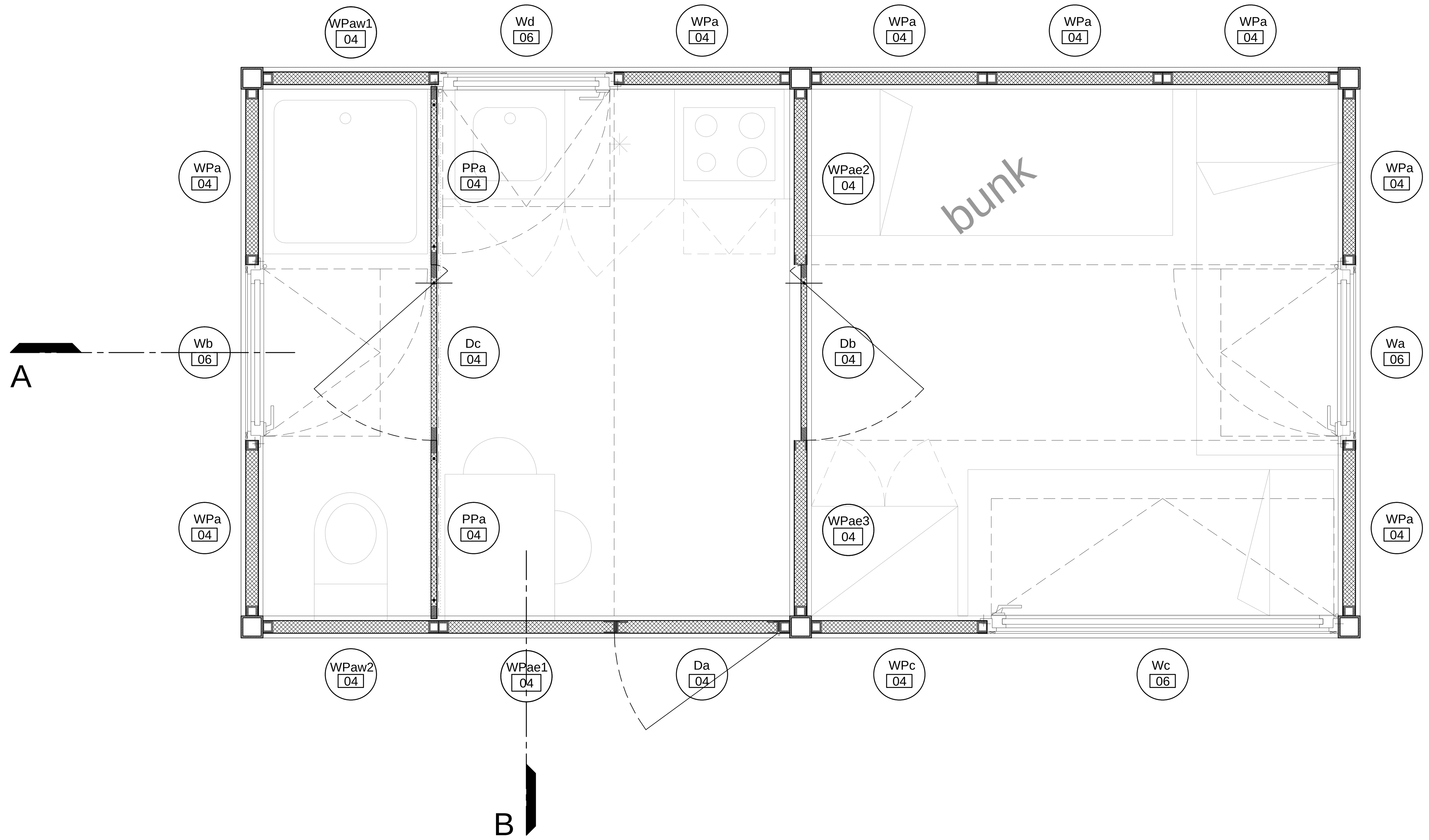
07 - Details of elevation panels, door panels and partition panels, scale 1/5

TÉCNICO LISBOA	Universidade do Minho	ALTO Perfis Pultrudidos Lda.	SHEET: 01
PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SCALE:	1/50
DRAWING:	Architectural general drawings		
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015

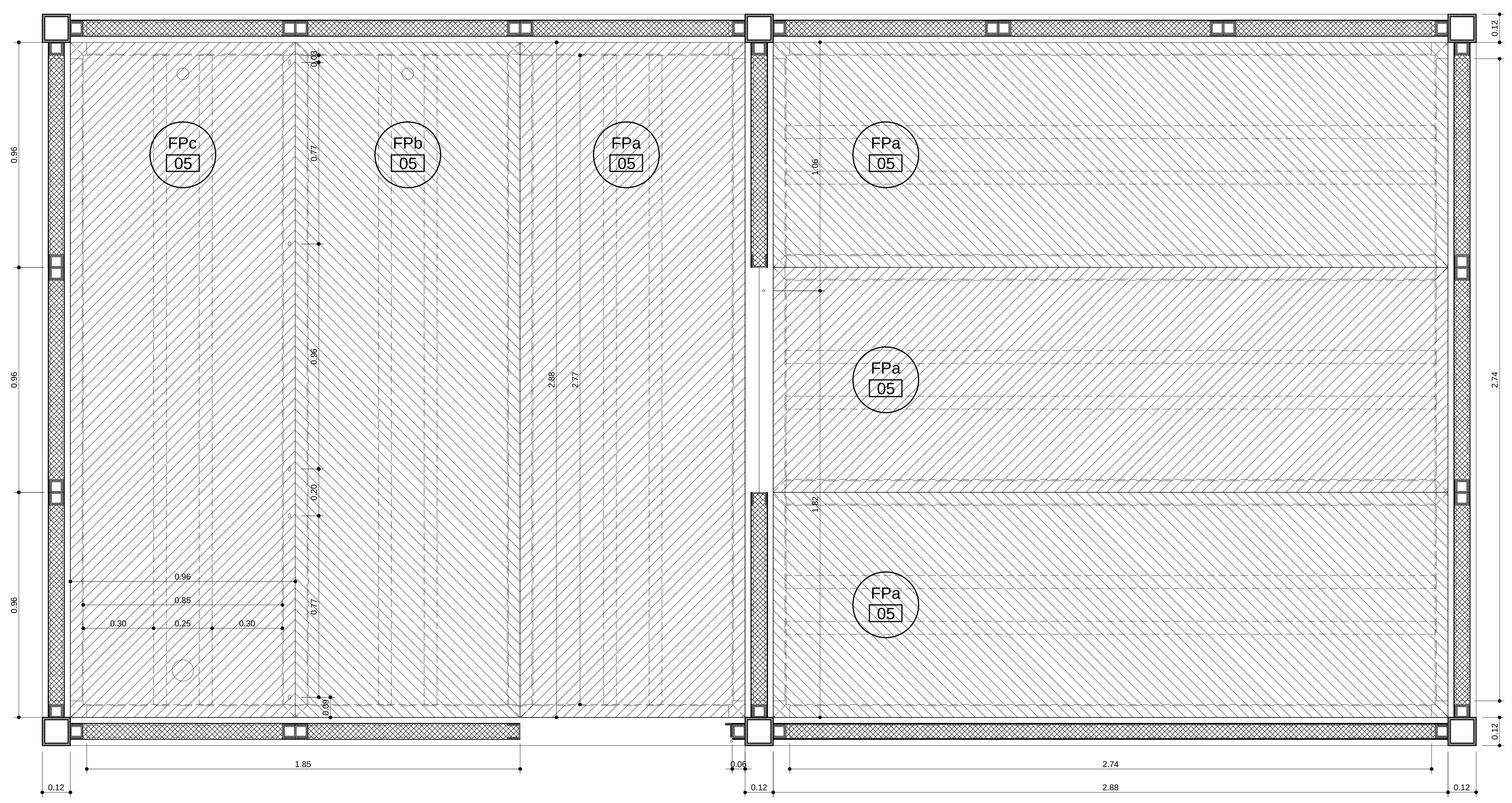
Roof Plan,1/20



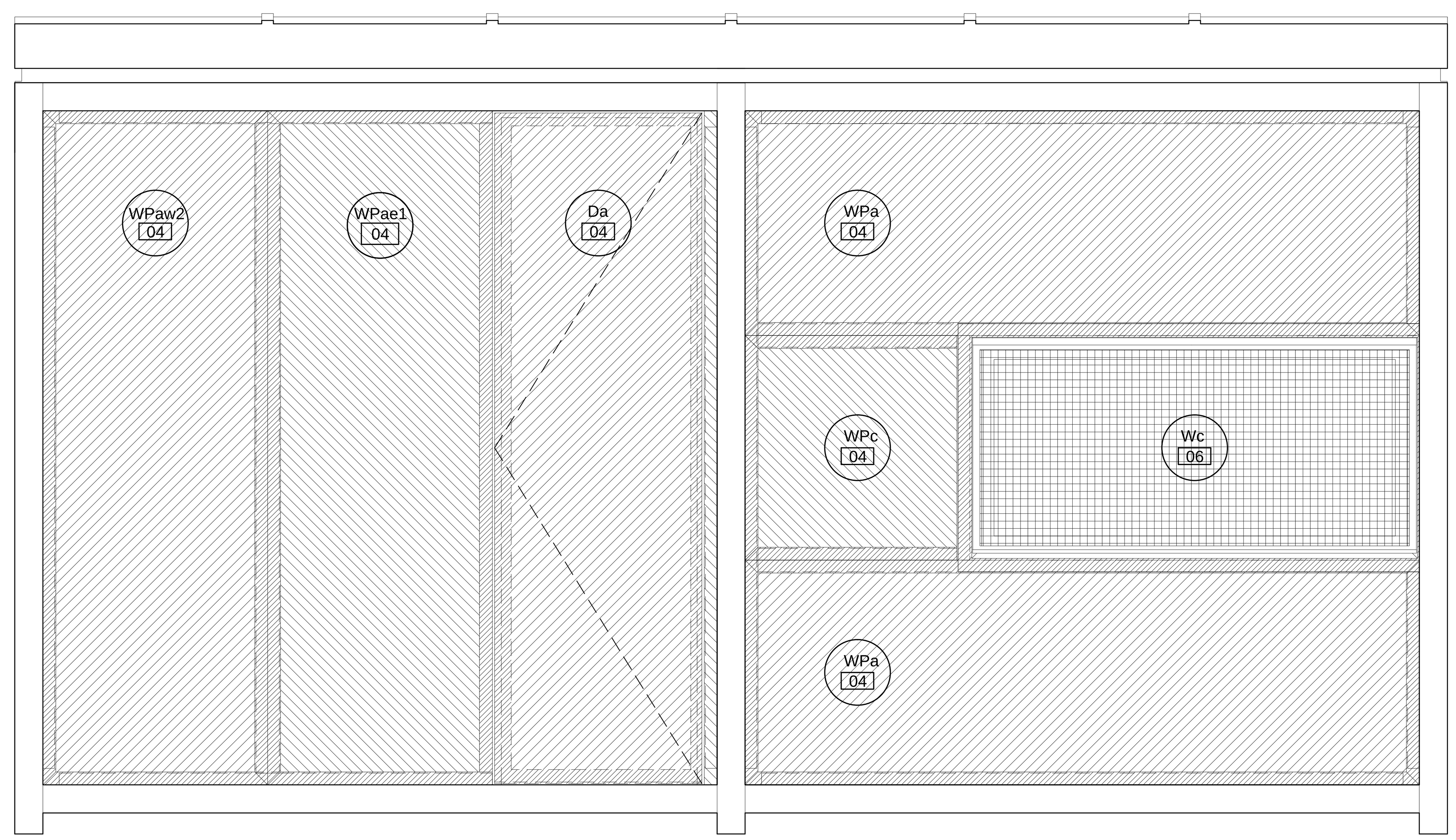
Floor Plan- interior layout, 1/20



Floor Plan, 1/20



South Elevation, 1/20



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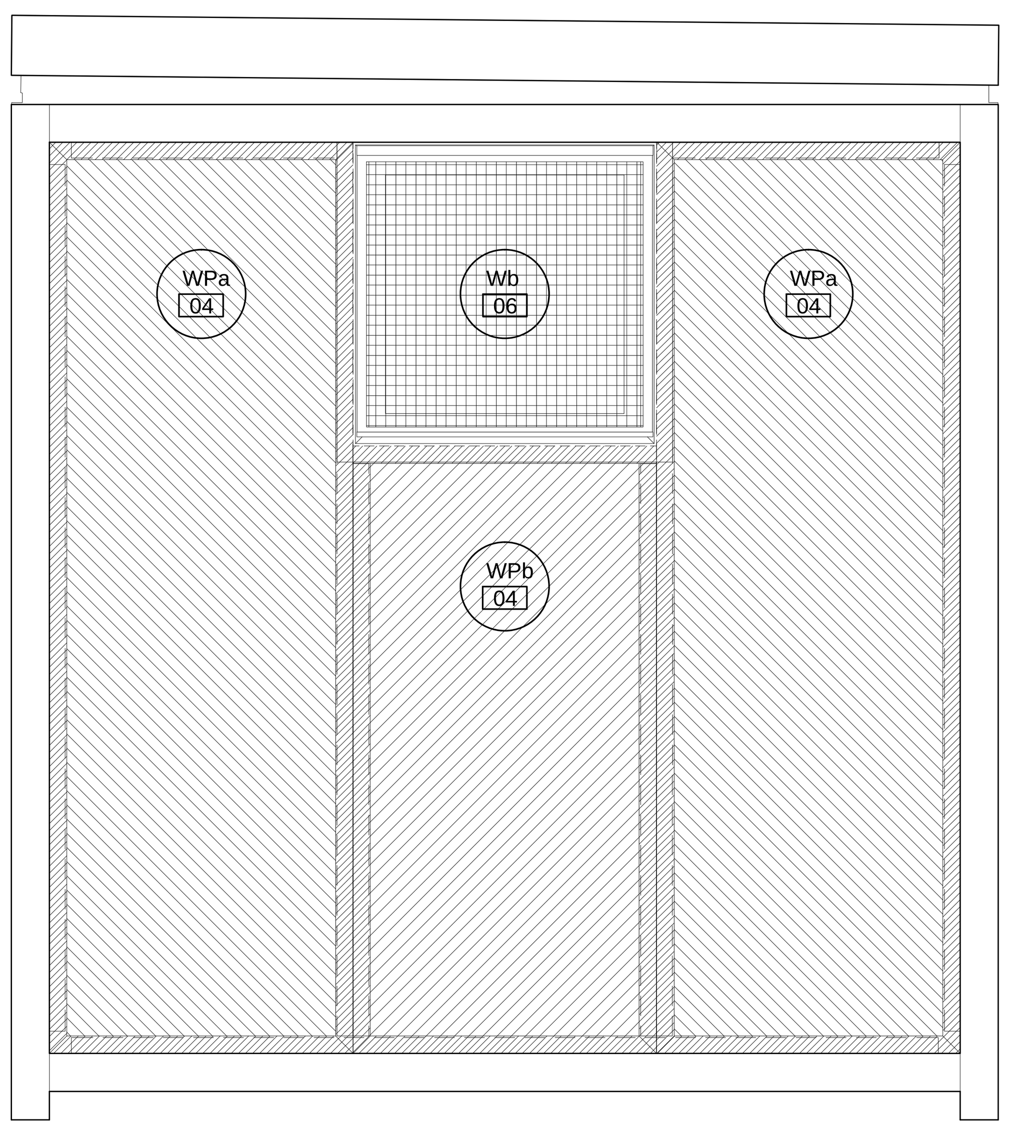
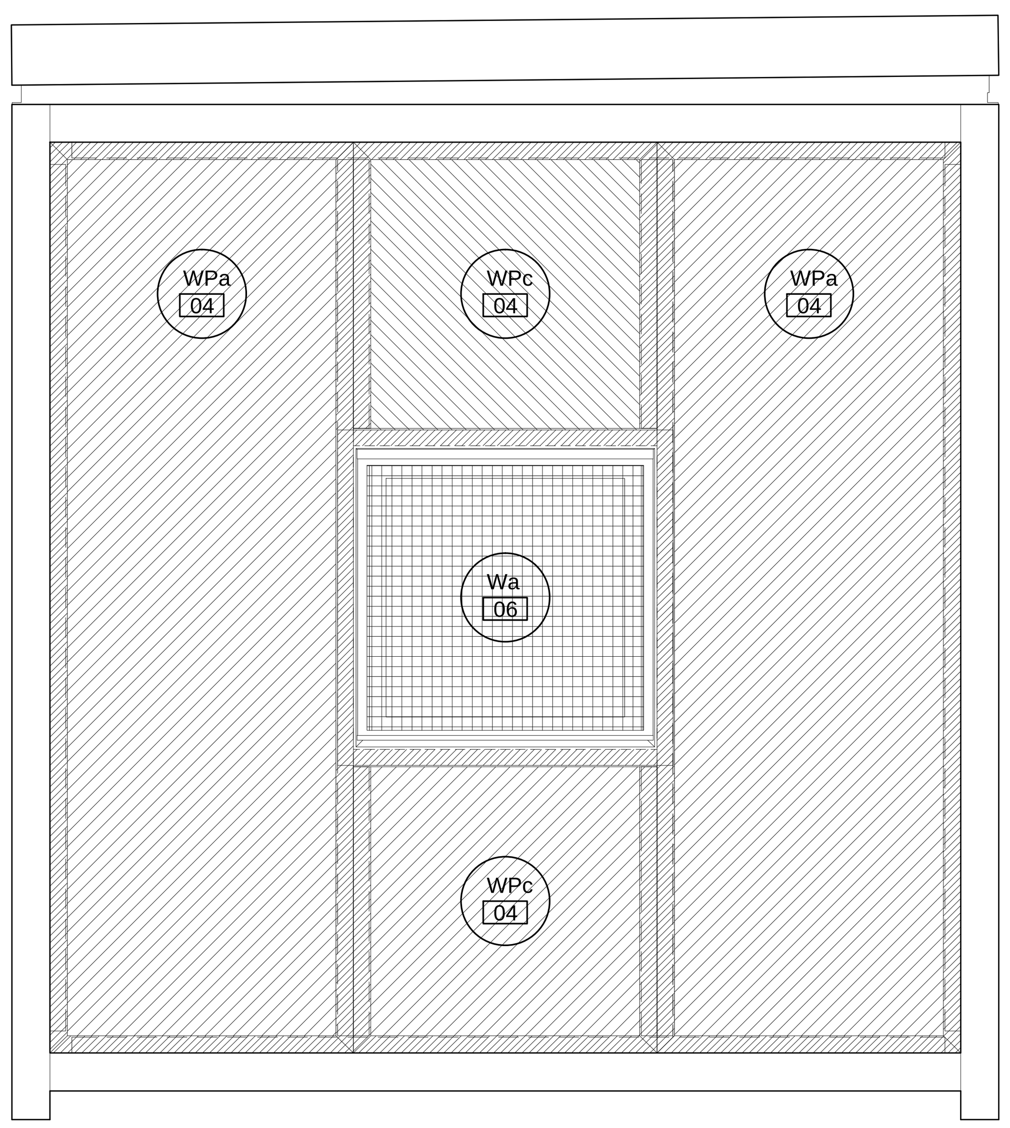
PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SHEET:	02
DRAWING:	Constructive drawings - plans and elevation	SCALE:	1/20
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015

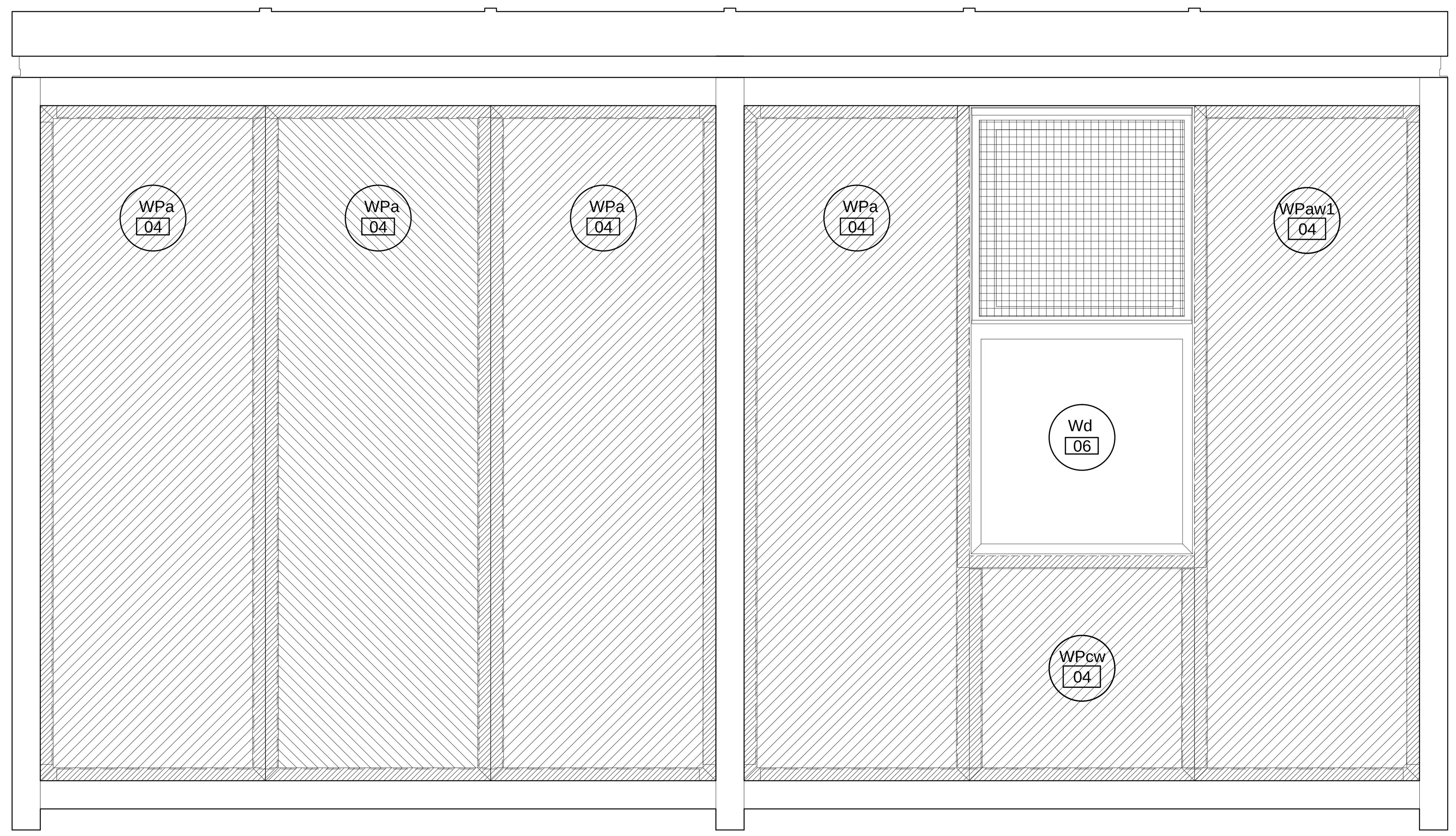
West Elevation, 1/20



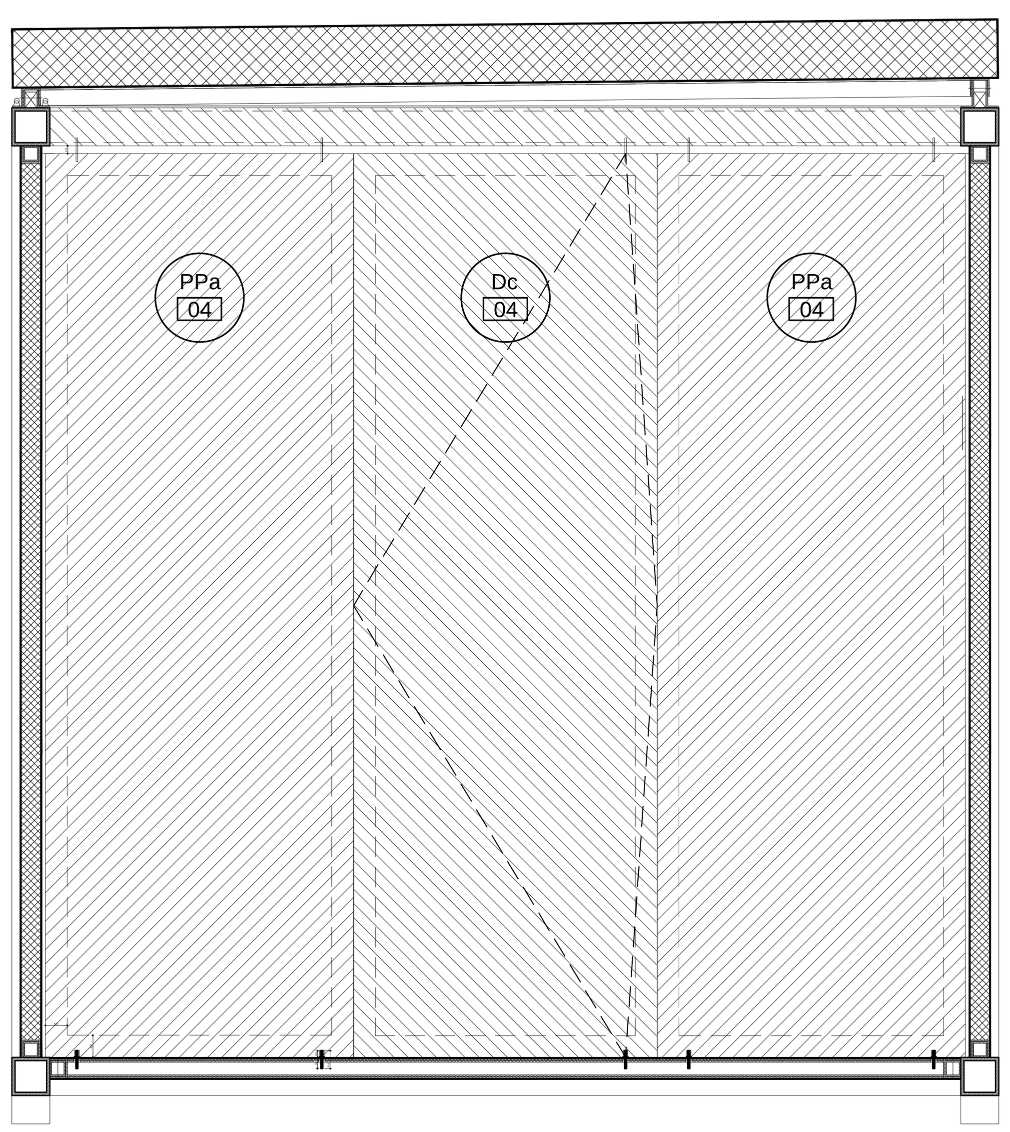
East Elevation, 1/20



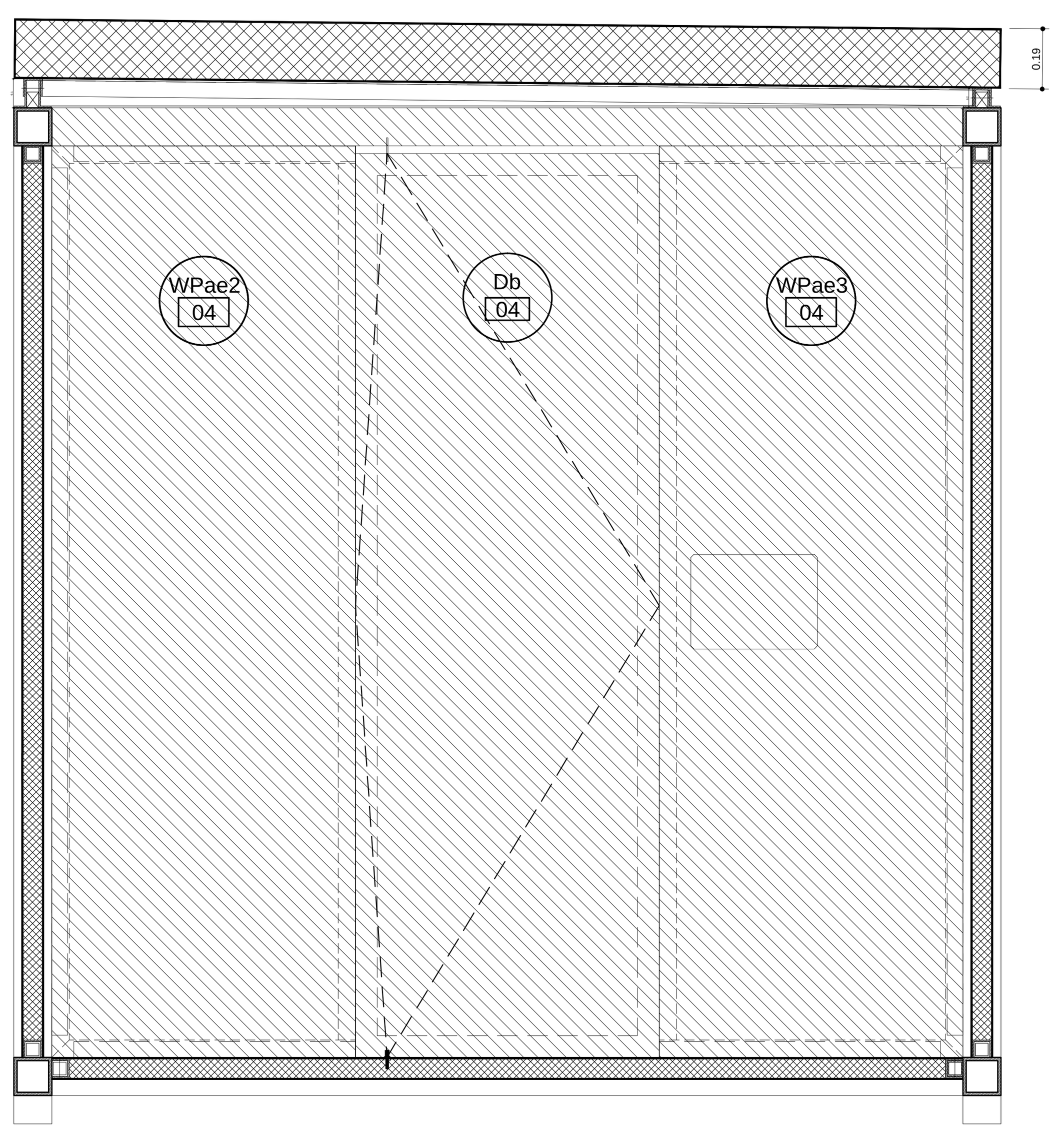
North Elevation, 1/20



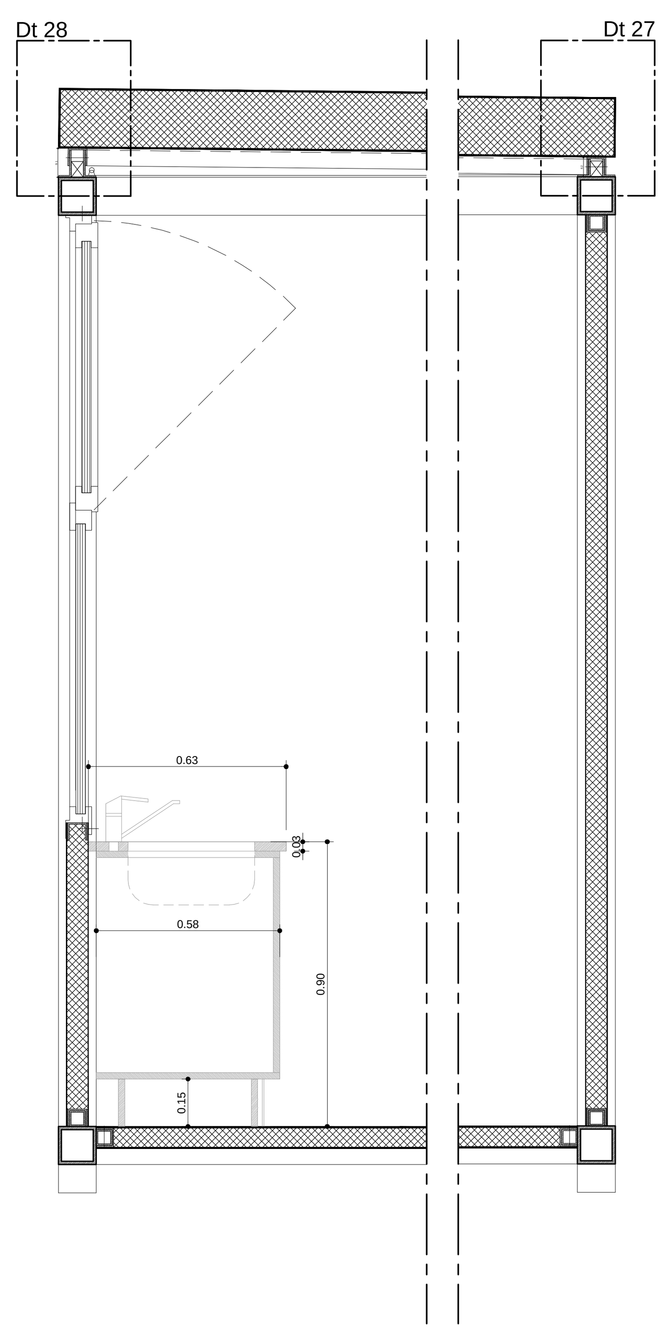
Partition Wall (kitchen/toilet), 1/20



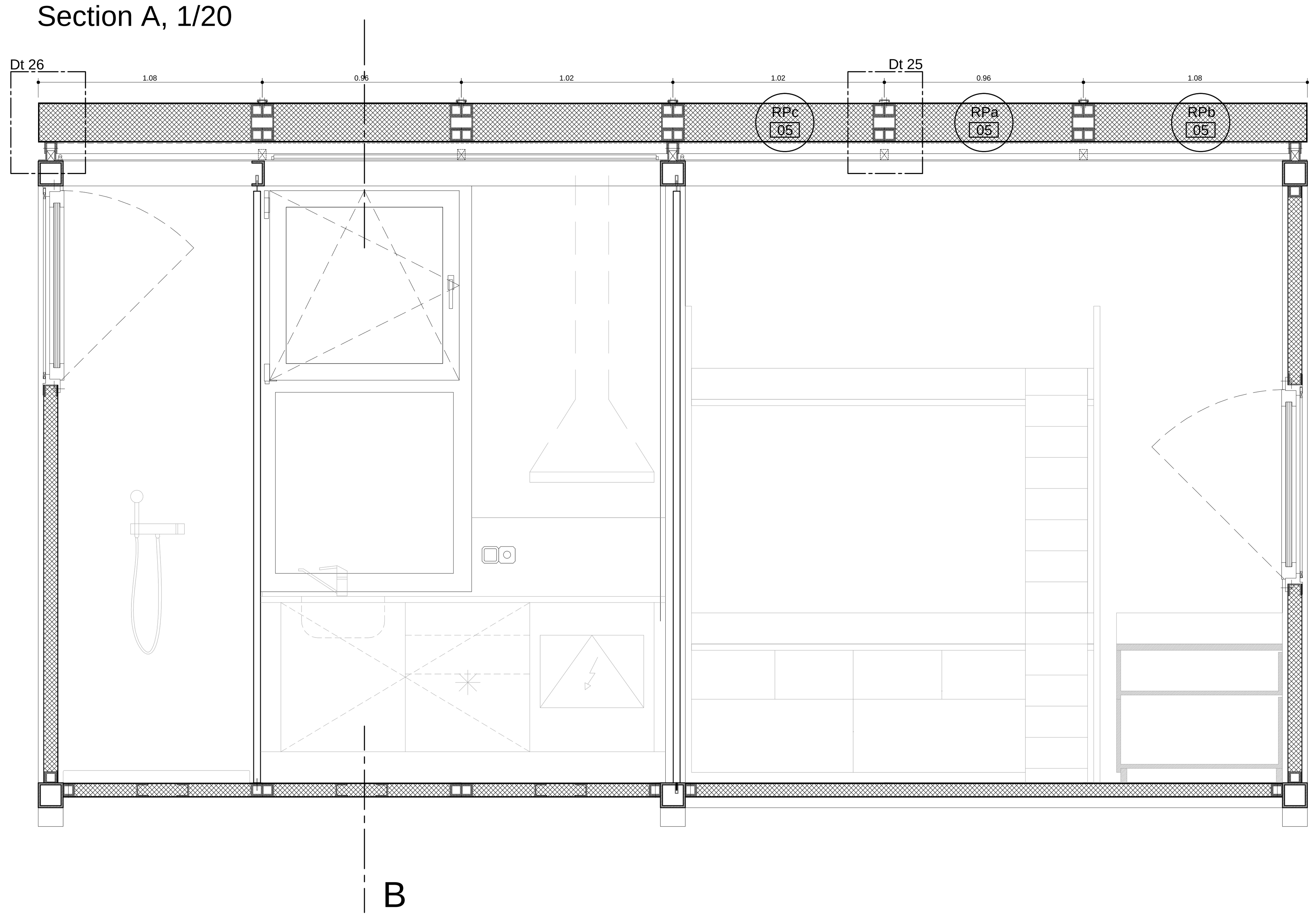
Partition Wall (kitchen/bedroom), 1/20



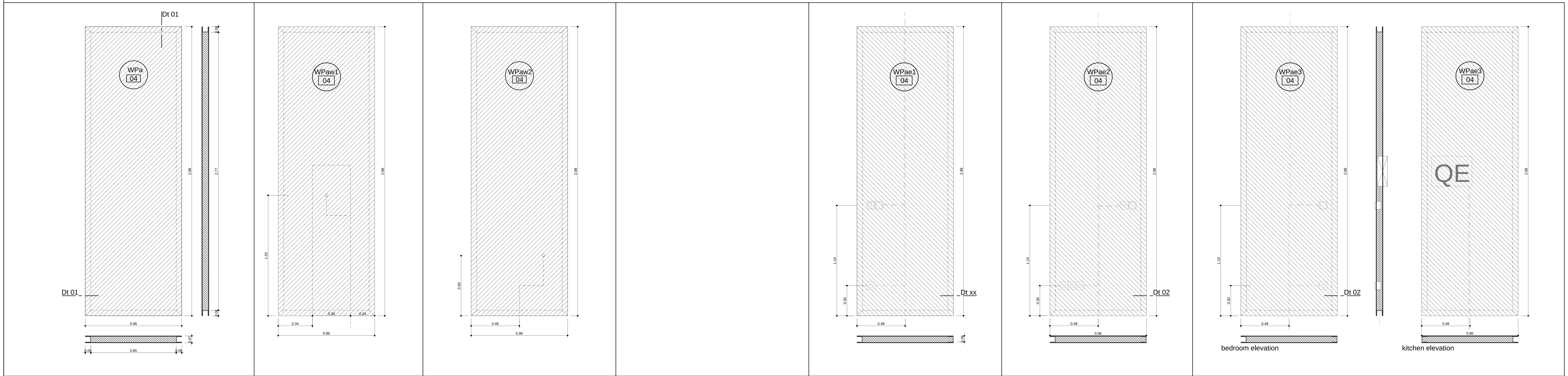
Section B, 1/20



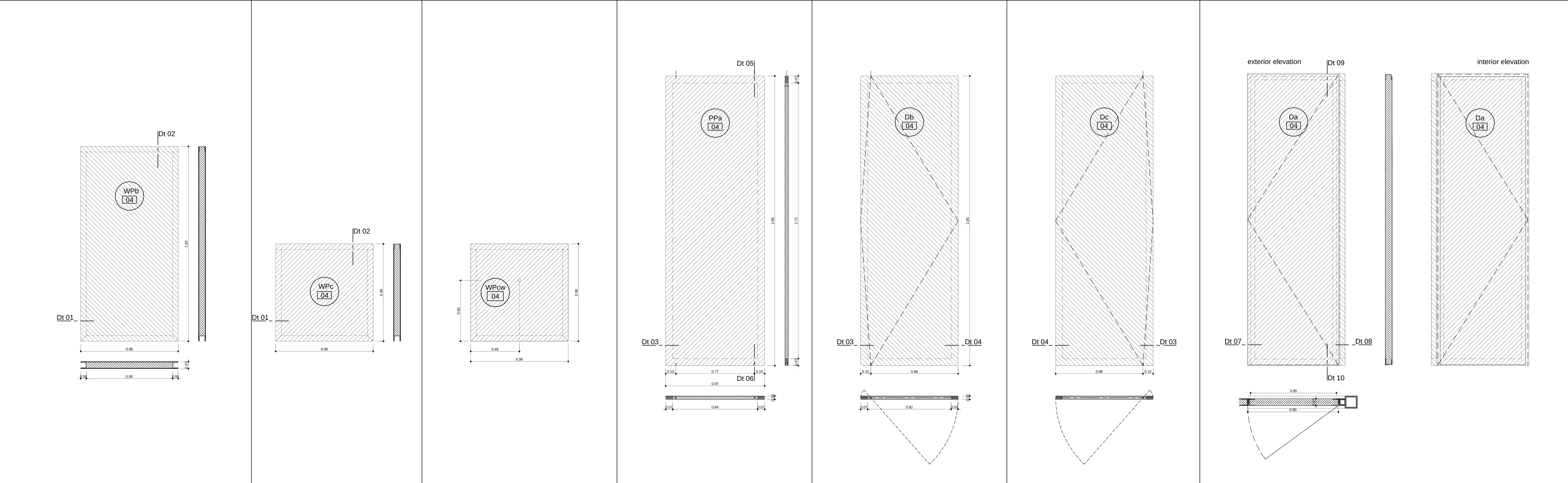
Section A, 1/20



PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SHEET:	03
DRAWING:	Constructive drawings - elevations and sections	SCALE:	1/20
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015



NOMENCLATURA	WPa - Wall Panel type a (96x288cm)	WPa w1 - Wall Panel type a (96x288cm) with water supply network 1	WPa w2 - Wall Panel type a (96x288cm) with water supply network 2		WPa e1 - Wall Panel type a (96x288cm) with electricity network 1 (sugestão)	WPa e2 - Wall Panel type a (96x288cm) with electricity network 2 (sugestão)	WPa e3 - Wall Panel type a (96x288cm) with electricity network 3 (sugestão)
UNIDADES / MÓDULO T1	10 (DEZ)	1 (UM)	1 (UM)		1 (UM)	1 (UM)	1 (UM)
REDES ÁGUAS	NÃO	SIM, VER PROJECTO INFRAESTRUTURAS	SIM, VER PROJECTO INFRAESTRUTURAS		NÃO	NÃO	NÃO
ELECTRICIDADE	NÃO	NÃO	NÃO		(3 interruptores p/ iluminação int. e ext + 1 tomada)	(1 interruptor p/ iluminação sanca + 4 tomadas)	(Quadro eléctrico + 1 interruptor p/ iluminação sanca + 1 tomada)
REVESTIMENTO	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01		VER FOLHA 01	VER FOLHA 01	VER FOLHA 01
FERRAGENS	NÃO	NÃO	NÃO		NÃO	NÃO	NÃO



NOMENCLATURA	WPb - Wall Panel type b (96x192cm)	WPc - Wall Panel type c (96x96cm)	WPc w - Wall Panel type c (96x96cm) with water supply network	PPa - Partition Panel type a	Db - Door type b (interior door, open left)	Dc - Door type c (interior door, open right)	Da - Door type a (exterior single door)
UNIDADES / MÓDULO T1	1 (UM)	3 (TRÊS)	1 (UM)	2 (DOIS)	1 (UM)	1 (UM)	1 (UM)
REDES ÁGUAS	NÃO	NÃO	SIM, VER PROJECTO INFRAESTRUTURAS	NÃO	NÃO	NÃO	NÃO
ELECTRICIDADE	NÃO	NÃO	NÃO	NÃO	NÃO	NÃO	NÃO
REVESTIMENTO	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01
FERRAGENS	NÃO	NÃO	NÃO	SIM - a rever pela ALTO: 4 pivots/pernos metálicos	SIM - a rever pela ALTO: 2 pivots/pernos metálicos + puxador e fecho	SIM - a rever pela ALTO: 2 pivots/pernos metálicos + puxador e fecho	SIM - a rever pela ALTO: dobradiças + puxador e fechadura
observações				prever furação nos perfis de apoio	prever furação nos perfis de apoio	prever furação nos perfis de apoio	ALTO: prever perfil alumínio com vedante de pelúcia no topo inferior da porta conforme desenhos

CONSITUIÇÃO PAINEL SANDUICHE P/ FACHADA:

2 lâminas de GFRP c/ 2mm;
4 perfis U 60;
2 barras c / 3mm para reforço banzos U;
espuma poliuretano c/ 66mm

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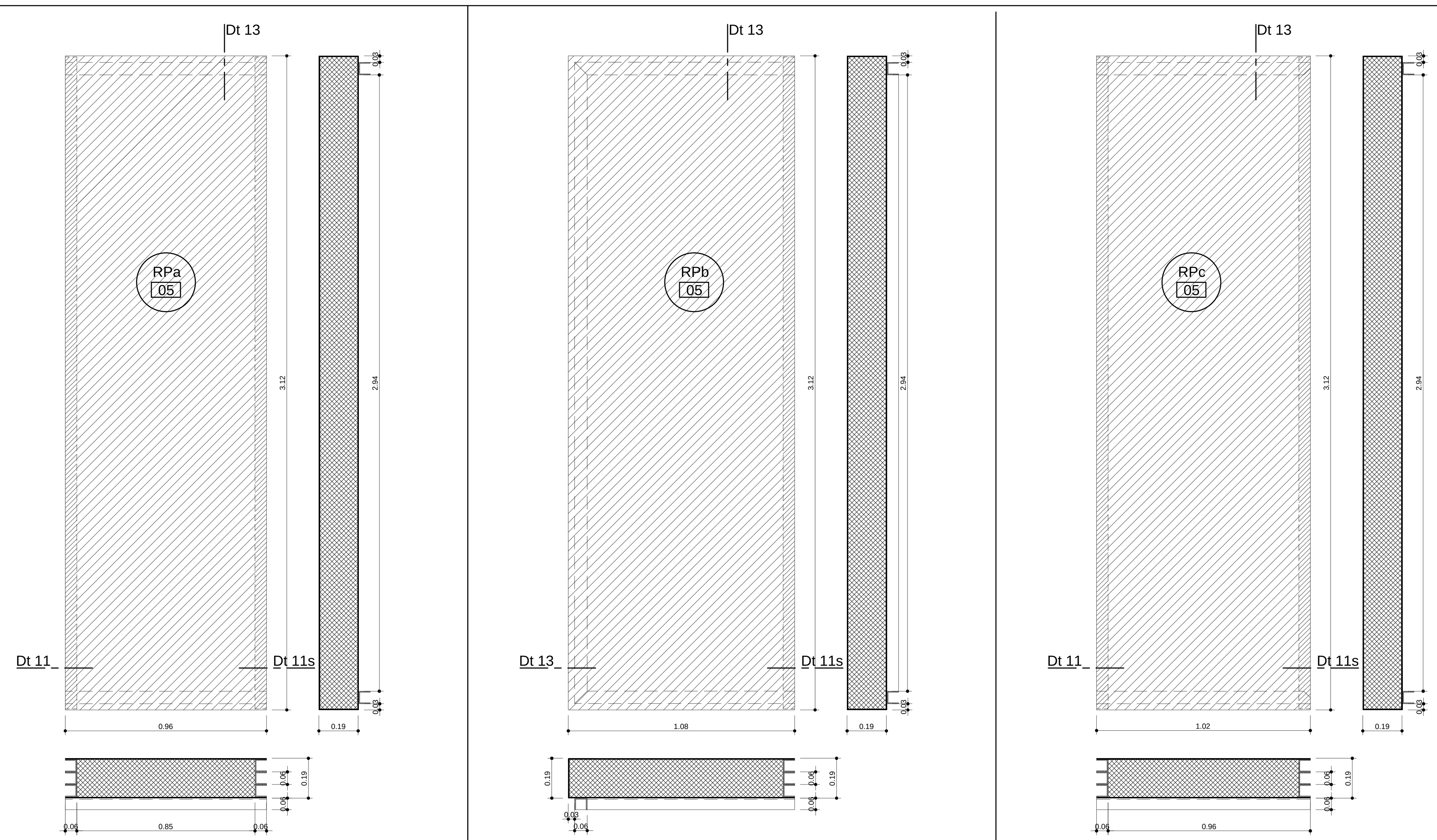
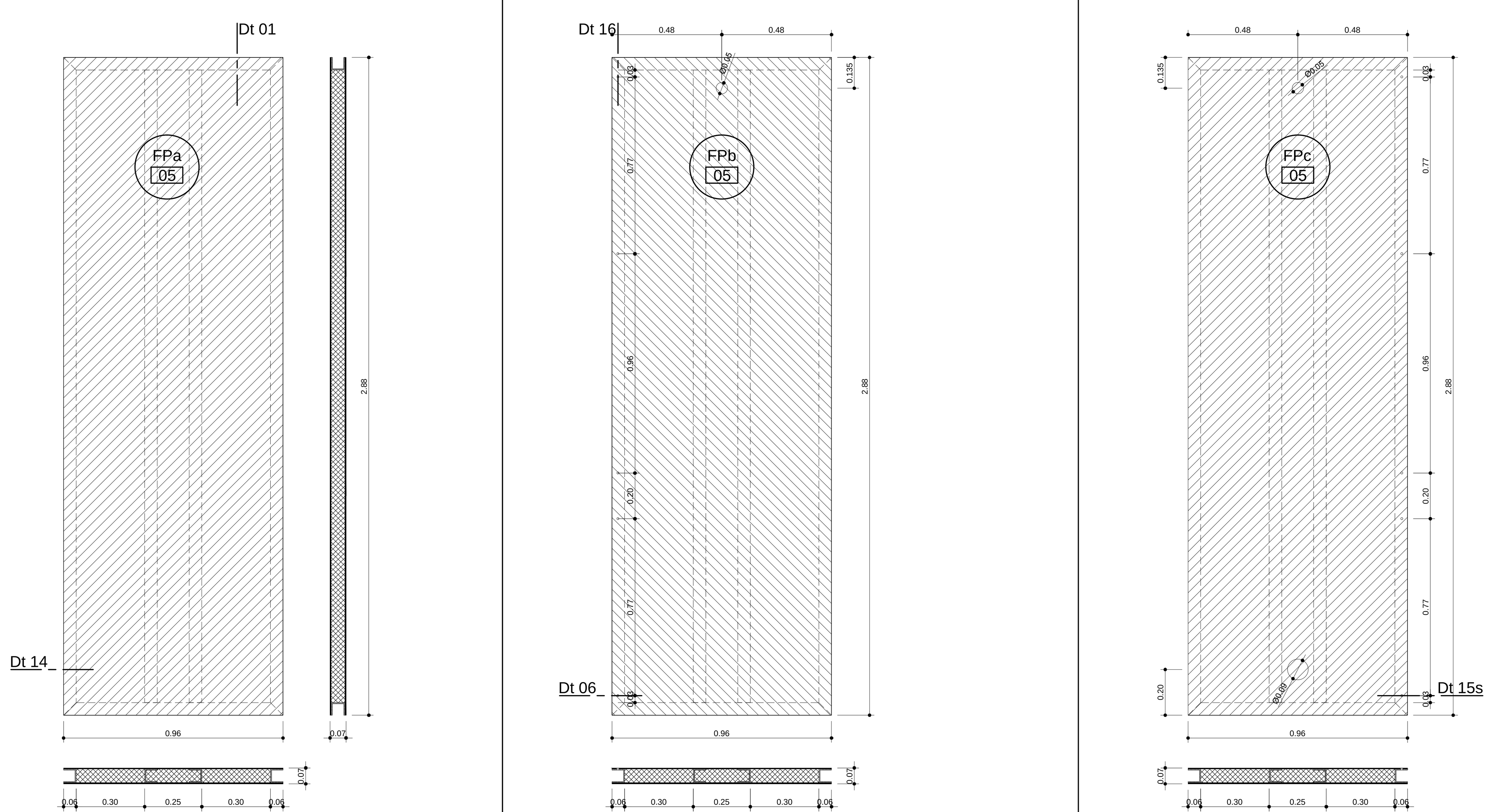
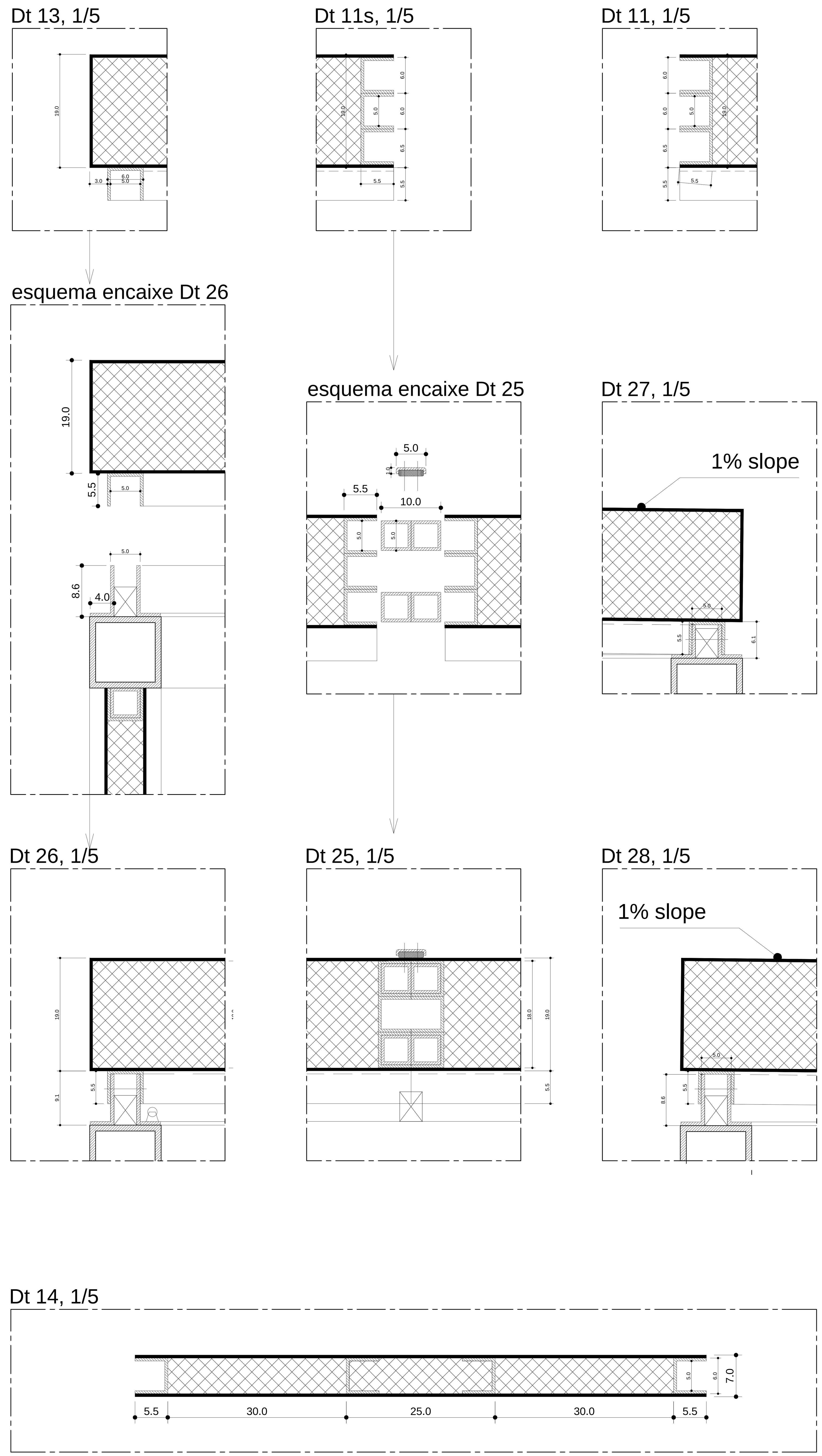
PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SCALE:	1/20
DRAWING:	Elevation schedule	SHEET:	04
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015



NOMENCLATURA	RPa - Roof panel type a (96cm wide)	RPb - Roof panel type b (108cm wide)	RPc - Roof panel type c (102cm wide)
UNIDADES / MÓDULO T1	2 (DOIS)	2 (DOIS)	2 (DOIS)
REVESTIMENTO	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01
LIGAÇÃO ENTRE PAINÉIS	rever com a ALTO necessidade folga nas juntas	rever com a ALTO necessidade folga nas juntas	rever com a ALTO necessidade folga nas juntas



NOMENCLATURA	FPa - Floor panel type a (simple)	FPb - Floor panel type b (kitchen)	FPc - Floor panel type c (toilet)
UNIDADES / MÓDULO T1	4 (QUATRO)	1 (UM)	1 (UM)
REVESTIMENTO	VER FOLHA 01	VER FOLHA 01	VER FOLHA 01
REDES ÁGUAS	NÃO	SIM, VER PROJECTO INFRAESTRUTURAS	SIM, VER PROJECTO INFRAESTRUTURAS
observações		prever furação nos perfis de apoio aos painéis divisórios, ver Dt 16	prever furação nos perfis de apoio aos painéis divisórios, ver Dt 16

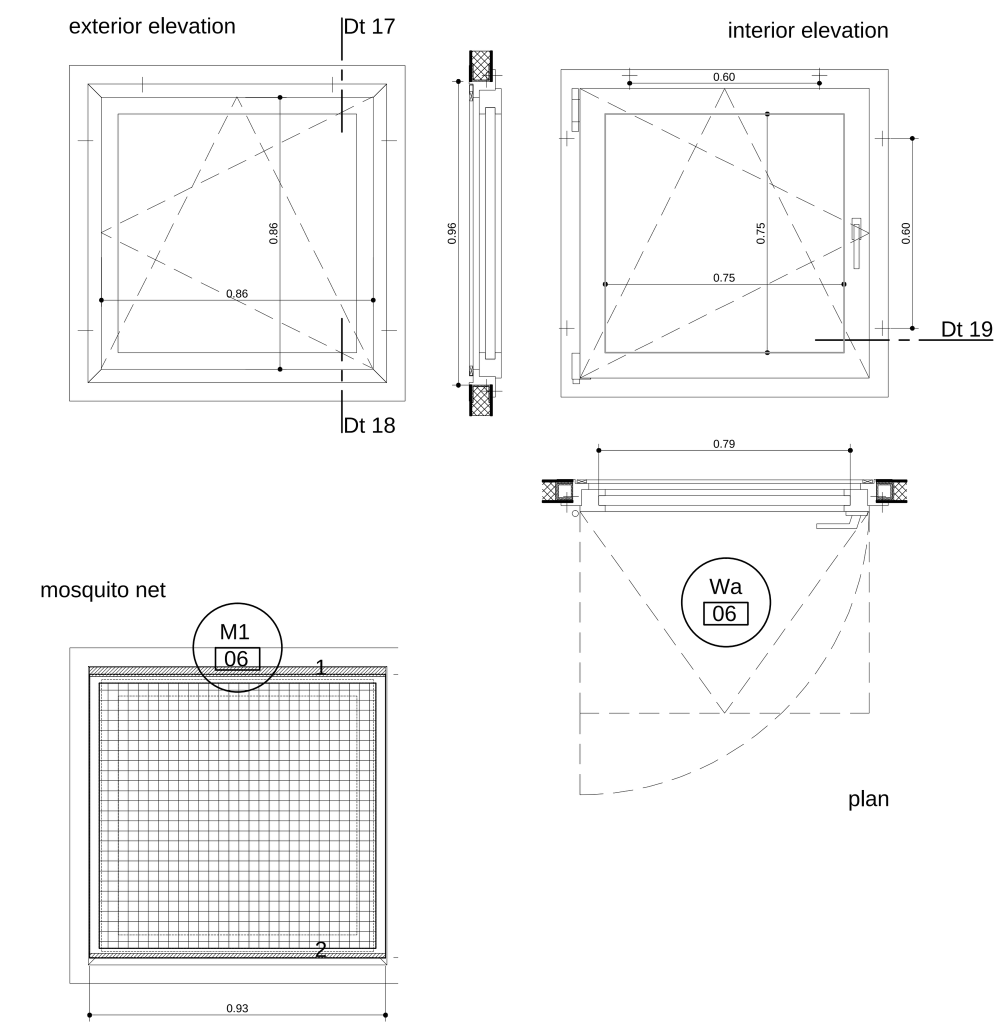


CONSITUIÇÃO PAINEL SANDUICHE P/ PAVIMENTO:

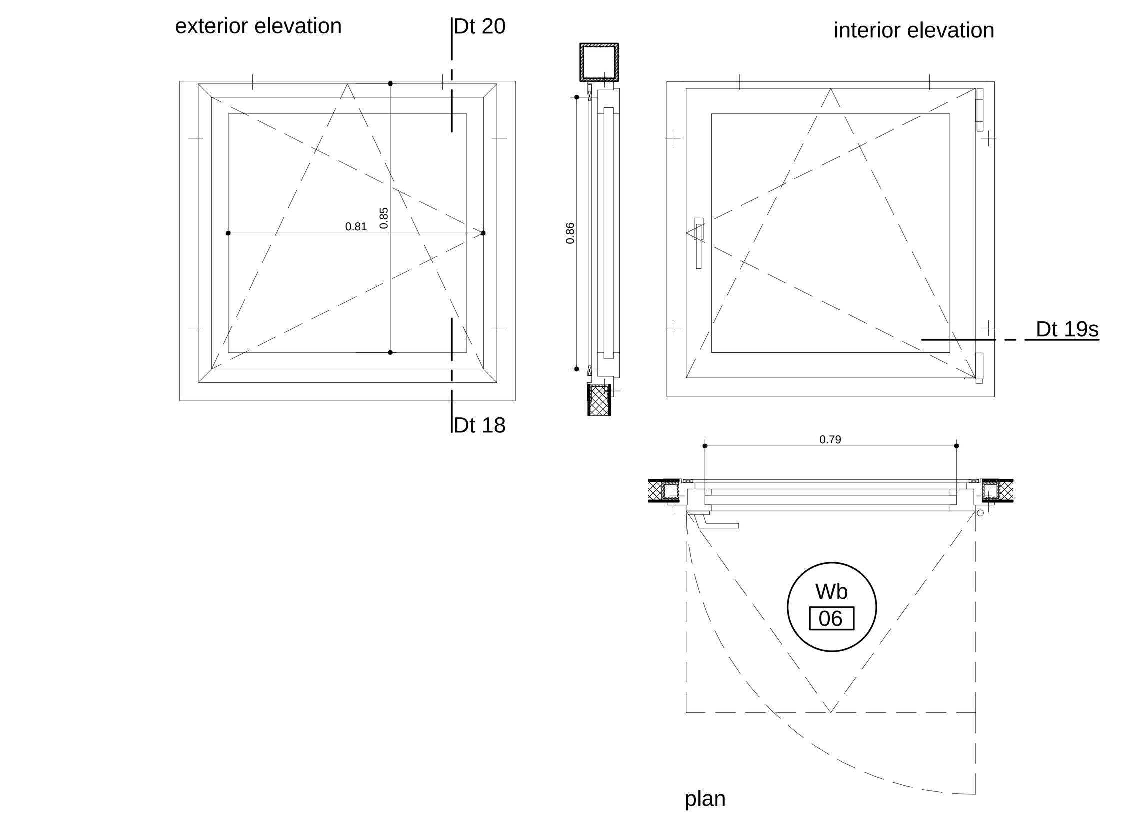
2 lâminas de GFRP c/ 5mm;
4 perfis U 60;
espuma poliuretano c/ 60mm

SHEET:	05
PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials
SCALE:	1/20 1/5
DRAWING:	Roof and floor schedules with details
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento
DATE:	June 2015

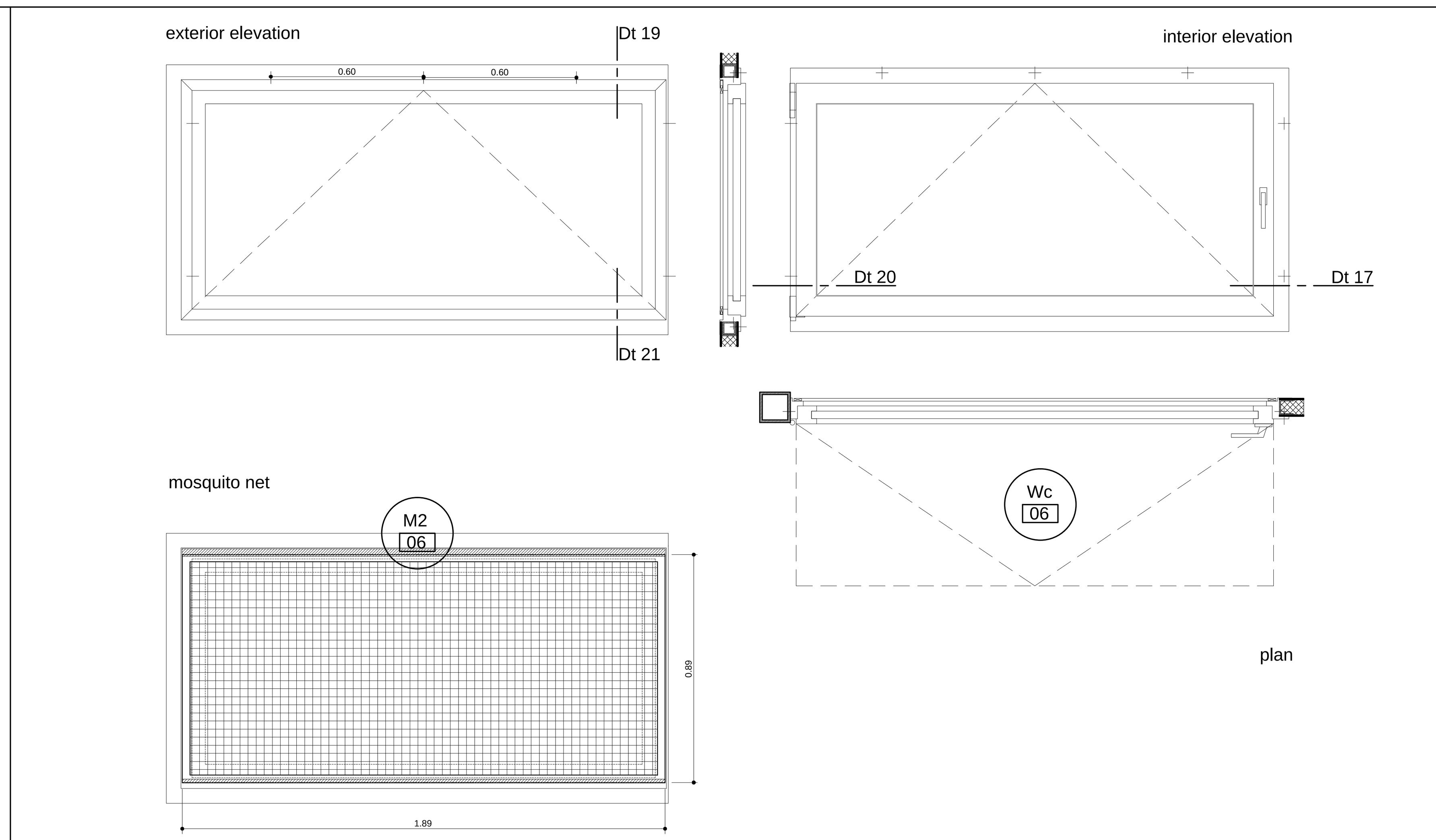
Wa - Window a, 1/20



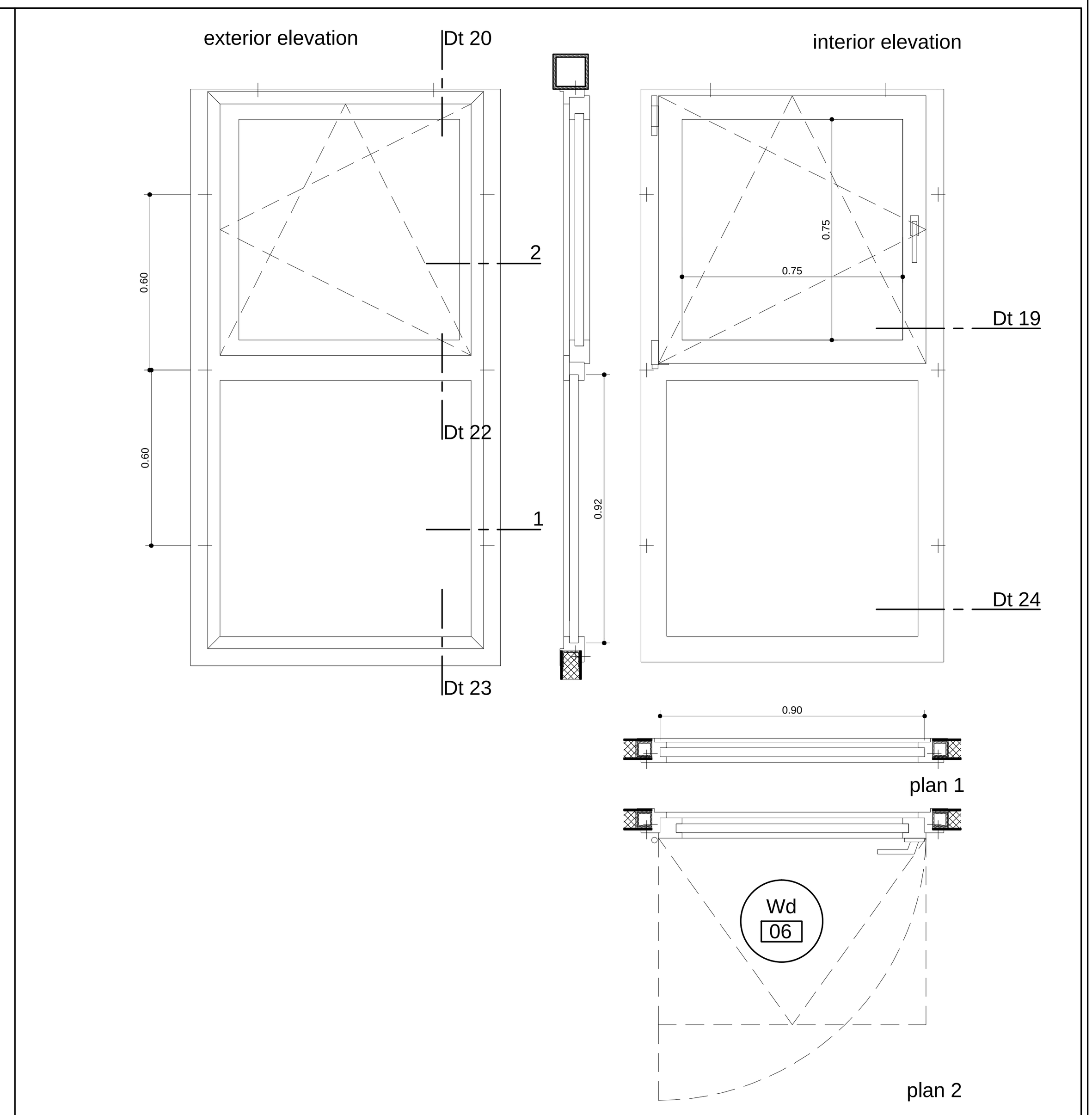
Wb - Window b, 1/20



Wc - Window c, 1/20

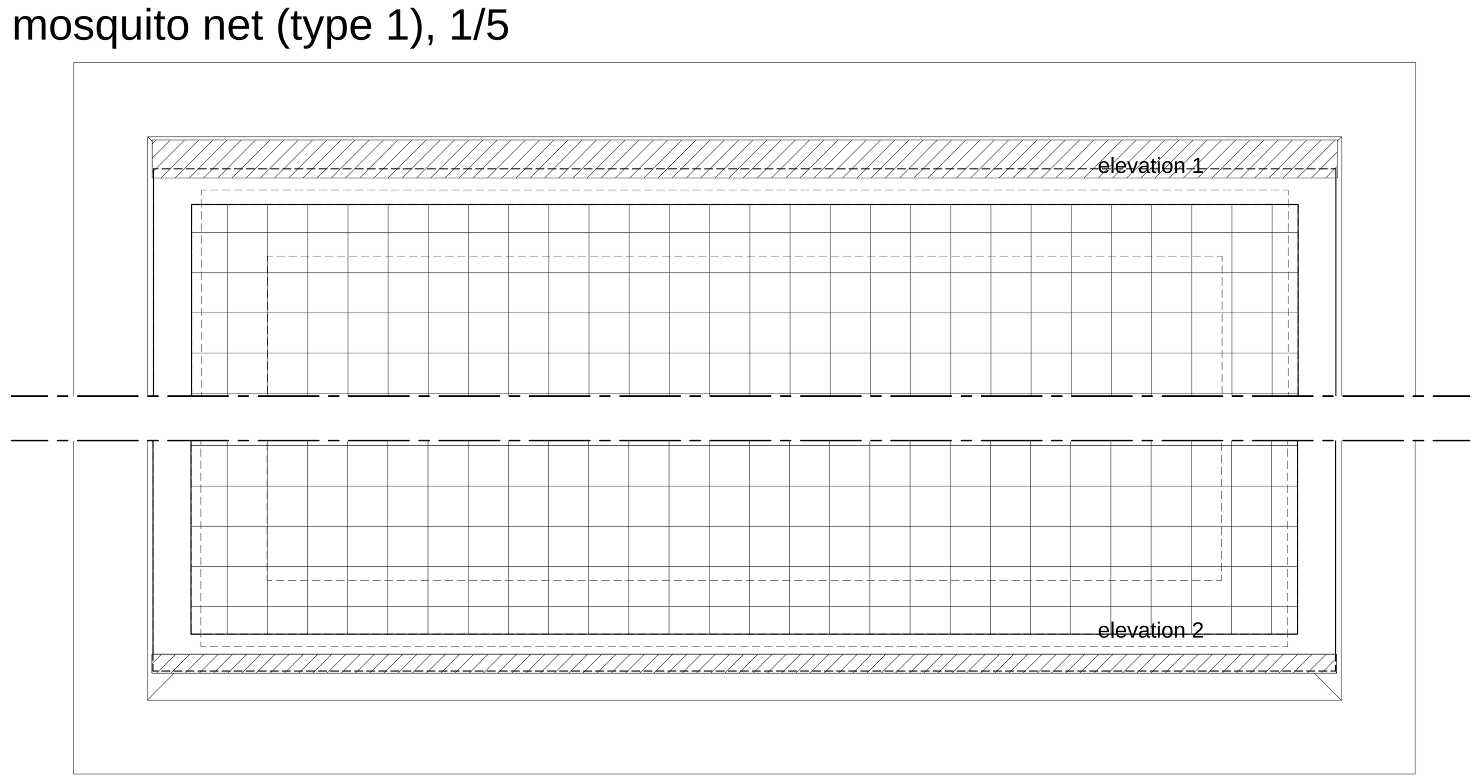


Wd - Window d,1/20

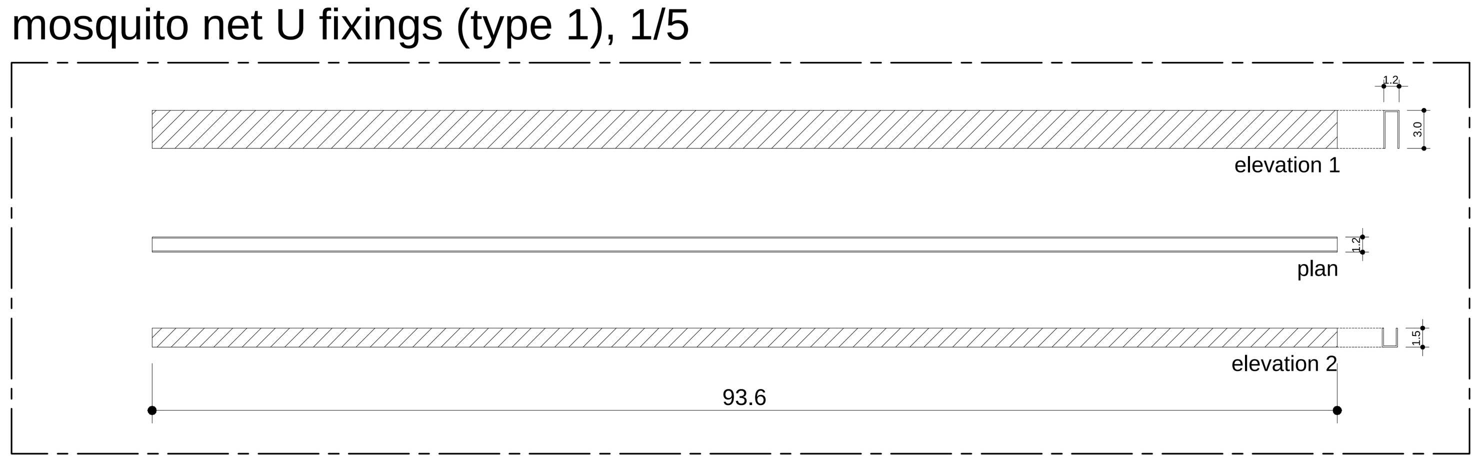


NOMENCLATURA	Wa - Window type a	Wb - Window type b	Wc - Window type c	Wd - Window type d
	M1 - Mosquito net type 1	M1 - Mosquito net type 1	M2 - Mosquito net type 2	M1 - Mosquito net type 1
UNIDADES / MÓDULO T1	1 (UMA)	1 (UMA)	1 (UMA)	1 (UMA)
COMPONENTES	UMA FOLHA	UMA FOLHA	UMA FOLHA	DUAS FOLHAS
FUNCIONAMENTO	OSCILO-BATENTE	OSCILO-BATENTE	BASCULANTE INFERIOR	FOLHA INFERIOR FIXA; FOLHA SUPERIOR OSCILO-BATENTE
CAIXILHO	PVC, aro renovação 40mm	PVC, aro renovação (s/ aba na verga)	PVC, aro renovação (s/ aba na ombreira/pilar)	PVC, aro renovação (s/ aba na verga)
dimensões vão	0,96 x 0,96 m	0,96 x 0,96 m	1,92 x 0,96 m	0,96 x 1,92 m
ENVIDRAÇADO	policarbonato alveolar 30mm	policarbonato alveolar 30mm	policarbonato alveolar 30mm	policarbonato alveolar 30mm
dimensões envidraçado	0,79 x 0,79 m	0,79 x 0,79 m	1,75 x 0,79 m	FIXO - 0,90 X 0,92; MÓVEL - 0,79 x 0,79 m
MANETE	a rever com a REHAU tipo e altura	a rever com a REHAU tipo e altura	a rever com a REHAU tipo e altura	a rever com a REHAU tipo e altura
REDE MOSQUITEIRA	aro alumínio, perfil 30 x 10mm	aro alumínio, perfil 30 x 10mm	aro alumínio, perfil 30 x 10mm	aro alumínio, perfil 30 x 10mm
fixações	2 perfís em U alumínio	2 perfís em U alumínio	2 perfís em U alumínio	2 perfís em U alumínio
dimensões rede	0,93 x 0,89 m	0,93 x 0,89 m	1,89 x 0,89 m	0,93 x 0,89 m

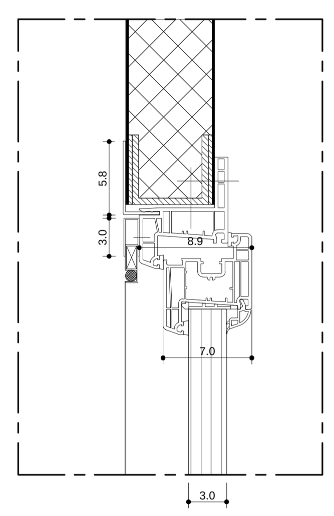
mosquito net (type 1), 1/5



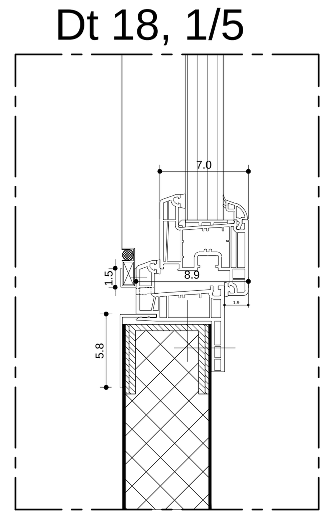
mosquito net U fixings (type 1), 1/5



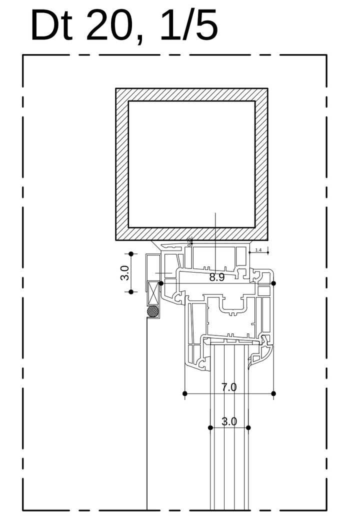
Dt 17, 1/5



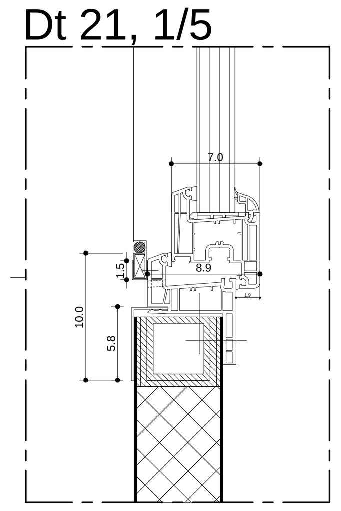
Dt 18, 1/5



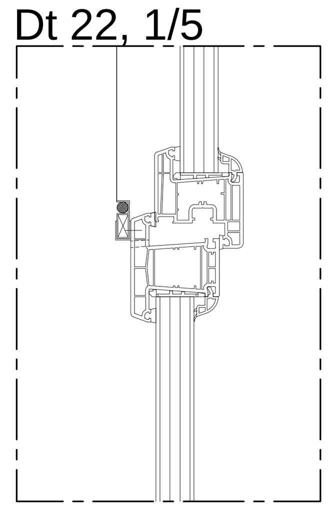
Dt 20, 1/5



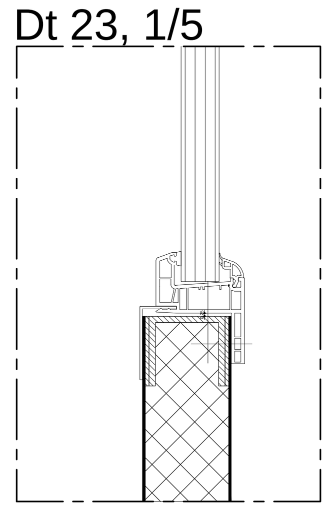
Dt 21, 1/5



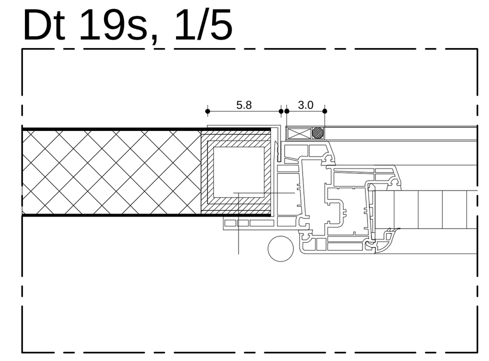
Dt 22, 1/5



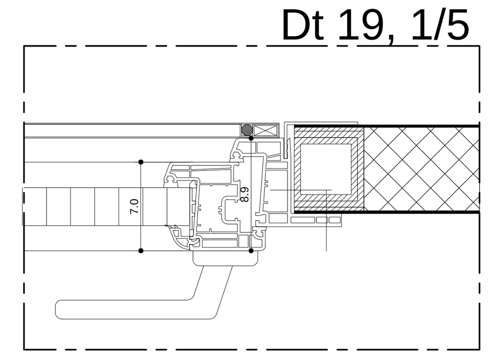
Dt 23, 1/5



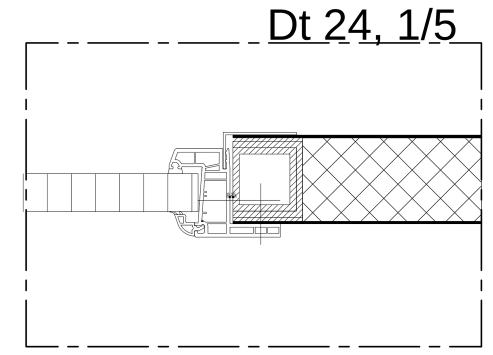
Dt 19s, 1/5



Dt 19, 1/5



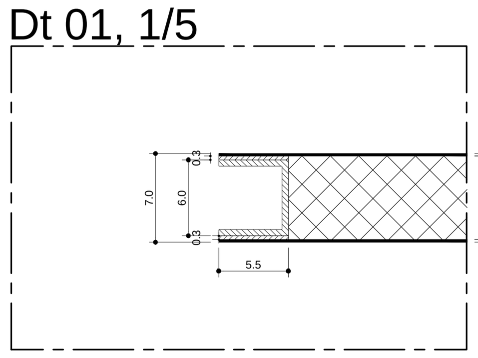
Dt 24, 1/5



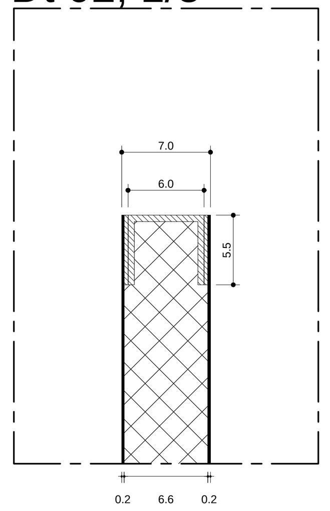
TÉCNICO LISBOA | Universidade do Minho | ALTO Perfis Pultrudidos Lda.

PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SCALE:	1/20 1/5
DRAWING:	Window schedule and details	SHEET:	06
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015

Dt 01, 1/5

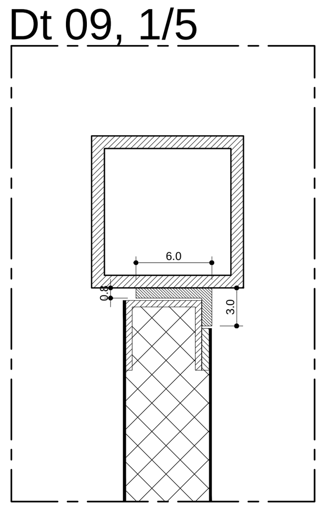


Dt 02, 1/5

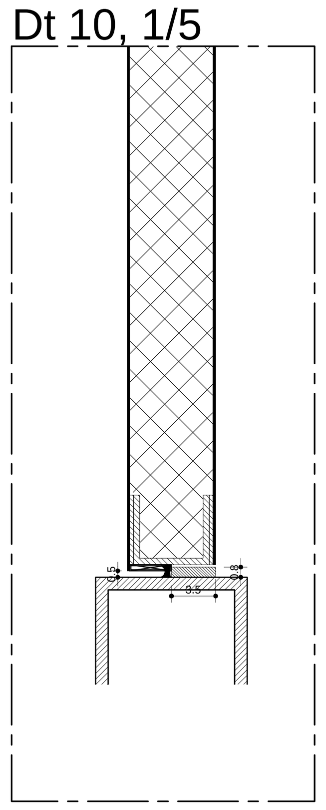


Door type a

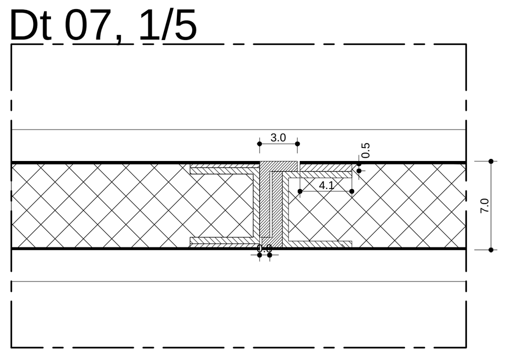
Dt 09, 1/5



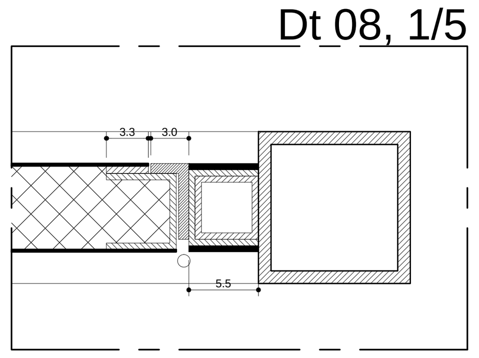
Dt 10, 1/5



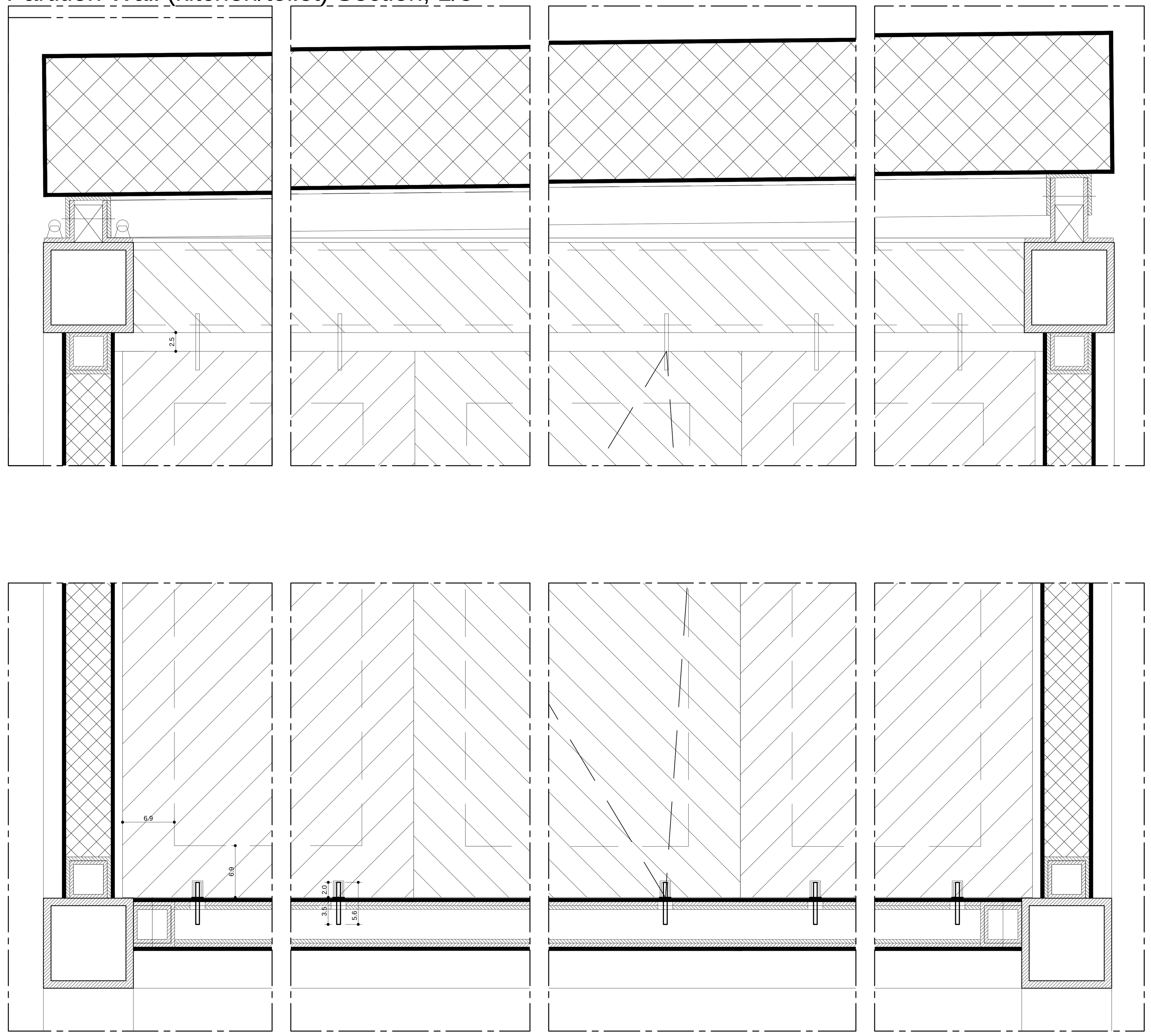
Dt 07, 1/5



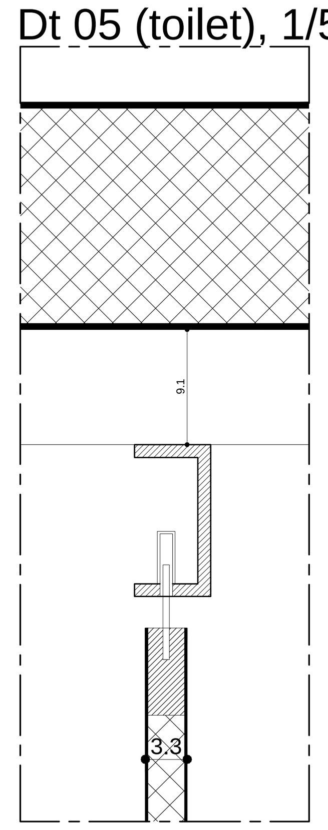
Dt 08, 1/5



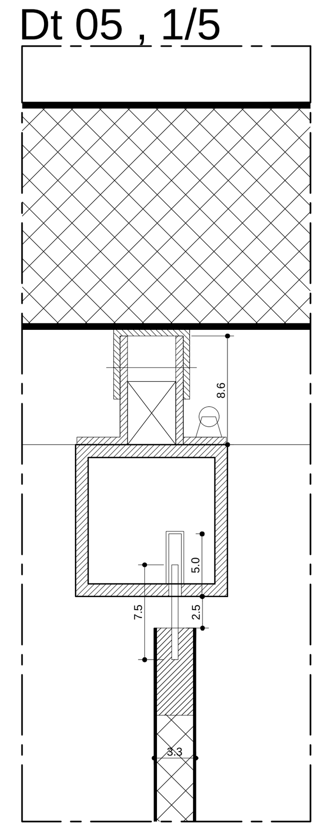
Partition Wall (kitchen/toilet) Section, 1/5



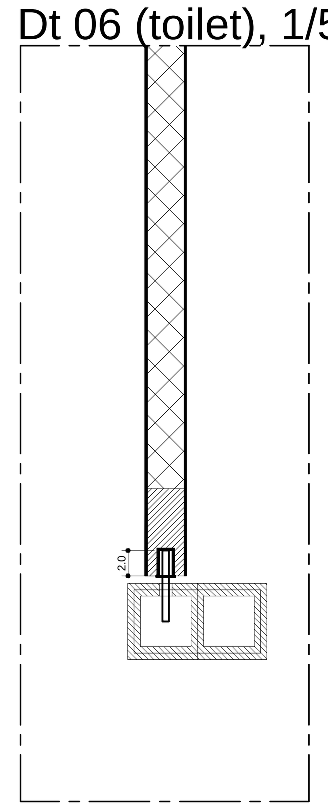
Dt 05 (toilet), 1/5



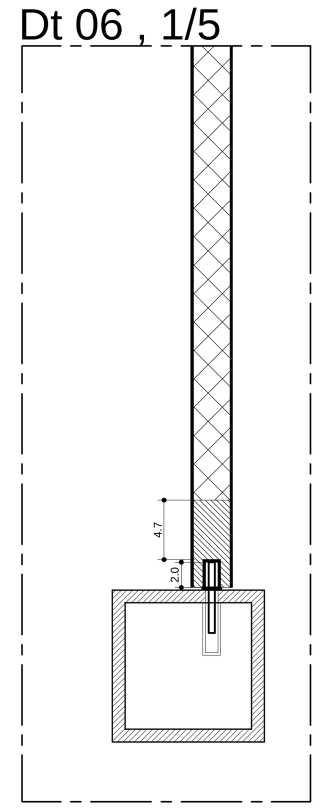
Dt 05 , 1/5



Dt 06 (toilet), 1/5

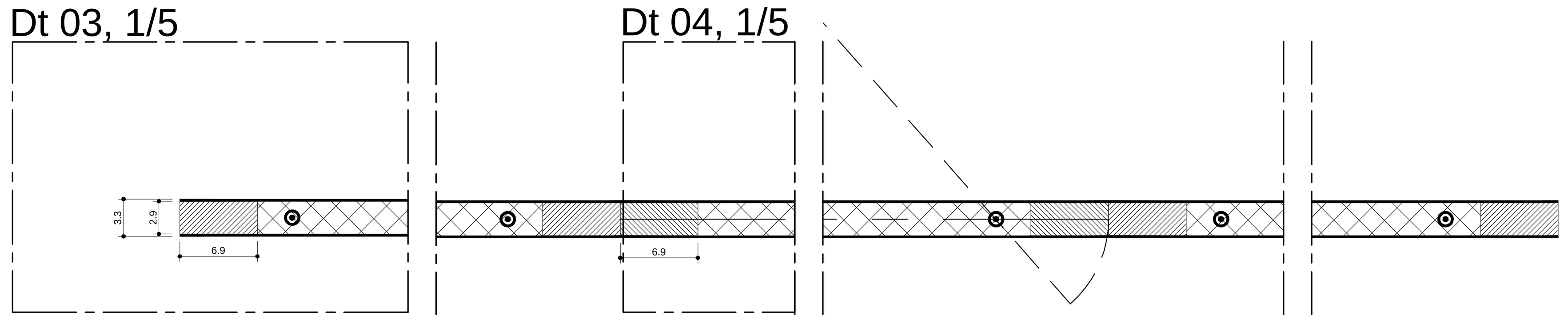


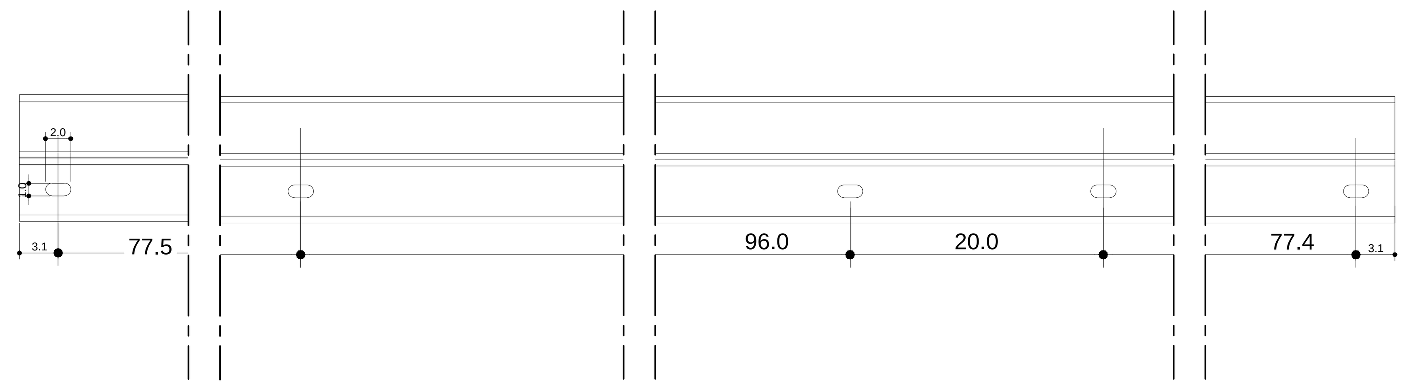
Dt 06 , 1/5



Dt 03, 1/5

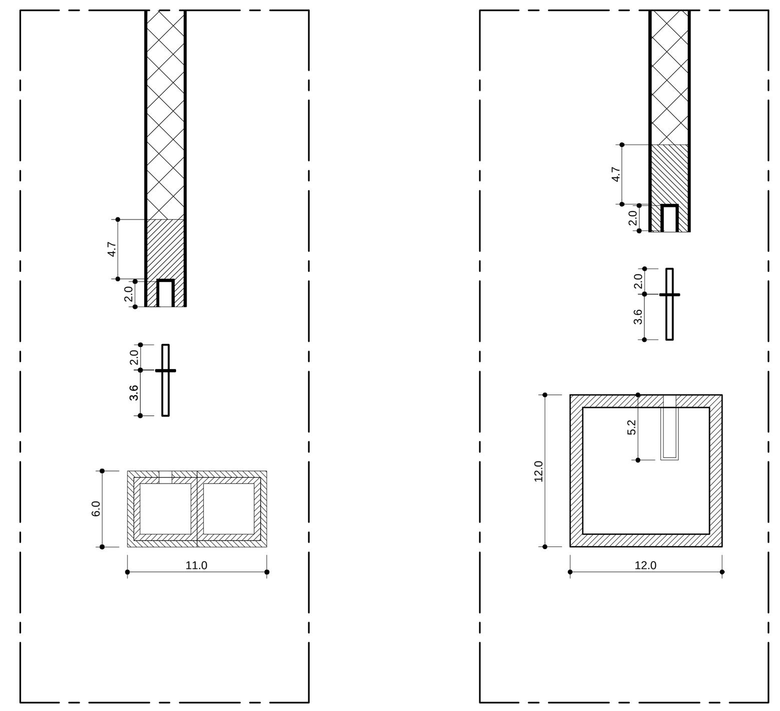
Dt 04, 1/5





Dt 16, 1/5

esquema encaixes Dt 06
sobre SHS50 e SHS 120, 1/5



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PROJECT:	Clickhouse: Architectural development of a transitional shelter in advanced composite materials	SCALE:	1/5
DRAWING:	Details of elevation panels, door panels and partition panels		
AUTHOR:	António Barreiros Ferreira, Joana Ginjeira do Nascimento	DATE:	June 2015

SHEET: 07