PALESTINE
SHELTER CLUSTER
Coordinating Humanitarian Shelter and Settlements

Stand-alone transitional solutions standards for new construction in Gaza

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Introduction

The Stand-Alone Transitional Solutions Standards for New Construction in Gaza have been developed to provide clear, context-specific guidance on the design and implementation of transitional shelters. These standards consider a range of shelter solutions with varying structural designs, cladding, roofing, and flooring options, including both single and double-storey configurations. Given the protracted nature of displacement in Gaza and the urgent need for adequate housing, these solutions are designed to be durable, adaptable, and responsive to the needs of affected populations.

The development of this document was led by Catholic Relief Services (CRS) in collaboration with the Shelter Cluster Palestine Transitional Solutions Technical Working Group (TSA TWG) and global shelter experts, these standards align with international best practices while being tailored to Gaza's unique environmental, social, and infrastructural constraints. The document provides detailed specifications on key shelter performance requirements, including living space, privacy, thermal insulation, ventilation, structural integrity, fire safety, electricity, sanitation, and water supply. It aims to ensure that transitional shelters not only provide immediate protection but also offer dignified, safe, and sustainable living conditions over an extended period.

These standards should be used in conjunction with the accompanying tipsheet on the establishment of new sites (Annex 1), which offers practical guidance on site selection, planning, and implementation. Additionally, Annex 2 presents a report by the University of Bath, providing context-specific recommendations for optimizing thermal comfort and ventilation in Gaza. Annex 3, developed by the subject matter expert organization Kindling, delivers essential fire safety guidance for transitional shelters. By adhering to these guidelines, humanitarian actors can enhance the quality and effectiveness of transitional shelter interventions, ultimately improving the living conditions and resilience of displaced communities in Gaza.

Credits

Development and coordination of Transitional Shelter Standards: CRS, Shelter Cluster
Annex 1 Site Considerations: Site Management Working Group, Wash Cluster, Protection Cluster and Shelter Cluster
Annex 2 Thermal Insulation and Ventilation: Prof David Coley, Dept. of Architecture and Civil Engineering, University of Bath UK
Annex 3 Fire Safety: Kindling

Transitional Solutions Standards

Stand-alone transitional solutions standards for new construction in Gaza

This includes a range of transitional solutions with different structures, featuring different types of cladding, roofing and flooring, and may include one or two- storey shelters. The standards have been adapted to Gaza's context in consultation with TSA TWG and global experts.

This document outlines shelter standards and should be read alongside the tipsheet on establishment of new sites (Annex 1).

Standard	Performance requirement	Rationale	Considerations
Living space	• Minimum 3.5 sq.m per person, excluding cooking space, bathing area and sanitation facility. • 5.0 sq.m per person where internal cooking space and bathing and/or sanitation facilities are included • Internal floor-to-ceiling height of at least 2.2 m at the lowest point	Performance requirement based on Sphere living space standard. If applied to an average HH of 6 people: • 21 sq.m excluding cooking space, bathing area and sanitation facility • 30 sq.m including cooking space, bathing area and sanitation facility **The total living space should be proportionate to the HH size.**	• Ensure that living space is accessible for people with disabilities. • The dimensions of the shelters should be adapted to the size of the households. If a standard model is insufficient for the size of the family, the basic shelter should be complemented by adding extra modules or expansions. • Small initial modules allow for more flexibility in adapting to small families with the possibility of scaling up if necessary. • Ensure sufficient open space around the shelters to allow for expansion and provide private outdoor areas.
Privacy	• At least 1 internal partition	Sphere cultural practices, safety and privacy: **Respect existing practices and customs and how these affect the design of the dwelling.**	• The design must allow for the installation of internal partitions, whether fixed or movable, or other alternative methods to ensure privacy. • Ensure privacy for windows (whether transparent or translucent options are preferred) • The number of partitions should be proportional to the HH size, for large HH, more partitions can be required.

Standard	Performance requirement	Rationale	Considerations
Thermal insulation and shading	• U-values of 0.72W/m2K for walls, roof and floor • U- values of 2W/m2K for doors and windows • Summer window shading above the window hinged so it can be flipped up in winter. Minimum half the height of the window and 10cm wider than the window on each side. 1.	In summer, overheating in Gaza during the daytime is likely with temperatures of 35 °C inside the dwelling, which would represent a health issue, so active cooling is needed e,g, fans, evaporative coolers etc.	• Non-combustible insulation materials are strongly advised (mineral/rock wool type materials) • No glazing on the roof. • Shading the roof (light structure on top of the roof in summertime) prevents heat from sunlight from heating the roof, and therefore prevents additional heat transfer into the living space • Consider adding an additional shelter element which can be attached to the outside of the unit to provide shaded external space. • Consider critical winterization needs of vulnerable members to improve thermal comfort of the shelter through provision of safe heating and essential NFIs.
Ventilation	• The dwelling must have a minimum ventilation rate of 10 ac/hr which can be achieved with 2 windows 60cm x 60cm or a pair of other equivalent holes on opposite walls or diagonal in each room. • Fan or other active cooling device (1 per room).	Need for cross-ventilation through openings and active cooling (fans) are necessary.	• For proper ventilation, each room needs two windows on opposite walls. • Having additional, easily closable vents at a high level (30x15 cm) that can be closed from the inside improves ventilation. • All openings must be easily closable and openable. • Provide security bars for windows • A security screen on the external door allows it to remain open for better ventilation. • If cooking inside the dwelling, a chimney is recommended when burning biomass.
Lifespan	• Minimum 5 years with basic maintenance	Transitional solutions typically have a lifespan of 3 to 5 years, usually until more permanent solutions can be implemented. However, in the context of Gaza transitional shelters are foreseen to be used for much longer than their intended lifespan, beyond 5 years.	Roof, walls, structure materials: • Corrosion protection for steel elements through galvanization or anti-corrosive paint • Resistance to moisture and mold accumulation using materials that naturally resist moisture or applying hygroscopic treatments • Operable glass or alternative to glass such as PET windows with screen to protect from mosquitoes

Standard	Performance requirement	Rationale	Considerations
		The basic maintenance consists of cleaning the roofs, unblocking the drains, cleaning the ventilation filters, maintenance of sanitation facilities, etc.	• Lockable doors made from durable materials • Flooring should be raised from the ground and easy to maintain. • Roofing should protect households from rain and be well secured to prevent uplift of roof. • The shelters must be installed on a level surface and have a foundation appropriate to the terrain type and the loads they will bear, particularly in stacked configurations. For lightweight structures (such as those made of wood, sandwich panels, plywood, tarps or OSB), special attention must be given to anchoring to prevent wind uplift. • The shelter (foundation, superstructure, cladding and roofing) needs to resist the wind load commonly found in Gaza.
Fire safety	• If prefabricated: Shelter materials and systems of materials should be tested in accordance with ISO EN 13823, and it is strongly advised they should achieve a classification of B-s1-d0 at minimum. • If locally constructed: Shelter materials, particularly the wall and roof facades, should be non-combustible where possible. • If using combustible materials, more attention should be paid to other shelter/settlement factors that contribute to fire growth and fire spread, such as increasing separation distances between shelters.	Using fire-resistant insulation and cladding materials can help to reduce the spread of fire within a shelter, and from one shelter to another. Additionally, the propensity of a material to produce high volumes of smoke and/or burning droplets presents direct hazards to occupants which can cause significant harm. Maximize separation distances to reduce the risk of fire spread (every 10cm counts). At least **3m separation distance is needed to prevent fire spread**. **Larger separation distances** should be considered when the shelters have combustible outer materials, low-quality non-combustible façades, doors or windows opening into	• It is strongly recommended that at minimum two exit doors are provided to give occupants a choice on direction of travel to escape a fire. • Internal door lock mechanisms should be easy to operate, e.g. thumb locks and sliding bolt locks are preferrable to padlocks and key locks which can be difficult to open in stressful or hazardous conditions. • Chimneys should be a non-combustible material with low thermal conductivity. If the roof is combustible, the penetration for the chimney should be surrounded by non-combustible material to avoid direct contact.

Standard	Performance requirement	Rationale	Considerations
		shared spaces, multiple stories, or are in areas with frequent high winds.	
Electricity	• The electrical installation will be based on the specific electrical loads required, such as cooking, heating, cooling, lighting, and power needs. Estimated HH electricity consumption (5kWh/day) • Ensure electrical systems are properly protected and earthed.	Compliance with local standards	Regular maintenance checks Connection to solar panels in the roof with battery or connection to an electricity grid.
Sanitation facilities	• Each HH has access to sanitation facilities that are in proper operating condition, have privacy, and are adequate for personal cleanliness and the disposal of human waste. • If HH-level sanitation facilities are not possible, provide separate facilities for men and women that ensure safety, privacy and dignity within 50m from the dwelling min 1 for 20 people • Each sanitation facility should include the installation of hand washing facilities	• Sphere standards for non-emergency context. • What is adequate, appropriate and acceptable? The type of WASH facilities adopted will depend on preferences of the intended users, existing infrastructure, the availability of water for flushing and water seals, the soil formation and the availability of construction materials. • For additional technical considerations, please refer to the WASH cluster	• Consult with the users, particularly women, girls and persons with disabilities, to decide the location, design and safety of facilities. • Consider access to hot water for bathing and laundry during specific contexts and during climatic variations. • In Gaza people are likely to improve privacy by assigning each toilet in a communal block to a specific HH. Toilets will need to either have an individual pit which is regularly dislodged; connect to septic tanks with a soak pit; connect to communal holding tanks which are regularly dislodged; or connected to a piped sewer network which discharges preferably to a wastewater treatment system
Water supply	• A protected source within 500m of the shelter, through communal tapstands, supplied by water trucking given the lack of suitable groundwater. To reduce the distance, water networks can be installed with additional tapstands or even HH water connections. To manage the intermittent	• Sphere standards for non-emergency context • Water quality should be ensured and monitored in accordance with WHO and national standards for potable water	

Standard	Performance requirement	Rationale	Considerations
	supply of water, HH water tanks will also be required. Quantity required for emergency context is minimum 15L/p/d but to avoid significant health issues this will need to be increased.	• The actual figure of quantity will need to be agreed with the relevant stakeholders because the cost of water may be high.	

Annex 1: Site Considerations

A TIP SHEET FOR THINGS TO CONSIDER BY PEOPLE PLANNING TEMPORARY SITES IN GAZA

The following document is for use by people returning to their neighborhood or displacement sites, for NGO and Civil Society Supporting them and for Municipal staff and utilities. If additional support on this is required, please contact madeline.green-armytage@acted.org to mobilise technical site planning capacity.

Context: Following 15 months of displacement, the massive scale destruction of residential and urban areas and the recent ceasefire, there is a large volume of people returning to, or near to, their place of origin. Many of these returnees will need to build temporary accommodation in a vacant piece of land. The following tip sheet is intended to advise them on the broad steps to follow in planning the site.

The document is based on 3 broad areas, Planning, Ground Assessment and Site setup, with 19 areas of consideration. The document is not comprehensive guidance, but a starting point.

1. PLANNING		
1.1	Land Ownership	▪ Who owns the land? ▪ Have they provided permission for land use? ▪ What constraints have they provided eg length of use, number of structures, number of people, others?
1.2	Returnees and displaced people	▪ Who are the people planning to live in the site? ▪ How many are there? What is their demographic? ▪ Is there a recognized leadership? ▪ Are they related? ▪ Are there any special needs e.g. elderly, disabled, single parent families, unaccompanied children?
1.3	Skills and Capacities	▪ In the planning team are the right stakeholders engaged to plan a site? They may come from municipal or civil society ➢ Site Management; site planners, civil engineer ➢ Water and sanitation engineers ➢ Shelter expert ➢ Protection specialist If these capacities are not available in your team, please contact madeline.green-armytage@acted.org to mobilise support.
1.4	Community consultation	Have the affected community and surrounding communities been consulted and their views and aspirations taken into consideration in the choice of shelter types

2. GROUND ASSESSMENT		
2.1	Explosive Threats	▪ Ensure the site has been assessed for any explosive threats Link here: https://survey123.arcgis.com/share/67798e9198924e719015bd2e9a548fa2?portalUrl=https://ims.unmas.org/portal

2.2	Access to Site	▪ Access to site is possible by foot/vehicle/heavy equipment? If access is limited, then what is the limitation? ▪ Sizing 30m2 per capita provides optimal maximum population including shared space
2.3	Site Perimeter	▪ Review the perimeter of site – is it clear of obstacles or hazards? Is it secure or open? ▪ Review the next-door land spaces for potential issues? ▪ Estimate the total livable land size (m^2) – *30m^2 per person is an indicator for number of people*
2.4	Site Clearance	▪ Is there debris on the site? How much? ▪ Is there solid waste on the site? How much ▪
2.5	Site Interior	▪ Is the land flat or sloped or hilly? ▪ Is there a low sump likely to flood? Could flood water come in? Could it get out? ▪ What site earthworks would be necessary to make the site livable – levelling, raising land
2.6	Site Services	▪ Identify the location of potential site services, particularly water mains, sewage networks, storm drainage; source of electricity

3.	**SITE SETUP**	
3.1	Perimeter Layout	▪ Sketch out the perimeter and note down any work that needs to be done and materials needed
3.2	Site Vehicle Access	▪ Depending on the size of the site it may be necessary to have a road around the perimeter ▪ It might be necessary to have roads and paths on the interior. Especially if there will be services in the center of the site requiring vehicle access
3.3	Site Drainage	▪ The principal drains need to head to the lowest point with exit for flood water ▪ Secondary smaller drains lead to the principal drain ▪ Smallest drains connect to the secondary or primary ▪ Where possible have drains follow beside roads and paths ▪ Plan culverts where drains crossroads or pathways
3.4	Shared Community Spaces	▪ Discuss with the planned population to identify the critical shared space needs of the site. Everyone is different and may have competing priorities ▪ Common needs: Children friendly space, meeting space, common kitchen areas, health post, protection post 2.
3.5	Equitable Services Spaces	▪ Agreed place for solid waste collection, may include separation of waste for recycling and disposal ▪ Agreed space for communal water points (this needs to be done in consultation with the residents of the site) ▪ Agreed space for latrines and showers. Note that people prefer to have 'their' latrine/shower near their tent. If it is shared, then it is shared with family or family friends. ▪ Agreed on the provision of sanitation services, whether on-site or off-site. If there are on-site services, ensure that they can be decommissioned.
3.6	Source of energy	▪ Agreed on the provision of sources of energy, location and infrastructures
3.7	Safety Measures	▪ Plan to have breaks between tents and shelters to act as fire breaks

		▪ Ensure common services and routes to them visible and if possible lit at night ▪ Ensure access routes has rumps for people with disabilities
3.8	Living Space	▪ Once roads, drains, shared space, services space and safety measures have been planned for the remaining land is what is left for living space! ▪ Family tents/shelters/rooms are large enough to accommodate every member of the family with sleeping and living space for adults and children/separation of different age and gender group within the family ▪ Is there room within the family space to accommodate unique family needs/adjustments ▪ Allocated plots have space for family extension/extended family unique needs
3.9	Management	▪ It is advisable to agree with the residents how all the services and living space will be collectively managed eg drain clearance, road/path maintenance, solid waste site. ▪ Consider any rules or agreement on how people can access services ▪ The site has an information kiosk or other CwC material in place for disseminating messages to the communities (e.g. information boards ▪ PSEAH elements are stated and taken into consideration in any site set up in compliance with humanitarian principles

Annex 2: Thermal comfort and ventilation

A Transitional Shelter for Gaza

David Coley and Dima Albadra

v2025.03.04

This report looks at the likely thermal conditions inside a transitional shelter in Gaza and the improvements from various design options. The work was completed for The Palestine Shelter Cluster (a grouping of the major aid agencies) to help obtain an architectural design specification for 60,000 shelters to be rapidly delivered into Gaza under the ceasefire agreement of January 2025.

Five software tools written by Bath University were used (all tools are free, and can be downloaded from zebra-model.org. There were designed to be used by non-experts):

1. Zebra-OC. This was used to look at the average monthly external conditions, then the average monthly internal including overheating and energy use if cooling and/or heating were specified. And finally to look at the impact of insulation, shading and ventilation rate.
2. Zebra-Uvalue. Used to find the U-values of the various design options.
3. Zebra-Ventilation. Used to find the size of openings needed to provide the ventilation rate suggested by zebra-OC.
4. ShelTherm. Used to look at the likely internal temperatures on hot summer days and cold winter days and how well a design moderates the external conditions.
5. The Shelter Assessment Matrix. Presented as a way to look at both the physical and cultural elements of the location and the way a potential design addresses them.

For ease and speed of use, we present our recommendations in red text.

The building is assumed to be just a box in a very exposed (sun-wise) position. Dimensions = 6 x 3 x 2.4 (high) m. However, it is noteworthy that the dimensions do little to impact the results. One internal partition has been assumed, **and hence ventilation needs to be provided separately to each room either side of the partition**.

The building is assumed to be either free running (no cooling or heating), or with conditioning. In both cases the preferred temperatures (the set points) are those from adaptive comfort theory. This theory gives different preferred internal temperatures at different times of year. They are found to be far less constrained than we might use in an office, or a home in an ordinary situation. However, given the occupant group, our research suggests they will be even more flexible.

1. Zebra-OC: The monthly situation

The external climate

Loading in the latitude and longitude (and correcting for the altitude of Gaza compared to the nearest weather station) we see the average monthly external temperatures (grey bars) and the assumed adaptive comfort range (blue and orange curves; from ANSI/ASHRAE - 55, 2020). Within this range it is assumed people will be comfortable in this climate. One can see that the temperatures at which people are comfortable change throughout the year.

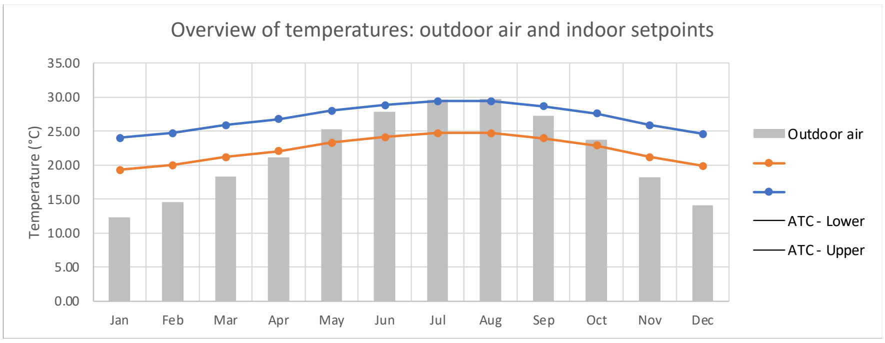


Figure 1. The external climate and the Adaptive Thermal Comfort (ATC) range (from zebra-oc).

The temperatures in the hottest months suggest that although hot, if we can make it no worse inside than out, indoor conditions should be comfortable, on average. We also see that although not warm, even in winter it is not seriously cold. One potential problem with using monthly means is that if the diurnal cycle (the difference between daytime and nighttime temperatures) is large, then the mean is less good a guide to the experience of the occupants. Later we will use ShelTherm to look at the situation hour-by-hour over a summer and winter day.

Looking at the solar data from zebra-oc (Figure 2) We see the main solar gain in summer will be on the horizontal (i.e. the roof). Therefore, our next conclusion is: **no glazing on the roof**. Probably obvious, but we have all seen strange design decisions in these settings. We also see that it would be worth considering/modelling roof insulation, which we do below.

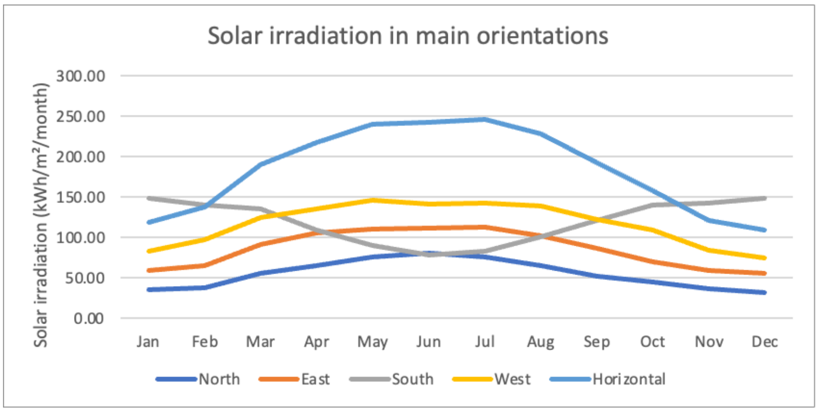


Figure 2. Site insolation.

The Base Shelter

We initially assume either a plywood box, or a profile steel box (6 x 3 x 2.4 (high) m), just to give a base line about how difficult conditions could be for occupants if care is not taken over the design. Zebra-Uvalue was used to calculate U-values for the roof walls and floor, assuming 22 mm ply, or 0.7 mm of steel. Note, due to the orientation of the materials, the wall and roof U-values are not quite identical, despite them using the same material. The results and additional assumptions are given in Table 1. Some variables and results are expressed in units of per m^2 (TFA). TFA is the treated floor area, i.e. the internal floor area of the building.

Table 1. Initial assumptions and calculated U-values.

Element	**Ply solution**	**Metal solution**
Orientation	One long side facing south, the other north	
Glazing U-value	5 W/m²K i.e. single pane of glass	
Floor U-value. (Floor assumed not in ground contact; if an uninsulated floor was in ground contact it would reduce the need for heating and cooling. Once insulated, the impact is far smaller)	2.95 W/m²K	4.76 W/m²K
Wall U-value	3.34 W/m²K	5.88 W/m²K
Roof U-value	3.71 W/m²K	7.14 W/m²K
Glazing	2m² of glazing on the south side. (This leads to 1.36m² of glass, due to the frames.)	
Infiltration	10ac/hr at 50Pa, similar to a poorly built house in UK	
Ventilation	30m³hr/person i.e. that required for very good air quality in winter and 10ac/hr in summer	
Shading walls (the face of the sky the wall can "see")	0.25 (quite exposed)	
Shading roof	0	
Shading window	0.25 (quite exposed)	
Window form	simple (style h in zebra-oc)	
Window shading	0.25 (quite exposed)	
Incidental gains	0.5W/m², i.e. half of UK norm.	
Average number of occupants over the day	3. This is the 24-hour average.	
Thermal bridging	15.84W/K (as calculated by zebra-oc)	
Thermal mass	Low, 10 Wh/Km² (TFA)	

Looking at the stripped cells in the bar charts (Figure 3), the heating demand is seen to be considerable (Ply = 216kW/m² per annum, twice that per m² (TFA) of a traditional UK house; Steel = 364 kWh/m², three times per m² (TFA) that of a traditional UK house) and hence we conclude:

- **Under no circumstances should an uninsulated steel solution be used. We also have deep concerns that the internal surface temperatures of exposed steel might be high enough to burn children's skin and be above the adult pain threshold after 20 seconds. This is what we found in Azraq, Jordan.**
- **We also see that the thermal bridges are not really an issue so don't worry about that from an overheating or energy demand angle, but consider possible issues with condensation if metal window, door or frame elements used and provide ventilation to deal with this.**
- **the heat losses from the roof and walls are the major source of losses, suggesting insulation of these elements should be a priority.**

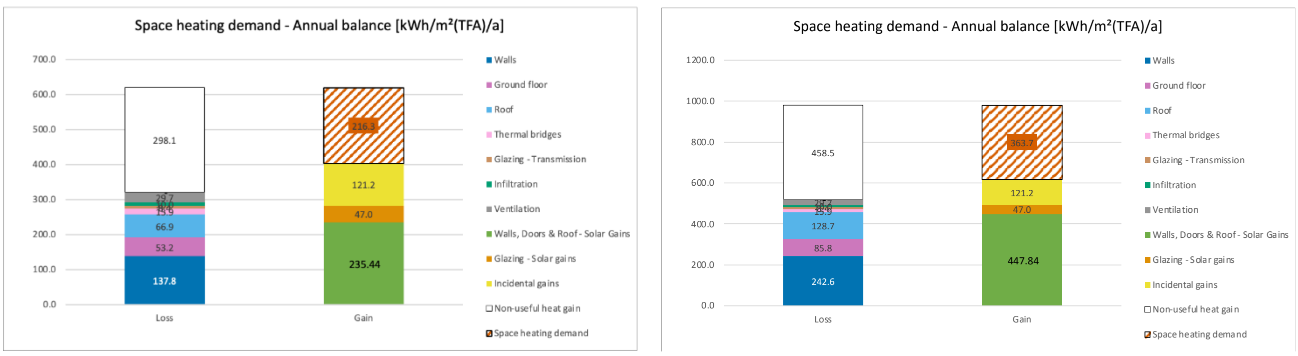


Figure 3: Heating demand. Ply (left); steel (right).

The cooling demand is also large (Ply = 151 kW/m^2 per annum; Steel = 242 kW/m^2).

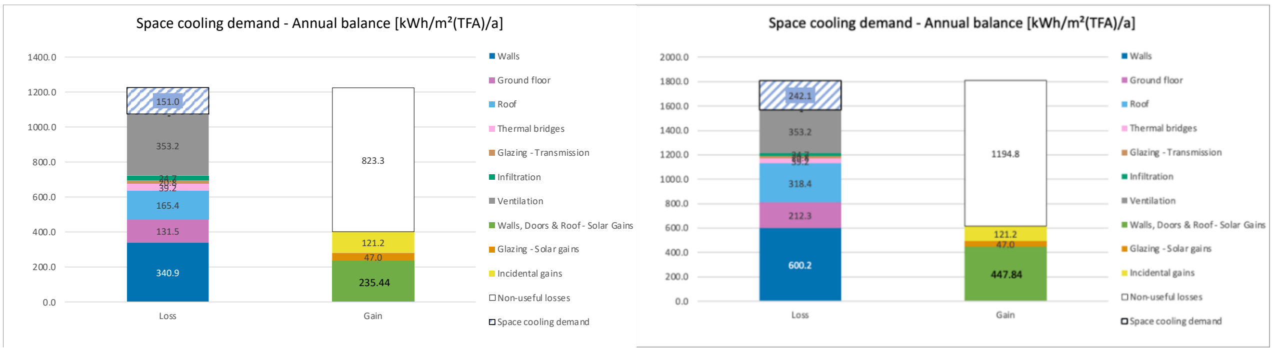


Figure 4: Cooling demand. Ply (left); steel (right).

Note, in these calculations we are not saying the homes have heating or cooling, just that we quantify the scale of the need, which might well be unmet, and hence conclude:

- **If the buildings are uninsulated and unconditioned, the internal temperatures will be far from acceptable to the occupants and might pose a risk with respect to morbidity and mortality.**

If heating and cooling systems are fitted, zebra-oc gives the consumptions shown in Table 2

Table 2. Conditioning energy consumption. The coefficient of performance for heating has been set at 1 and that for cooling 2.5. The cost of electricity that of the UK and in British £. It is unknown what the cost might be in GAZA.

Solution	Heating, kWh/m^2 (TFA) per annum	Cooling, kWh/m^2 (TFA) per annum	Cost to occupants, based on £0.25 per kWh and a TFA of 18m^2
Ply	216	60	£1242
Steel	364	97	£2075

Hence we conclude:

Solving the problem with the internal temperatures via the provision of heating and cooling systems without first insulating the buildings is probably unsustainable.

Design 2, insulate walls roof and walls

We consider either one cm or five cm of EPS insulation sandwiched between two steel sheets (Table 3). Two and ten cm of mineral wool would have much the same impact. If ply was used not steel, the energy consumptions predicted would be slightly lower.

Table 3. U-values (W/m^{2}K) used when modelling two depths of insulation

	1 cm EPS	5 cm EPS
Roof	2.39	0.65
Walls	2.23	0.64
Floor	2.05	0.63

The impact on heating and cooling demand is shown in Figure 5.

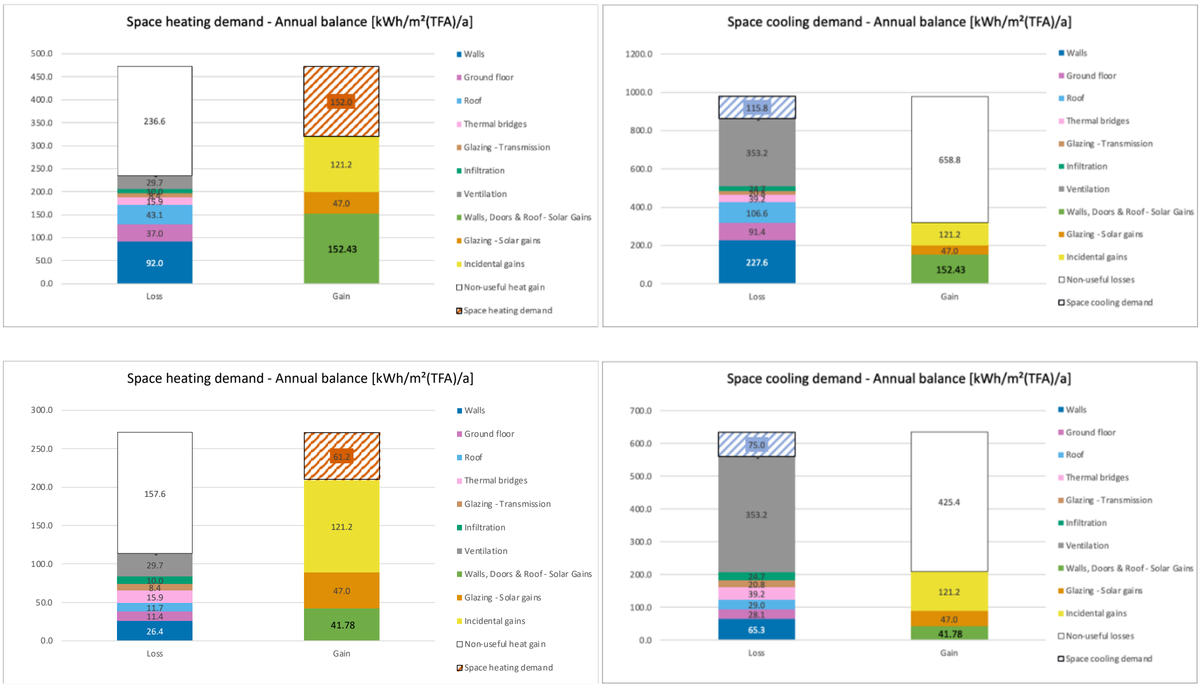


Figure 5. Insulated heating and cooling demand (top 1 cm of EPS, bottom 5 cm).

We see that compared to the original steel solution, 1 cm of insulation gives a 58% reduction in heating demand and a 52% reduction in cooling demand. Compared to the original steel solution, 5cm of insulation gives a 83% reduction in heating demand and a 69% reduction in cooling demand.

With respect to energy consumptions for heating and cooling (at £0.25 per kWh), 1cm of insulation equates to 3,571 kWh per annum or £893 and 5cm to 1,681 kWh per annum or £420.

Hence we conclude:

- **By using a small depth of insulation (1 cm) we can get a similar performance out of a steel shelter as an uninsulated ply one (care would be needed not to compress the insulation at any point as this would cause localized high temperatures in summer and condensation in winter). However this is still a poor level of performance.**
- **Although any depth of insulation is useful, to have a major impact, 5 cm of EPS or anything that gave a U-value of very approximately 0.65 W/m²K would be sensible if conditions are to be kept reasonable and, if conditioning is to be supplied at a future date, energy use and cost sustainable.**

We now tackle the solar gains in summer through the window.

Summer window shading

A simple way of doing this would be a solar shade above the window. For example a simple hinged horizontal element that can be deployed in summer and not in winter. Most of the impact could be achieved with a shade that extends 10 cm either side of the window and is approximately half the height of the window. A brise-soleil solution would also be possible, but not vertical screens.

We will only consider the design with 5 cm of EPS insulation. We assume the shade cuts out all direct sunlight falling on the window.

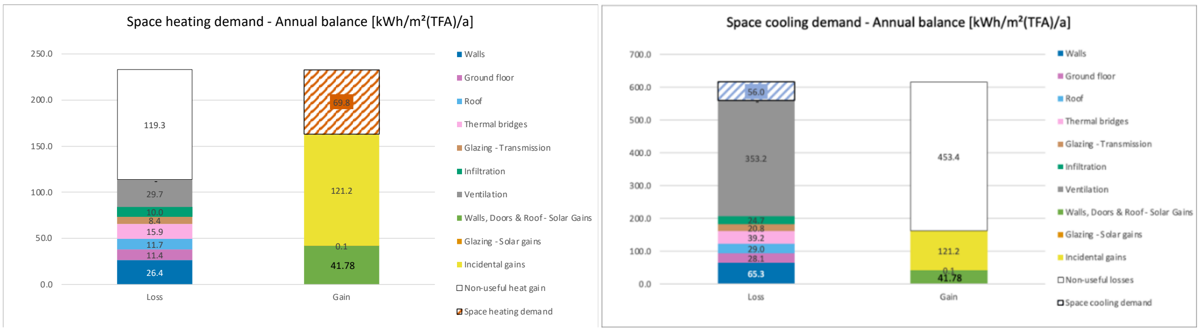


Figure 6. The impact of shading the windows.

We still have a cooling demand, but it is smaller. Heating energy demand has increased very slightly because of the loss of solar gains in winter. Hence we conclude:

All windows that might face the sun should have a solar shade designed so it can be deployed in summer and not in winter.

Impact of reduced air flow

Given our experience in other settings, we have deep concerns over what happens inside the shelter if ventilation is restricted by the occupants. Reasons for this reduction might include: sand ingress, security concerns, blocking of windows so anyone outside the shelter cannot see inside.

Modelling the design with 5cm of EPS insulation we find cooling demand rises by 40% if only infiltration occurs, i.e. the occupants have blocked or not used the ventilation. On top of this, the overheating rises from 8,200 kelvin-hours to 12,300 kelvin-hours.

One kelvin hour of overheating means the building is 1 kelvin (1 °C) above the set point (in this case the thermal comfort band) for one hour in the year. Or 2 kelvin over for half an hour, or 0.5 kelvin over for 2 hours. Or any such combination.

For the predictions for the shelter it is hard to get one's head around the scale of overheating, but we can get an idea by assuming the overheating only occurs during the day time (12 hours) and during 3 months. This gives us 3 x 31 x 12 = 1,116 hours for the overheating to occur in.

8200/1116 = 7.3 °C of overheating, during summer days. If the airflow is restricted this increases to 12300/1116 = 11 °C. This is a worry. As the adaptive thermal comfort upper temperature in the summer is about 29degC, this means we could easily see temperatures of 40 °C in the shelters if airflow were restricted. However, even with good airflow there is a clear health issue if cooling can not be supplied.

So we conclude:

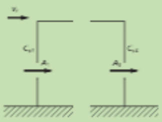
- **Even with high levels of insulation, and ventilation pathways not blocked by occupants, we could see dangerous temperatures and the supply of cooling if possible (PV on roof?) is therefore desirable.**
- **At a minimum fans must be provided.**
- **It is critical that some way of providing air flow to the buildings is considered. We suggest a conversation with the potential occupants.**
- **Shaded external areas should be provided for use if the shelter temperatures become unbearable.**

Ventilation

We now look at opening areas. This is done via zebra-ventilation.

If we assume 0.7 m^2 of opening on each side of the space and a wind speed of 1 m/s (a low value) we get:

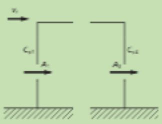
4a. Wind driven cross ventilation



Total open area of façade 1, A_1 m^2	0.7
Total open area of facade 2, A_2 m^2	0.7
V_r, wind speed, m/s	1.00
Δ_{Cp}	0.50
A_w, m^2	0.49
Q_w, flow rate, m^3/s	0.21
Qw, flow rate, ac/hr	17.79

In the above we assumed a need for 10 ac/hr, the above shows 17.79 ac/hr. Hence, we can reduce the opening size. We select 0.4 m^2 on each side of the building, diagonally across the building would be fine too:

4a. Wind driven cross ventilation



Total open area of façade 1, A_1 m^2	0.4
Total open area of facade 2, A_2 m^2	0.4
V_r, wind speed, m/s	1.00
Δ_{Cp}	0.50
A_w, m^2	0.28
Q_w, flow rate, m^3/s	0.12
Qw, flow rate, ac/hr	10.17

We have 10.17 ac/hr, so that looks fine. The square root of 0.40 is 0.63, **so we need an opening of about 60 cm x 60 cm on each major side of the building (two openings in total); or of side 45cm on two sides of each room (four openings in total). Or a pair of other equivalent holes (vents), or multiple openings adding to 0.4 m^2 on each side of the building.** Now, the door(s) might be able to play much of this role if security is less of an issue during the day. However, we see why the Azraq shelters were going to massively overheat (small vents on gables, doors closed for security). **This, we think, is the major problem in Gaza – the provision of ventilation if no active cooling**. (We have assumed no one is burning biomass in the building – if they were, this would need some form of chimney).

The following sketches show how ventilation might be provided. In one the design relies on opening windows, in the other vents. The latter allows the windows to be kept close for security reasons. In each case the total opening area each needs to be around 0.4 m^2 per room, or more. Providing vents can address privacy issues – however, each room should have at least one window to avoid prison-like conditions.

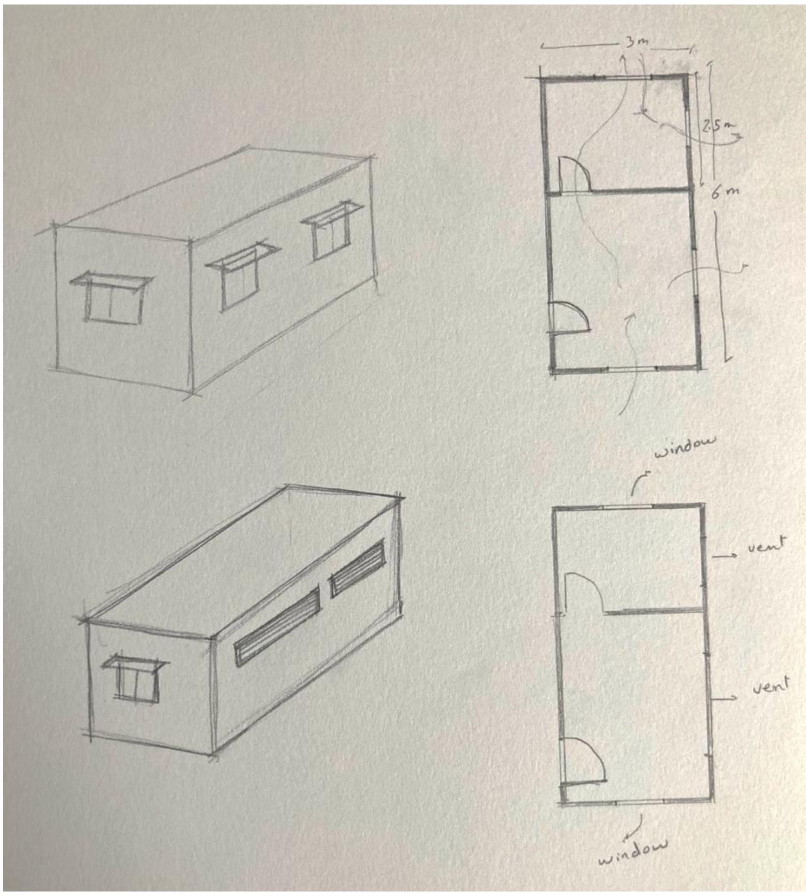


Figure 7. Possible window and vent layout.

2. Use of ShelTherm

ShelTherm was specifically developed by Bath University for the humanitarian sector. Unlike zebra-oc it looks not at the mean situation over a month or year, but hour-by-hour during a single day in summer and a day in winter. It also accounts better for the exact build-up of elements (not just their U-value) and their thermal mass (how well they store heat). The best way to think about ShelTherm results is to look at the graphs and ask, are the conditions inside the shelter better or worse than the outside? The logic being that any reasonable shelter should moderate the external environment in a way that is beneficial to occupants.

We model both the uninsulated steel shelter and the one with 5 cm of EPS insulation. We assume the specific heat capacity of EPS is 1,300 J/kg and of steel 420 J/kg; and the density of EPS is 20 kg/m^3 and that of steel 7,850 kg/m^3.

This modelling was done using the nearest weather station which is at 400 m^2 above sea level. Much of Gaza is around sea level. Although zebra-OC adjusts the weather data for this, ShelTherm unfortunately does not. The reduction in temperature with altitude is most commonly represented by the environmental lapse rate (0.6 degC per 100m). Hence the red and blue lines shown in Figure 8 and 9, should be elevated by 0.6 x 4 = 2.4 deg. This gives a maximum internal temperature of 34.5 °C degC during typical summer days in the insulated shelter (note: this is the commonly achieved maximum, very hot days or heatwaves will cause higher temperatures). **This is clearly outside the comfort range, but the results show that conditions inside the shelter should be no worse than those outside**, and probably better. In part, because they will be protected from direct sunlight. This sunlight might make the temperature feel like 49 °C on days when the air temperature only 35 °C. Thus, if the temperature inside the shelter is 32 °C on such a day it will feel 17 °C cooler inside than out.

Being number free, this simple (ShelTherm) way of expressing the conditions we feel is of use to those working in country, as they will have personal knowledge of the summer and winter external temperatures, and hence can reflect on any implications of this conclusion. During typical winter days we are close to thermal comfort, and the conditions might not be considered extreme in the context of displaced persons or camps. And are a lot better than tented accommodation.

For the shelter without insulation we see conditions are extremely tough in winter with internal conditions similar to those outside. In summer temperatures are higher than outside, and can exceed 45 °C (after adjustment is made for altitude). This could be fatal.

Hence once more we conclude that:

The shelters must contain insulation, and airflow needs to be provided in a way that occupants do not feel forced to undermine.

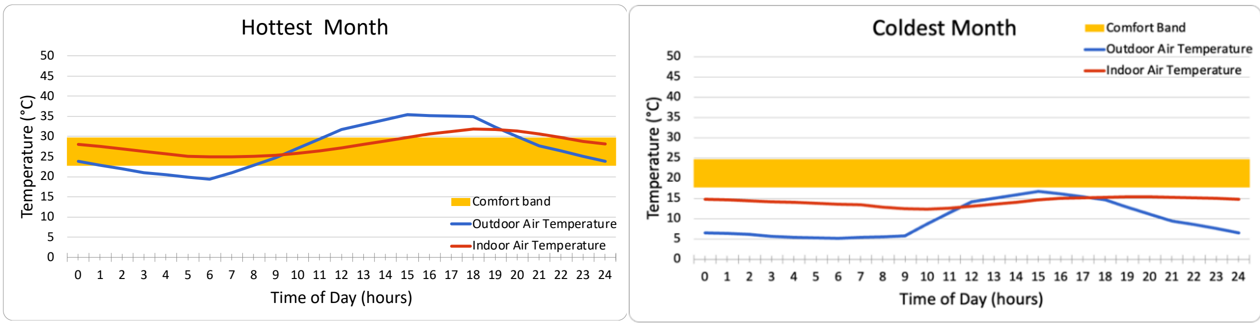


Figure 8. The insulated shelter over one day in summer and one in winter. From ShelTherm.

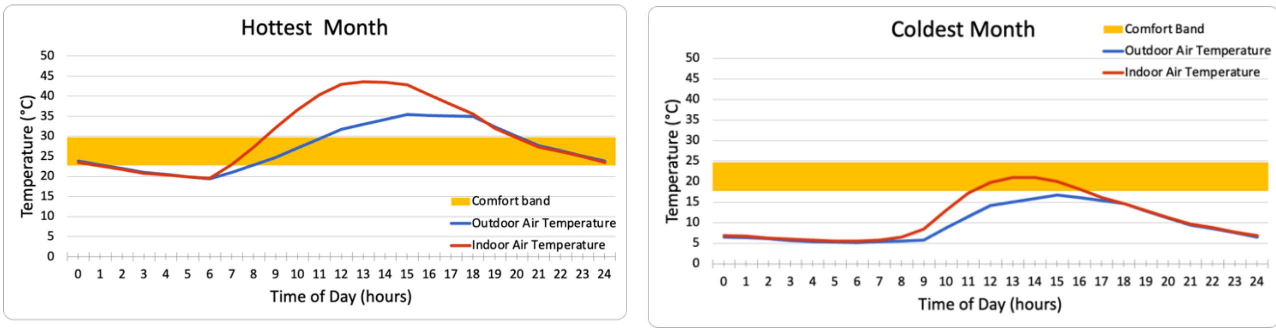


Figure 9. The uninsulated metal shelter over one day in summer and one in winter. From ShelTherm.

<u>Humidity</u>

An additional issue is humidity. Neither ShelTherm nor Zebra-OC directly accounts for humidity. It is well known that humid environments make thermal comfort more difficult to achieve. The monthly mean relative humidity ranges from 63% to 70% in Gaza, so whilst not dry, conditions should be such that normal sweating should provide heat loss via evaporation – particularly if electric fans can be provided. **We believe accounting for humidity is unlikely to change our basic conclusion: insulated, airtight dwellings with the potential for cross ventilation should be provided.**

3. Socio-cultural considerations

Socio-cultural considerations are important even when designing a shelter mainly to achieve thermal comfort. For example, a window might be blocked or walls tampered with in order to create a socially appropriate living space. In our work with Syrian refugees in Jordan (who share a Levantine Arab culture with Palestinians), and through participatory design workshops in many locations we've created shelter configurations that can address several sociocultural concerns and issues such as privacy vs ventilation, and have the following general comments.

3.

Site layout is particularly important to address privacy and ventilation. Therefore, avoiding an overlooked grid-like layout is advisable.

4.

Accommodation is more likely to be successful if designed so as to provide for and encourage agency and freedom to make adaptations as part of the process of home-making. **One key element we found in our research was the ability to move the shelter, post-construction.** This gave the chance to build extended family groupings and courtyards. Given this, when designing there is the need to reflect on whether any of the thermal comfort elements of the delivered design might undermined by this adaptation and home making.

We strongly recommend the use of participatory design, i.e. the involvement of the occupant group or a connected group, in the design. This can take many forms, and timeliness is always an issue, but at least asking for comment would seem sensible, if at all possible.

Amongst many findings from our work in Jordan, our participatory design workshops exposed the following strong feelings:

- An exterior somewhat private shaded space is desirable for social interactions, a safe play space for children, or simply a space to hang the laundry if it is culturally inappropriate to dry the laundry in a public space. From a thermal comfort perspective, it provides an alternative to the hot (or cold) confines of the shelter. Small water features and greenery was reported by almost every family as something that would improve their wellbeing
- Use of colours or drawings instead of plain white exterior walls. This makes camp settings less institutional and monotonous.
- Shelves (saves having to fix your own and tampering with the wall construction).
- Creative solutions for windows and other openings to solve the conflict between the equal needs for thermal comfort (ventilation), privacy and prevention of sand ingress.
- Each room must have one window, as otherwise people reported feeling 'like being in prison'.
- Acoustical privacy is important; a thin partition (e.g. fabric) is therefore inadequate.
- Avoid large logos: Some people that we spoke to complained about the omnipresence of UNHCR logos that do not allow them to forget that they are refugees.
- A minimum of at least two rooms.

Figure 10. The difference in the feeling of place if uniformly white shelters are used compared to a more colourful solution – we found the latter more preferred.

Figure 11. Examples of interior courtyard space. This is far easier for occupants to achieve if shelters are movable.

Figure 12. Examples of external spaces created by occupants. Such spaces often function as a reception space and lead to much better thermal comfort during hot summer days.

In the design workshops we found that smaller units allow for customisable configurations with each family provided with at least two. It allows for multi-family configurations, which was desirable from a safety, privacy and sharing resources angles. It also creates courtyards which provide that desired external green space.

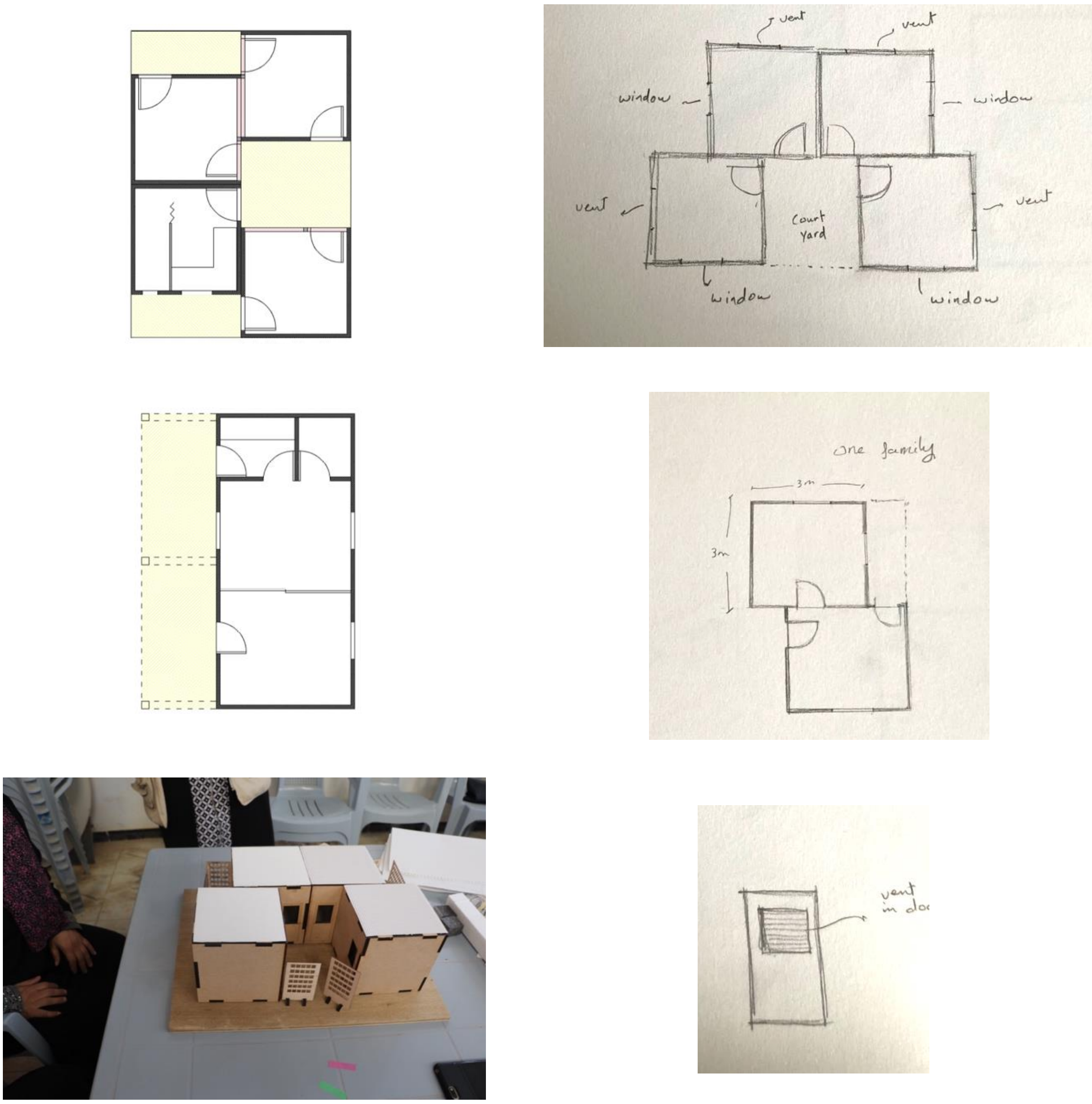


Figure 13. Some ideas from our participatory workshops.

4. Use of The Shelter Assessment Matrix (SAM)

SAM provides a formal auditable method for the assessment of a shelter, a shelter design, or the writing of architectural specifications, or the writing and scoring of tenders. SAM can be download for free from zebra-model.org (look for Humanitarian Tools on the main menu).

At its most simple, users can just reflect on the list of items it considers (Table 4) before designing or writing an architectural specification in order to check they haven’t forgotten to cover an issue. The tool itself will prove useful if designers or suppliers want to score a design in order to identify any potential issues before deployment. In addition, it can be used as the core of a post occupancy survey of deployed shelters.

Table 4. The nine major design criteria, the 34 related issues and 52 context specific sub-issues that form the basis of SAM.

Design criteria	Issue	Context specific Sub-issue (local knowledge often required)
Pre-construction	**Cost**	Low cost per shelter.
	Delivery	Ease of delivery and distribution to site of a shelter.
	Political & local acceptability	Appearance, materials and design consider potential political challenges/issues (e.g. in some contexts appearance of permanence due to the use of concrete block is politically unacceptable, as might shelter that is better than that experienced by the local population)?
Construction & Flexibility	**Ease of construction**	People and tools needed to construct one shelter?
	Speed of construction	Length of construction process.
		Construction in phases or stages useful.
	Adaptability	Ease of adaptation or customization a shelter.
		Hanging heavy items in a shelter.
		Installing shelves or other storage spaces in the shelter.
	Scalable	Scalability.
Lifetime & Maintenance	**Durability**	Life span of a shelter.
	Maintenance	Ease of repair/reconstruction.
	Cleaning	The walls.
		The floor.

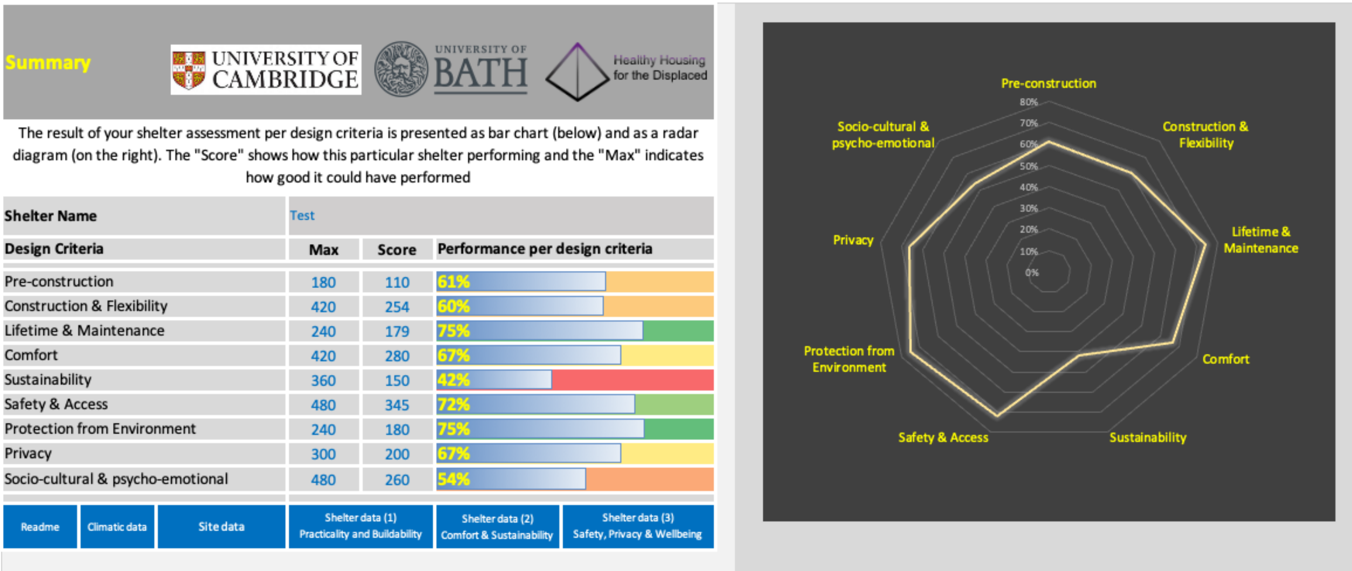
Design criteria	Issue	Context specific sub-issue (local knowledge often required)
Safety and access	**Security**	Break in through the **doors and windows** of the shelter.
		Break in through the **fabric/envelope** of the shelter?
	Disabled access	Provision of suitable ramps, low thresholds and minimum door widths.
	Fire resistance	Fire resistant, resistance against fire spread, fire protection.
	Evacuation	**Ease of egress** in emergency (e.g. to escape fire, earthquake or domestic violence).
	Natural hazards resistance	Resistance to **earthquake**.
		Resistance to **floods**.
		Resistance to strong **wind, typhoon and/or cyclone** etc.
Protection from environment	**Weather tightness**	Sufficient **weather proofing** (e.g. resistance to persistent rain).
	Insects	Mitigation against insects and/or vermin ingress/ attack/ swarming/termites.
	H&S (injury hazards)	Mitigation measures against **sharp edges**.
		Mitigation against **trip hazard**.
Privacy	**Acoustic attenuation**	Provision of good acoustic attenuation (privacy) e.g. i) from inside to outside shelter. ii) between adjoining shelters.
		Provision of good acoustic attenuation (privacy) e.g. between zones in the shelter.

	Visibility	Privacy of beneficiaries from **outside to inside** shelter (particularly visibility of women inside from men outside).
		Privacy of beneficiaries such as view(s) from **inside to outside** shelter.
		Privacy/**visibility** between zones within shelter.
Socio-cultural & psycho-emotional	**Cultural fit**	Cultural acceptability of those displaced (appearance, materials used, shape, zoning, robustness).
	External social space	Enabling residents to socialize outside the shelter, for example under a shaded area.
	Natural Environment	Enabling residents to pursue activities in the adjoining space to the shelter that promote connection to natural environment with psychological benefit (e.g. through creating small garden or space for animals).
	Social fit	Enabling beneficiaries to **conduct a social life according to residents' requirements** (e.g. receiving visitors, children's study).
		Separation of functions (cooking/sleeping/etc.)?
	Practical considerations	Practicality or comfortable in Ease of **moving in/around** in the shelter.
		Ease of sitting e.g. setting upright position against a wall.
		Provision of adequate **wet areas** e.g. cooking, toilet, clothes washing and bathing?

Design criteria	Issue	Context specific Sub-issue (local knowledge often required)
Comfort	**Air Quality**	Cooking fume extraction important.
		VOCs or other harmful compounds emitted from shelter.
		Ventilation strategy to control air quality/ prevent dampness, mould and lingering odours.
		Protection against dust or sand ingress.
	Daylighting	Design daylit? *(note link in column M to daylight calculator).*
	Thermal Performance	Mitigation against **diurnal/seasonal cold** (i.e. mitigation measures include: insulation/thermal mass/solar gains/ventilation/air tightness).
		Mitigation against **diurnal/seasonal heat** (i.e. mitigation measures include: insulation/thermal mass/shading/ventilation).
Sustainability	**Reusability**	The extent of reusability.
	Recyclability	The extent of recyclability.
	Environmental Impact	Embodied carbon & environmental impact: *Calculate/compare the environmental impact of your design using the online tool in cell O15. Then rate shelter accordingly.*
	Localness	Use of local materials.
	Rainwater harvesting	Rain water harvesting.
	Renewables	Solar power.

Applying SAM to a typical shelter generates results like those shown in Figure 14. We see the max possible score a shelter can have for each of the 9 design criteria, together with the score the shelter has achieved. This is presented: numerically, as a bar chart and a radar plot. These 9 top-level scores have been calculated based on the 52 context-specific scores inputted by the user. In turn these reflect a combination of how important each of the 52 sub-issues was seen in this context, how well the shelter design addresses each, and the quality of the evidence of this.

This particular shelter seems to do well with the exception of sustainability and possibly in the way it addresses the socio-cultural and psycho-emotional aspects.


Summary

The result of your shelter assessment per design criteria is presented as bar chart (below) and as a radar diagram (on the right). The "Score" shows how this particular shelter performing and the "Max" indicates how good it could have performed

Shelter Name	Test		
Design Criteria	**Max**	**Score**	**Performance per design criteria**
Pre-construction	180	110	61%
Construction & Flexibility	420	254	60%
Lifetime & Maintenance	240	179	75%
Comfort	420	280	67%
Sustainability	360	150	42%
Safety & Access	480	345	72%
Protection from Environment	240	180	75%
Privacy	300	200	67%
Socio-cultural & psycho-emotional	480	260	54%

Figure 14. SAM output for a shelter.

We recommend that:

The architectural specification for the shelters in Gaza is prepared after a quick reflection on the 52 context-specific issues shown in Table 4.

Designers or aid agencies reflect on the 52 context-specific issues shown in Table 4 before starting design or deployment of a design.

We encourage agencies/designers to use SAM to assess their shelters before deployment. The University of Bath is happy to complete this work for free.

Agencies are encouraged to complete a post occupancy analysis of their shelters, again based on part on Table 4.

Annex 3: Fire Safety Guidance for transitional shelters

- *If prefabricated:* Shelter materials and systems of materials (e.g. composite wall sandwich panels) should be tested in accordance with ISO EN 13823, and it is strongly advised they should achieve a classification of B-s1-d0 at minimum,[1]
- *If locally constructed:* Shelter materials, particularly the wall and roof facades, should be non-combustible where possible – e.g. cement block, mud, sheet metal preferred over timber, thatch etc. – although combustible materials may be used in the frame (i.e. timber frame shelters) if they do not form part of the external façade,
- It is strongly recommended that at minimum two exit doors are provided to give occupants a choice on direction of travel to escape a fire:
    - Fundamentally this ensures at least one alternative route is available if one exit door becomes quickly compromised by the fire,
    - Provision of at least two exits is particularly important for the following, as these higher hazard features will result in much higher likelihood of early fire conditions which compromise occupant safety:
        - For locally constructed shelters in which combustible materials constitute the bulk of the walls and roof,
        - For prefabricated shelters with classifications lower than B-s1-d0.
    - Windows should not be viewed as a viable evacuation route in small, single storey shelters in which smoke build-up and fire growth can be rapid.
    - If the shelter has more than one storey, extra provisions may need to be made for evacuation of upper storeys, including windows on the upper storeys that are large and low enough to be escaped through and/or external stairs.
- Internal door lock mechanisms should be easy to operate, e.g. thumb locks and sliding bolt locks are preferrable to padlocks and key locks which can be difficult to open in stressful or hazardous conditions,
- It is unacceptable for a door to be locked from the outside if it cannot be unlocked from the inside without a key,
- Chimneys should be a non-combustible material with low thermal conductivity. If the roof is combustible, the penetration for the chimney should be surrounded by non-combustible material to avoid direct contact.

Fire safety guidance for settlement planning

Shelters should be spaced sufficiently to eliminate or slow the spread of fire. Whilst Sphere recommends 2m separation distances (or ideally double the height of the shelters), research indicates at least 3m separation distance is needed to prevent fire spread between single story shelters for even some types of noncombustible cladding. Larger separation distances should be considered for the following conditions:[2]

- Where combustible materials forming the outermost roof and/or wall façade of the shelter,
- Where non-combustible materials that are prone to low-quality or porous construction form the outermost façade – e.g. sheet metal walls are both highly conductive and tend to allow flame ingress due to gaps formed by the corrugation of the metal,
- Where a door and/or window opens out into the space between shelters,
- Where a shelter has more than one story,
- Where a site is known to experience frequent high wind conditions,

Note: Sphere recommends a 30m fire break is installed every 300m.

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[1] *There is no shared defined standard for what classification represents satisfactory performance in the humanitarian sector, and the classification of materials can be difficult to understand. The most effective method to understand performance of shelters in fire is to conduct fire tests of full shelters with representative fuel loads but this is not currently common practice.*

[2] *Whilst ideally separation distances would be sufficient to eliminate fire spread between shelters, it is acknowledged that this is seldom possible where space is limited. It is therefore important to note that every 10cm of separation distance can be vital to reduce the risk of fire spread or slow it down.*