Supplementary material

Table S1: Extended table- Novel designs sustainability comparison

	Shelter solution (shelter type)	Application	Transportation	Social sustainability		Environmental sustainability		Economic sustainability		References	Notes
				Pros	Cons	Pros	Cons	Pros	Cons		
1	Conrad Gargett's By Conrad Gargett Riddel firm (Emergency shelter)	Only prototyped	Flat packed- Can be disassembled and reassembled with ease	- Flexibility in positioning the shingles and therefore the openings - No mechanical fixings	- One room design- - Does not consider social needs as it is a global shelter - No toilet or kitchen provision	- Frame is made of a grid of intersecting plywood - Some cladding shingles made of plywood	- Some cladding shingles made of translucent plastic and clear plastic		Unknown cost	(Conrad Gargett, 2018; Furuto, 2013)	
2	Exo stackable shelter By Michael McDaniel (Transitional shelter)	Reaction produced around 50 Exos total, most were for testing purposes.	Stackable	- Easily deployed in two minutes by four people - Units can be attached to each other for more space - No tools or heavy machinery needed.	- Does not consider social needs as it is a global shelter - One room design - No toilet or kitchen provision	- Use of wood - Some units come with an LED light display for unlocking and locking the door. - Recyclable	- Aircraft-grade aluminium - Flooring is made of heavy-duty steel tubing and Birchwood		Shelter cost $5,000-$6,000 (Unaffordable)	(FIBONACCISTONE, 2018; Kessler, 2015; McDaniel, 2017)	closed in April 2016 due to funding issues
3	U-dome (Transitional shelter)	- Two U-Domes were assembled in Sacramento-California - Some shelters were distributed at River Haven transitional shelter community - Some shelters distributed at the Arcata Night Shelter (for homeless persons)	Flat packed	- Easily deployed - Can incorporate local materials	- Does not consider social needs as it is a global shelter - One room design - Small size (18m^2) proposed for a family of five members - No toilet or kitchen provision	- Off-grid energy sources compatible but not included	- 5 mm thick corrugated polypropylene panels connected with nylon fasteners		Basic shelter cost $2,495- added accessories can be purchased. (Above average)	(designboom, 2018; World Shelters, 2009, 2018b)	Other shelters have been designed by the same company; World Shelter, such as (TShel2/ Green Dome/ / Q-Shelter)
4	TranShel (Transitional shelter)	- Produced a shelter for display at the Shelter Consortium meeting in Geneva (May 2009)	Flat packed	- Easily deployed, can be erected by four adults - Expandable, adaptable as a core house using local materials - Panels provide ready attachments exterior and interior for using local materials	- Does not consider social needs as it is a global shelter - One room design - Small size (18m2) and a wall height of 1.8m proposed for a family of five members - No toilet or kitchen provision	- Reusable - Material has no off-gassing - Recyclable - Possibility of adding local materials	- Frameless hard-panel structures of panels made from corrugated polypropylene		Shelter cost $2,965-$2,360 (Above average)	(World shelters, 2018; World Shelters, 2018a)	
5	Concrete Canvas shelter (Transitional shelter)	- Most projects were military shelters and were sent for tests (US military, Swedish military, Dutch military and United Arab Emirates military)	Foldable and inflatable	- Has two sizes to meet various family's needs (25m2 or 50m2) - Easily deployed, ready in 24 hours	- Does not consider social needs as it is a global shelter - One room design - No toilet or kitchen provision	- Durable- design life of over 10 years - Covered by sand or earth fill, which will give protection, thermal mass and insulation.	- Thin walled concrete structures which also means that it requires water for construction - Plastic inner - The 50m2 shelter needs a vehicle or winch to aid with unfolding the shelter prior to inflation - It must be demolished for its end life	- Use of Nylon	Shelter cost $23,000 to $30,000 (Unaffordable)	(Concrete Canvas, 2018a, 2018b; Howard, 2013)	Medium to long-term operations
6	The Liina Transitional Modular Shelter (Transitional shelter)	Was only prototyped for experiment	Flat packed	- Easily deployed- Can be assembled in six hours by two adults - The interior is divided into different spaces - A private kitchen is provided	- The space subdivision is not responding to the cultural needs (Designed for Ararat region in Turkey but considered as a global shelter) - Small size (18m^2) for a family of 4-5people - No toilet provisions	- Built of plywood and laminated veneer lumber panels - Durable- lifespan of around 5 years - Wood fibre insulation -Covered by a canopy	- Nylon straps (liina) are used		Unknown cost	(Archdaily, 2018; Meinhold, 2011)	

	Shelter solution (shelter type)	Application	Transportation	Social sustainability		Environmental sustainability		Economic sustainability		References	Notes
				Pros	Cons	Pros	Cons	Pros	Cons		
7	The Pallet House (Transitional shelter)	Some prototypes were built for various exhibitions	Could be disassembled	- Easily deployed - No skilled workers needed - Adaptable - Possibility of adding local materials as cladding	- Not fully completed with the palettes, so it depends on the availability of materials in the location. - The basic unit is small ($18m^2$) and requires 80 pallets - No toilet or kitchen provision, but it can be added as it is more of a technique than a design	- Made of wooden shipping palettes covered by local materials using wattle & daub technique - Wood or straw roof (p) - Possibility of LM	- An option of using corrugated sheets as a roof cover	Materials cost around $500- palettes only (for a shelter of $18m^2$) (Below average)		(I-BEAM, 2018)	
8	Life shelter (Transitional shelter)	Hundreds of Syrian refugees has been living in the shelters (Northern Iraq)	Flat packed	- Easily deployed- Can be assembled by 2 people in 3-4 hours without tools - Adaptable as it is a modular design - Can integrate local materials - Durable- expected life span of 15+ years	- Does not consider social needs as it is a global shelter - One room design - Small size ($18m^2$) - No toilet or kitchen provision	- Stone wool insulation - Durable- Has a life span of 15+ years. - Reusable for permanent housing	- Panels and end-walls made of Stone wool insulation boards reinforced with steel - Galvanised steel floor frame - Cement cladding roof	For large quantities order, the price start from $790- excluding taxes (Below average)		(Lifeshelter, 2018; Real Relief, 2018)	
9	Rapid Deployment Module (RDM) (Semi-permanent shelter)	- Used few times as medical facilities and other functions. - 26 shelters were bought from BP for their work in Mexico - Multiple shelters were provided to Moore Oklahoma - There were trials to distribute them as refugee shelters	Flat packed	- Easily deployed- Can be assembled by 2 people in 25 minutes - Integrated floor structure that makes the shelter sets slightly off the ground	- Does not consider social needs as it is a global shelter - One room design - Small size ($12m^2$) - No toilet or kitchen provision (although some shelters had an addition of toilet and shower)	- Lightweight roof is vented, and the shade fly provides passive-cooling and heating. - Reuse shipping box as the base structure - Durable- Expected lifespan of 10 years	- Materials used for walls are not mentioned- only that they are hard walls and could double up as white boards. - The roof is made from vented fabric roof and its weather protective level is questioned despite the weather-protection claims		Shelter cost $15,000-$18,000 (Unaffordable)	(Maxey, 2013; VisibleGood, 2018; Williams, 2013)	Although the inventors call it semi-permanent shelters, it looks more as a transitional shelter.
10	Tentative Concept (Post-disaster shelter)	Not known application	Flat packed	- Has a floor that is raised above the floor	- Small size ($8m^2$)- Can hosts two adult and two children (very tight area per person) - No toilet or kitchen provision	- Use of fibreglass shells - Use of textile that is quilted and contains insulated perlite in between - Collects water on the roof - Recyclable decks floor	- Tough fabric walls are not enough to maintain a thermal comfort. - The textile is quilted and contains insulated perlite in between		Unknown cost	(DESIGNNOBIS, 2018; Treggiden, 2015)	Though the perlite is a natural material, it is a possible cause of rhinitis and pneumonia
11	Hex house (Shelter (not specified))	Prototyped- But no known application	Flat packed	- Sufficient size ($47m^2$) - Various rooms - Private toilet and kitchen provision	- Does not consider social needs as it is a global shelter (the porch and openings locations may interfere with the privacy requirements of some cultures).	- Durable- Has a life span of 15y-20y - It includes rainwater harvesting systems. - Includes underground water storage tanks - Includes rooftop solar panels - Use of foam insulation	- Use of steel SIPs		Shelter cost $15,000-$20,000 and on a different source $55,000-$60,000 (Unaffordable)	(Hex House, 2018; McKnight, 2016)	
12	Weaving a home (Tent)	Not applied	Foldable	- Culturally acceptable as it is inspired by the Bedouin tents	- Short-term solution- It can only replace the rapid used tent but not a longer-term shelter solution. - No toilet or kitchen provision	- Solar-powered skin that absorbs sunlight, convert it into usable electricity and store it in a battery kept underneath the tent. - Roofs are equipped with a water storage tank.	- Plastic members threaded into a cloth		Unknown cost		

Table S2: Extended table- Existing solutions sustainability comparison

	Shelter solution (Shelter type)	Application	Transportation	Social sustainability		Environmental sustainability		Economic sustainability		Notes	References
				Pros	Cons	Pros	Cons	Pros	Cons		
1	Refugee Housing Unit (Transitional shelter)	15,000 shelter bought by UNHCR where only 5000 where distributed.	Flat packed	- Easily deployed-can be erected by four people in four hours - Moveable	- Does not consider the specific social needs as it is a global shelter - One room shelter - Small size (17.5m^2) which is not enough for many cultures. - No toilet or kitchen provision	- Small roof-based solar panel	- Short lifespan- up to three years with maintenance - The frame consists of lightweight galvanised steel pipes - Polyolefin foam roof and wall panels - Plastic screws, bolts and brackets	- The cost is around $1250 (Below average)		- Concerns regarding vulnerability to fire - Issues with the internal metal-tube frame, ventilation and rigidity - No groundsheet - Not accessible to wheelchair (raised door) - A new version of the shelter is being designed.	(Better shelter, 2018; Fairs, 2017)
2	Bangladesh 2007 (Core shelter)	1250 shelter	Not transportable	- Expandable - Locally sourced woven bamboo	- Small size (15m^2) due to limited land availability - The provision of toilet and kitchen is unknown.	- Wind protection (used cyclone resistance techniques) - Built over a mud plinth for flooding protection - Walls from locally sourced woven bamboo - Beneficiaries self-built the shelters	- Permanent base of bricks over the plinth - Corrugated sheets roof - Concrete foundation		- Material costs $1600 (Above average)		(UN-HABITAT & IFRC, 2010)
3	Kenya- Dadaab 2009 (Core shelter)	Up to 3,500 shelter per annum	Not transportable	- Culturally acceptable - Larger space than previously distributed Tukul tents - Women participated in block-making and construction	- Small size (18m^2) - The provision of kitchen is unknown. - A separate space for building toilets is provided	- Use of traditional materials - Mud blocks made by beneficiaries - More durable than Tukul tents - Use of timber - Larger pillars and widened foundations made out of mud blocks for better flood resistance.	- Corrugated iron sheets roofing - Mud and water availability limited the project - Unplanned mud excavation resulted in holes often becoming refuse pits, or mosquito-breeding - Sustainable timber sources were hard to find	- Material costs $480 (Below average)	- The local available material were limited and therefore the transportation cost per-unit was raised		(UN-HABITAT & IFRC, 2010)
4	Haiti 2010 (T-shelter)	1050 shelter	Not transportable	- Sufficient size (27m^2) - Outdoor porch - Traditional techniques- Clissage (woven slats of wood) - Users were able to modify the shelter - Accessible by people with reduced mobility	- Internationally procured materials - The provision of toilet and kitchen is unknown (not included in the plan)	- Traditional materials - Timber frame - Passive cooling as uncovered clissage allow good ventilation - Mud or mortar can be added to walls - Durable (3y-5y) - Roof of wood and corrugated bituminous	- Concrete floor supported by masonry wall - Corrugated bitumen roofing		- Material costs 1650CHF- equals $1680 (by Sep,2018) (Above average)	- The weight and brittle properties of the wall most likely will not perform well in a severe earthquake or under high winds.	(IFRC, 2013)
5	Philippines 2011 (Transitional shelter)	1823 shelter	Could be partially disassembled	- Traditional techniques- Amakan- (woven bamboo or palm leaves) - Easily deployed in five days by five people - Locally sourced materials	- Small size (17.8m^2) - The provision of toilet and kitchen is unknown	- Durable (5y) - Framed with coconut wood beams and joists for roof and floor - Plywood floor - Locally sourced materials	- Corrugated metal roof - Concrete foundation	- Materials cost 500CHF- equals $509 (by Sep 2018) (Below average)		- Damage should be expected during strong storms. - In order to resist fungal and insect attack, treatment has to be done to coconut wood and plywood as they are not rot resistant.	(IFRC, 2013)
6	Ethiopia 2011 (Semi-permanent shelter)	2175 shelter	Not transportable	- There are three shelters' sizes (10m^2, 14m^2 and 21m^2) for various family needs - Built by refugees - ocal materials - Separate private toilet	- The design (Tukul) is the one used by the host community not the refugees. - No planned spaces for the livestock that were brought by the refugees - The provision of kitchen is unknown	- Followed local cooling and heating techniques - Constructed with locally procured materials such as bamboo, grass, rope and mud	- Difficulties in sourcing and transporting mud for plastering the walls. - Grass for thatching the roof and for strengthening the mud walls is seasonal	- Material costs are ($640, $800, $920) for the (10m^2, 14m^2 and 21m^2) respectively (Below average) - Locally procured materials reduced the transport costs and injected cash into the local economy			(IFRC, UN-HABITAT, & UNHCR, 2013)

	Shelter solution (Shelter type)	Application	Transportation	Social sustainability Pros	Social sustainability Cons	Environmental sustainability Pros	Environmental sustainability Cons	Economic sustainability Pros	Economic sustainability Cons	Notes	References
7	Madagascar 2012 (Progressive shelter)	598 shelter	Not transportable	- Culturally acceptable as the shelter is an adaptation of the traditional houses in Madagascar. - Use of local materials	- Small size ($12m^2$) - The budgetary constraints resulted in smaller shelter size compared to household size - The provision of toilet and kitchen is unknown	- Wooden frame - Thatch roof was one of the two roofs options - Use of local materials	- Not enough consideration was given to other local materials such as bamboo. - Corrugated iron roof was one of the two roofs options	- Material costs $128 (Below average) - Project cost per shelter $250			(IFRC et al., 2013)
8	Fiji 2012 (Transitional shelter)	254 shelter	Able to be disassembled	- Sufficient size ($21m^2$)	- The provision of toilet and kitchen is unknown (through images probably they are not included)	- Panels, stairs, doors and windows were prefabricated on site - The structural frame was designed to withstand severe cyclonic wind loads - Raised compacted earth floor	- No rigid wall linings were permitted, so plastic sheeting was used instead. - Corrugated iron sheets roof		- Material costs $1800 (Above average) - Project cost per shelter $2,900 - The remote location increased the total cost as timber was imported	- The shelter could not be classified as a safe refuge, though they were designed to withstand the wind load of a Category Four cyclone	(IFRC, UN-HABITAT, & UNHCR, 2014)
9	Myanmar 2012 (Temporary shelter)	2843 shelter (8-unit shelter)	Not transportable	- Shelters used locally available materials	- Small size per household ($15.6m^2$) while the whole shelter size is ($124.7m^2$) - Eight families live in one shelter - Does not consider cultural needs for women to bath and cook within their shelters. - The provision of toilet and kitchen is unknown	- Shelters used locally available materials	- In a certain time, bamboo was not in season and the project was forced to use lower-quality materials.	- Material costs $600 per room/household (Below average) while the material costs of the whole shelter is $4,800 - Project cost per room/household $88 ($700 per shelter)			(IFRC et al., 2014)
10	Philippines 2012 (Transitional shelter)	4139 shelter	Not transportable	- Two shelter sizes (18 m^2 and $24m^2$) which meets various family sizes. - Local materials - Built in 3-5 days - Separate toilet is provided	- Small size as the $18m^2$ shelter is for six people and the $24m^2$ is for seven people and more - The provision of kitchen is unknown	- Families were supported to use salvaged materials - Used fallen coconut trees for construction	- Salvageable materials were less available than needed	- Material costs $380 (Below average) - Project cost is $580			(IFRC et al., 2014)
11	Jordan 2013 (T-shelter)	13,500 shelter	Not transportable (Although the original design is)	- Easily deployed- Built in 12-16 hours by four people	- Does not consider social needs as windows overlook public areas, no porch (cancelled from the design) - Has one room design - Small size compared to the needs ($24m^2$ for six people) - No provision of private toilet and kitchen	- Use of foam insulation	- Short lifespan (2y-4y), the users still live in them (5 years till today) - Made of interlocking steel structures - Covered with a double layer of Inverted Box Rib, It was hard to seal off against dust, wind and rain - Heat gain is an issue		- Material costs $1,270-$1,410 (Above average) - Total cost per shelter $2,330 or in another source $3,442		(Alshawawreh, Smith, & Wood, 2017; IFRC et al., 2014; UNHCR, 2016)
12	Iraq 2015-2016 (Transitional shelter)	1406 shelter	Not transportable	- Locally procured materials that were originally imported - Divided interior - Provision of private toilet and kitchen	- Small size ($22.5m^2$)- due to cultural reasons, families complained about the size - Uniformly designed which limited the household needs to be better addressed	- Plywood sheets for floor covering - Fibre-glass sheet for bathroom floor - PU insulation - Durable	- Steel structure - PU insulated sandwich panel for wall coverings	- Material costs $5,500 (Within existing range) - Project cost per household $9,621			(Global Shelter Cluster, 2017)

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