A Comparative Study of Temporary Shelters used in Cold Climates

What can be learnt from the design of the Yurt and the Scott tent to inform the future design of shelters systems for emergency relief?

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Abstract

From July to October 1999, the author participated in the design and testing of a new cold climate shelter system for use by Non-Governmental Organisations in the Balkans. The limited period of this project did not allow for a review of shelter typologies used in cold climates by other user groups, a review that should have been an inherent part of the design phase.

Conclusions from a logistical analysis indicates that the standard winterised aid shelter could learn from the way in which expedition shelter is packed for transportation and from the assembly procedure of the yurt. In terms of the thermal environment, three distinct strategies are analysed and questions are subsequently raised concerning the appropriateness of insulation levels and the radiant environment provided within the thin canvas enclosure of the current UN aid tent in severely cold climates. A discussion of clothing and bedding in all three shelters questions whether aid provision adequately compensates for a low shelter insulation value.

1 Introduction

This essay explores several concerns regarding the emergency shelter policies of international humanitarian organisations following recent aid programmes in the Balkans and previous emergencies in cold climates. Current emergency shelter provision for forced migrants in severely cold climate environments can rarely achieve comfortable thermal conditions for its occupants[1]. This fact is acknowledged by the United Nations, yet several nomadic groups and polar expedition teams do manage to achieve thermal comfort under comparable conditions. Vernacular shelter, expedition shelter and cold climate emergency shelter respond to disparate design briefs but all share some similar design criteria, most notably that of providing temporary dwelling in harsh and cold environments. This essay illustrates where the thermal strategies and the logistics of transportation for these shelters are similar, where there are radical differences, and where there are ideas for the improvement to the design of the current standard aid tent.

2 Shelter Typologies

2.1 Emergency Shelter

The provision of emergency shelter is a last resort when no other solution can be found[2]. Preferable solutions include repairing damaged property, placing refugees within the home of a host family, or providing secondary accommodation within warehouses or adapted public buildings such as schools. The photographs below show repairs to private property undertaken last year in Western Kosovo.

Figure 1 Emergency repairs to private property in Kosovo

emergency roof repairs to a lightly damaged property in Prelip, Western Kosovo

convective heat losses at the doorway could be minimised through the creation of plastic porches

a lean-to roof created at first floor level of a damaged two storey building with no roof

UNHCR, however, has formed a contingency plan for emergency shelter based on a series of minimum standards of response for a large range of emergency scenarios. This has produced the UNHCR winterised tent for emergencies in cold climate environments.

The UNHCR Tent

The UNHCR tent is a double skin canvas ridge tent with an insulated inner tent and a canvas fly-sheet. It is a tensile structure supported by a galvanised steel pole frame and relies on guyed fixings to the ground for stability. Figure 2 shows the UNHCR tent in the field and at the Martin Centre.

[1] UNHCR Handbook for Emergencies (1999). p. 145 (section 82).
[2] UNHCR Handbook for Emergencies (1999). p.145/6.

Figure 2 The UNHCR Temperate and Winterised Tents

UNHCR temperate climate tents are pitched in the foreground of Chegrane Refugee Camp, South-West fYRO Macedonia.

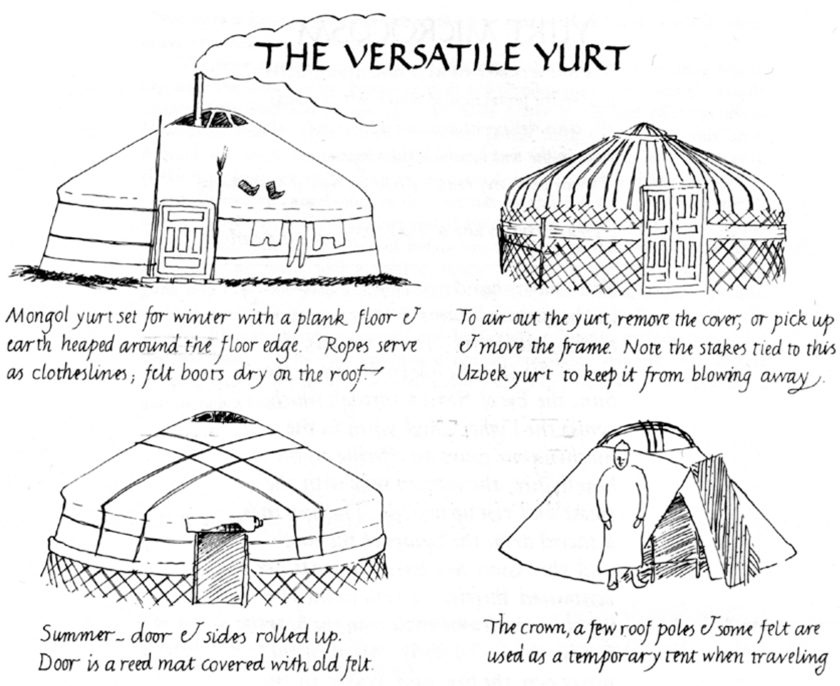
The winterised tent is similar to the temperate tent except it has an additional fly-sheet and a steel manifold to take a stove flue pipe.

2.2 Vernacular Shelter

Nomadic peoples in cold climates have evolved many sophisticated and environmentally responsive shelter solutions to the climate in the Arctic and the sub-Arctic regions. These include the conical bent pole 'kata' tents of the Lapps and those of the North American Taiga; the Koryak and Chukchi tents from the high north of Asia who used repeated timber tripod frames covered with reindeer hide; the Evenk shelter which has birch bark panels sown onto the wall fabric and the conical compound tents from Siberia that were the precursors to the yurt.

The yurt is used by all nomadic Mongol and Turkish peoples and is now found in a huge territory spanning from Mongolia and Southern Siberia to Turkey. It is interesting to note that the yurt has very few variations in form or detail within this area, yet it is notable for its mobility and climatic adaptability[3]. For these reasons it stands out as a useful example of vernacular shelter for comparison with contemporary emergency shelter.

Figure 3 The Yurt



[3] Oliver, P. (1997). p. 832.

The yurt is an armature structure in which the covering fabric plays no part in the fundamental structural stability of the system. The walls are formed from wooden lattice sections called *khana* and each *khana* section is joined together with goat hair cord. The roof poles are tied to the top of the wall lattices and attached to a timber roof ring (or crown) and a woven fibre band is then wrapped around the 'wall plate' and tensioned in order to counter the outward thrust of the roof weight[4]. The structural framework is covered with rolls of felt made from sheep's wool that is then beaten and flattened into rolls.

[4] Faegre, T. (1979). p. 86.

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2.3 Polar Expedition Shelter

Figure 4 Types of expedition shelter

large/ permanent	*medium/temporary*	*small/temporary*
Jamesway and Polarhaven	Scott-Type and Arctic Oven	Dome and Northface

Potter and Yang assert that there are three types of temporary polar expedition shelter[5]: the large Jamesway and Polarhaven (J&P) shelters; the Scott-Type and Arctic Oven (S&A) tents; and the small adapted mountaineering tents such as those fabricated by Dome and Northface (D&N). The J&P shelters are semi-permanent shelters and ,whilst they are easily de-mounted, are not really portable without large vehicular support[6]. The D&N tents are adapted tensile systems from the commercial leisure market and, whilst they are used on short expeditions in northern coastal regions of Antarctica, they are too small and not particularly well designed for prolonged expeditions[7]. The S&A tent has the closest resemblance to the design brief for emergency shelter, being light, portable and providing an environment suitable for prolonged transient expeditions, hence this shelter form is selected for further study.

Figure 5 The Scott tent

The Scott tent, so called because it was used on Scott's expedition to the Antarctic at the beginning of this century, is similar to yurt in that it is also an armature structure with four hollow-section aluminium poles forming a pyramid on a square plan. The fly-sheet is made from a finely woven cotton fabric called 'Ventile' and a lightweight cotton inner sheet that is laced to the inside of the structure. The tent is erected by first digging out a square from the snow to a depth of 200mm and digging pile holes for the corner posts. Long aluminium poles are then sunk half a metre into the snow with the tent already attached[8].

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[5] The Polar Record *34 (189). p. 115*
[6] http://www.weatherhaven.com/photos/product01.htm
[7] *pers comm* Whittamore, L. (British Antarctic Survey)
[8] *pers comm* Whittamore, L. The Scott tent is stored as a rolled up kit with poles, flysheet and liner all attached prior to erection which reduces pitching time during an emergency.

3 Comparative Analysis

3.1 Logistics

Figure 6 Logistics Summary for the Yurt, the Scott tent and the UNHCR winterised tent

	Floor Area	***Weight***	***Unit Weight***	***Number of Occupants***	***Weight per Occupant***
	m2	*kg*	*kg/m2*		*kg/pp*
Turkic Yurt[9]	28	250[10]	8.9	5	50
Scott Tent[11]	6.25	30	4.8	2	15
UNHCR Tent[12]	16	100	6.25	4	25

3.1.1 Weight

Weight is the limiting criteria for transportation for all three shelters, as all user groups have limited resources available with which to move their shelter. A family of yurt dwellers might move to a new location as regularly as every week depending on the vegetation cover necessary for cattle feeding[13], whilst a polar expedition team might only stay at a site for a matter of days in order to collect material samples or make observations. The UNHCR shelter has been designed to be carried and erected by a displaced family unit of 3 or 4 persons, so its weight and bulk is also of primary importance. In terms of useful comparison, it is more appropriate to compare the floor plan area and the number of anticipated occupants, together with the weight of each shelter, given the variance in shelter size and living density.

The extent to which a yurt is portable, rather than simply 'foldable and collapsible[14], clearly depends on its size Even the smallest Turkic examples, with a nominal weight of 50kg per person, cannot be carried any appreciable distance by manpower alone. On the other hand, modern materials and fabrics employed within the Scott tent allow the shelter to be easily carried by two people. The Scott tent uses aluminium poles and small gauge, finely woven cotton fabric which have high strength-weight ratios relative to those of timber, canvas and felt, which are used in the yurt and the UNHCR tent. It is, however, noteworthy that the low unit weight of the Scott shelter comes at a cost, as the lightweight cotton liner provides negligible insulation, whilst both the UNHCR tent and the yurt have some form of insulated fabric.

The UNHCR tent, with a unit weight of 6.25kg/m2 and a weight per occupant of 25kg per person, is 'too heavy' for relief purposes according to Wolfgang Neumann, head of the Technical Division of UNHCR. Three people can just about carry the tent in packed form but, as with the yurt, this is not possible for any appreciable distance and relies instead on aid trucks. This issue remains a dilemma for UNHCR, as continuing dependence of displaced persons upon aid resources, such as transport, reduces their autonomy and complicates further migrations or movement. The unit weight of the Scott tent is a target for the future development of the UNHCR tent, although the present cost of aluminium and Ventile cotton fabric exclude these materials for use within emergency shelter systems.

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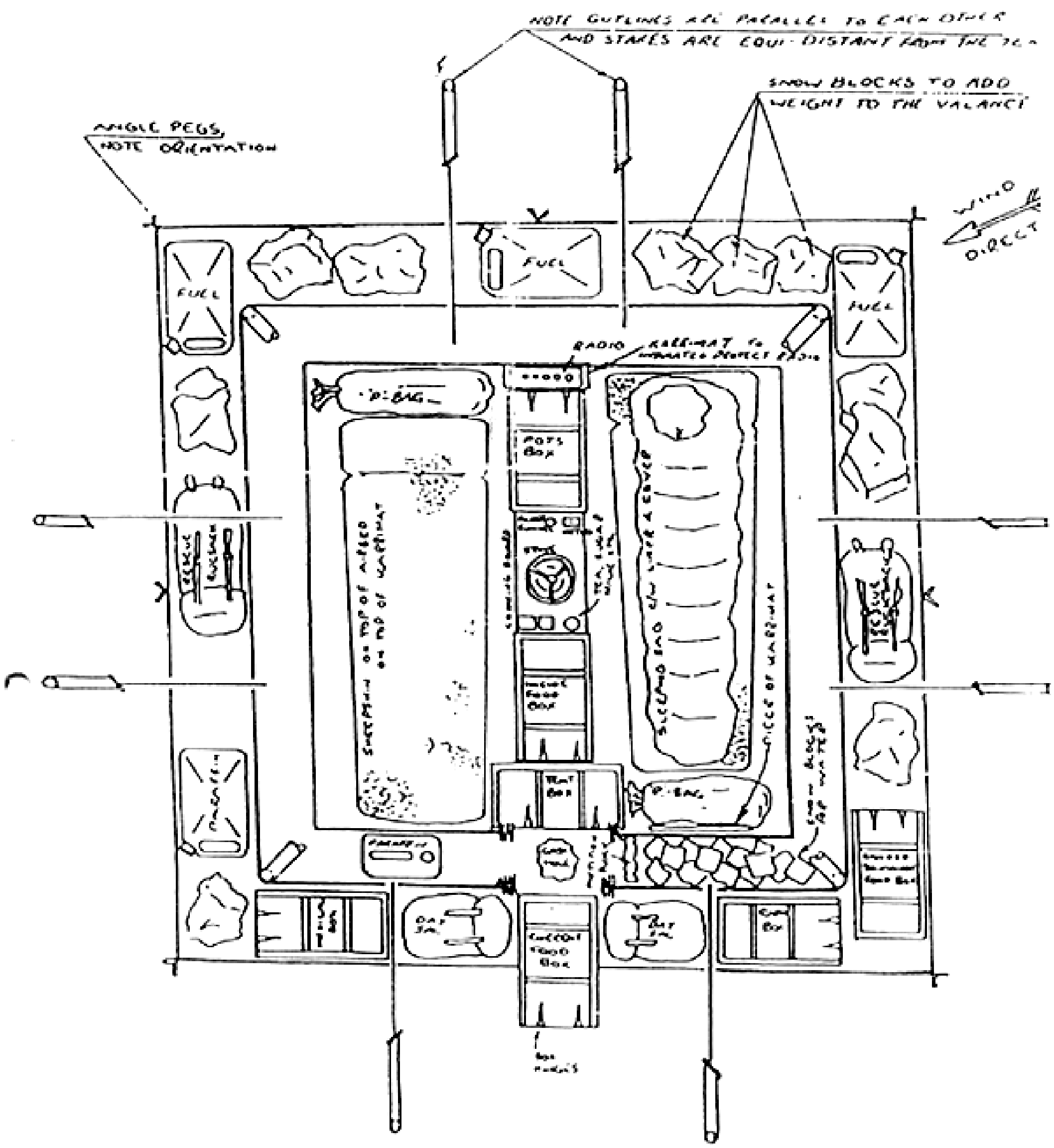
[9] Oliver, P. (1997) *Encyclopaedia of Vernacular Architecture of the World*. Volume 1, p. 831-833. (unless otherwise stated).
[10] P*ers comm* Zhimbiev, B. A typical yurt can weigh around 250kg whilst a full size yurt for a large family weighs around 800kg.
[11] *pers comm* Whittamore, L.
[12] UNHCR Handbook for Emergencies (1999).
[13] *pers comm* Zhimbiev, B.
[14] *pers comm* Zhimbiev, B.

3.1.2 Packing

Aside from weight, the way in which each shelter is demounted and stored for travel also impacts upon the portability of the shelter. The Scott tent is based on a modular storage system and all components and equipment for an expedition are boxed in preparation for transportation either by sledge or skidoo. An expedition might take 8 to 10 boxes, each containing items such as radios, tents, personal belongings, food, cooking equipment and first aid. Several semi-permanent Weatherhaven shelters even utilise the box used for transportation as a fitted insulated floor. Upon reaching a site, the boxes and packing materials for the Scott tent are then put to use as camp furniture, as storage units or as part of the shelter construction.

Figure 7 *Plan of the Scott tent*[15]



[15] Drawing after British Antarctic Survey field manual.

Figure 7 shows that packing boxes form a raised platform either side of the double zipped entrance to the Scott tent in order to prevent the snow collapsing into the tent when crawling in or out. In addition, packing material forms the kitchen unit within the shelter onto which the stove and cooking utensils are placed.

Neither the yurt or the UNHCR tent use modular storage, although the former would typically be packed into five or six separate component bundles, including the roof poles, *khana* sticks and rolls of felt, in preparation for transportation either on the backs of camels or by cart[16]. The UNHCR tent is densely packed in kit form within a single heavy-duty canvas bag and current policy allows for transportation and distribution separately from other relief items such as cooking equipment and bedding. This effectively excludes any potential logistical gains that might be made through the provision of multiple components within reusable casing, as with the Scott tent.

[16] Alexander, D. (1990). p 15.

3.2 Thermal Comfort - *Shelter Insulation, Clothing and Bedding*

The chief factors affecting thermal comfort include but are not limited to: (1) air temperature, (2) relative humidity, (3) mean radiant temperature and (4) air motion[17]. One definition of thermal comfort is defined as "that condition of mind in which satisfaction is expressed with the thermal environment"[18], which implies the inclusion of subjective criteria, as well as directly measurable data. With the limited data available, this short essay examines only the effects of shelter fabric insulation, clothing and bedding upon thermal comfort. Figure 8 shows the approximate heat loss calculations and clothing levels for each shelter and occupants in an environment at -20 degrees Celsius[19].

[17] Lechner, N. Heating, Cooling, Lighting (1991). p. 28.
[18] ASHRAE (1989). Section 8.16.
[19] Refer to the excel spreadsheet

Figure 8 *Heat loss calculation for each shelter together with typical clothing levels of occupants*

Yurt U-Values	**Thickness**	**r**	**R**
	m	*Wm-1oC-1*	*Wm-2oC-1*
Walls/Roof			
Rsi	-	-	0.123
Felt	0.2	25.6	5.12
Rse	-	-	0.03
Total R			5.273
U-value			**0.2**
Floor			
Rsi			0.15
felt	0.025	25.6	0.64
Total R			0.79
U-value			**1.3**

yurt volume weighted Heat loss Calculation			
	Area	*U-value*	*Conductance*
	m2		
floor	28	1.27	35
wall/roof	56	0.19	11
Total UA	**84**		**46**
n			4
V *(m3)*			63
nV/3			**84**
Total Conductance			**130**
ti (°C)			15
to (°C)			-20
dt (°C)			35
Q *(W)*			**4553**
Q/Surface Area *(W/m2)*			**54**

Yurt dwellers clothing

Clothing *(Clo)*	1.6

Scott tent U-Values	**Thickness**	**r**	**R**
	m	*Wm-1oC-1*	*Wm-2oC-1*
Walls/roof			
Rsi			0.123
Cotton	0.001	27	0.027
Air cavity			0.15
Canvas	0.001	27	0.027
Rse			0.03
Total R			0.357
U-Value			**2.8**
Floor			
Rsi			0.15
canvas	0.001	27	0.027
Total R			0.177
U-value			**5.6**

Scott tent volume weighted Heat loss Calculation			
	Area	*U-value*	*Conductance*
	m2		
floor	6.25	5.65	35
wall/roof	15	2.80112045	42.01680672
Total UA	**21.25**		**77**
n			4
V *(m3)*			5.2
nV/3			**6.93**
Total Conductance			**84.26**
ti (°C)			15
to (°C)			-20
dt (°C)			35
Q *(W)*			**2949**
Q/Surface Area *(W/m2)*			**139**

Expedition clothing

Clothing *(Clo)*	3.5

UNHCR Tent U-Values	**Thickness**	**r**	**R**
	m	*Wm-1oC-1*	*Wm-2oC-1*
Roof			
Rsi			0.123
Cotton	0.0005	27	0.0139
Air	0.005	38	0.192
Canvas	0.002	27	0.054
Air cavity			0.15
Canvas	0.002	27	0.054
Rse			0.03
Total R			0.62
U-Value			**1.6**
Floor			
Rsi			0.15
LDPE	0.00025	0.04	0.00625
canvas	0.001	28.57142857	0.000035
Total R			0.156285
U-Value			**6.4**
Door/End			
Rsi			0.123
Cotton	0.0005	27	0.0139
Air	0.005	38	0.192
Canvas	0.002	27	0.054
Rse			0.03
Total R			0.4129
U-Value			**2.4**

UNHCR tent volume weighted Heat loss Calculation			
	Area	*U-value*	*Conductance*
	m2		
floor	16	6.4	102
Door/end	12	2.4	29
roof	23	1.6	37
Total UA	**51**		**169**
n			4
V *(m3)*			24
nV/3			**32.00**
Total Conductance			**201**
ti (°C)			15
to (°C)			-20
dt (°C)			35
Q *(W)*			**7019**
Q/Surface Area *(W/m2)*			**138**

Balkan winter clothing

Clothing *(Clo)*	1.8

The three shelter types have radically different approaches to heat conservation. The yurt has both a flexible and thermally-responsive insulating fabric, in the form of removable layers of felt that wrap around the wooden lattice and pole structure. During summer, the felt is rolled up to allow cross ventilation. In some parts of Asia, the felt is permanently replaced with woven reed mats in order to maintain privacy as well as thermal comfort[20]. Each felt layer is between 20 and 30mm thick and during winter months. A yurt may have as many as 8 felt layers to minimise heat lost from the open hearth at the centre of the floor plan. Figure 8 indicates that the approximate U-value of the winter yurt is 0.2, which represents under half the recommended U-value for wall design included in the current British building regulations. This comparison serves to illustrate that even though the yurt is referred to as a 'shelter' in this essay, it has the potential to provide an internal environment comparable to that of permanent housing. Mongolian Yurt dwellers wear clothes made of wool and animal skins, which combine to give a clo value of approximately 1.6[21].

The Scott tent lies at the other end of the thermal design spectrum. The 'Ventile' fly sheet and cotton liner combine to provide only limited insulation, amounting to a U-value of 2.6. The primary function of these two sheets is to break the wind and reduce convective heat loss from the shelter, which is of particularly importance in an environment with a near constant wind at a speed of 15/20 knots[22]. No attempt is made to achieve a warm, ambient air temperature inside the tent as the rate of heat loss, and hence the associated fuel consumption, would be too high to maintain for an expedition lasting for a period of weeks or months.

In order to compensate, clothing and bedding with exceptionally high insulation values are used in order to maximise the retention of body heat. Clothing used on polar expeditions is based on the layer principle, which means each expedition member will wear up to 5 or 6 layers of clothing, each additional layer with an increased insulation value, together with a moisture and wind resistant outer layer[23]. This allows the wearer to maintain thermal comfort, as clothing can easily be taken off as the weather conditions change.

Artificial insulating fabrics, such as 'Polartec' fleecing fabric made from recycled glass and 'Synchilla' made from recycled plastic, now dominate contemporary expedition clothing as these materials have much higher thermal resistance to weight and volume ratios, compared with those of natural fibre clothing garments[24]. 'Goretex' and 'Sympatex' are both composite laminate fabrics with microscopic holes in the fabric surface which mimic the behaviour of skin pores and are able to wick away moisture respired from the body more effectively than natural fibres[25]. Clothing insulation can be described as a single equivalent uniform layer over the whole body and its insulating value is expressed in terms of clo units. The specialised clothing used on expeditions combine to provide insulation up to a value of 3.5 clo[26], which represents the maximum effective value before clothing hinders normal movement[27].

Expedition bedding reduces to a minimum conductive heat losses to the air and the ground by using a combination of natural and manmade materials, including closed cell foams, inflatable bedding, seal fur and feather-down sleeping bags[28]. This strategy gives a level of thermal comfort not possible when using natural fabrics alone, although it is interesting to note that garments such as woollen jumpers and sheepskin rugs are still used. Reasons for their continued use include the reported 'warm' sensation of natural fibres on human skin[29] and although this is a matter of personal preference, it does underline the inherently subjective nature of thermal comfort.

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[20] Oliver, P. (1997) p. 833.
[21] *pers comm* Zhimbiev, B.
[22] *pers comm* Whittamore, L.
[23] *pers comm* Whittamore, L.
[24] *pers comm* Johnson, K.
[25] *pers comm* Whittamore, L.
[26] Derived from tables in the ASHRAE handbook.
[27] *pers comm* Baker, N.
[28] *pers comm* Whittamore, L.
[29] *pers comm* Whittamore, L.

Emergency shelter is aiming to provide comfortable living space rather than simply a survival environment and in this sense, the UNHCR tent aims to combine the thermal strategies employed by both the Scott tent and the yurt. With a U-value of 1.62, the aid tent provides a degree of insulation for occupants, but nothing like that which is provided with the yurt. The current UN standards recommend a minimum internal temperature of 15 to 19 degrees Celsius[30]. This is deemed necessary in order to provide a suitable environment for a beneficiary population that may be in poor health and unprepared for cold weather[31], as well as for vulnerable groups such as children and the elderly. In all cases, occupants are likely to spend large amounts of time inside a confined space and a concerted effort to provide thermal comfort in an otherwise extremely unpleasant living environment is of paramount importance. In order to heat the tent to the required internal ambient temperature, a large stove unit is recommended for use with the shelter, typically one with an output of five to seven Kilowatts[32]. Additional winter clothing and bedding may also be distributed to the tent occupants to ensure a minimum level of personal insulation in line with UNHCR's cold climate 'individual survival' policy[33], but the UNHCR Handbook offers no more details about this minimum level. The Sphere Standards for Humanitarian Response[34] mention that people affected by disasters should have 'access to sufficient blankets and clothing to provide protection from the climate', but, again, is no more specific. The table below is an estimation of typical winter clothing in the Balkans[35]:

Figure 9 *Clothing levels in the Balkans*

Garment	*Clo Value*
Briefs	0.04
T-shirt	0.08
Long underwear top	0.2
Long underwear bottom	0.15
Socks	0.06
Boots	0.1
Shirt	0.34
Thick trousers	0.24
Thin sweater	0.25
Jacket	0.36
Total	**1.82**

A clothing insulation value of 1.82 clo represents approximately the maximum realistic insulation value achievable using non-specialist fabrics[36]. It is interesting to note that this is half the clo value available to those using specialist fabrics for polar expeditions, such as 'Polartec' and 'Symatec', mentioned earlier in this chapter.

[30] UNHCR Handbook for Emergencies(1999). p.146 (section 86)
[31] *pers comm* O'Connor, R.
[32] UNHCR Handbook for Emergencies(1999). p.146 (section 86)
[33] UNHCR Handbook for Emergencies(1999). p.146 (section 86)
[34] The Sphere Project was launched In July 1997 and seeks to develop a set of standards in core areas of humanitarian assistance in order to better the quality of assistance provided to people affected by disasters. It is supported by all major humanitarian organisations.
[35] from the author's personal experience
[36] *pers comm* Baker, N.

Figure 10 *Heat input scaled relative to surface areas and the internal temperature achieved in an outside temperature of –20 °C*

Shelter	Heat input *kW*	Ti *°C*
Yurt	4.5	15
Scott tent	1.2	3.7
UNHCR tent	*2.8*	*3.8*

The table above confirms that with the same proportional heat input, the yurt achieves by far the highest internal air temperature. It is interesting to note how close the results of the Scott tent and the UNHCR tent are, given the differing clothing levels between user groups.

Figure 11 *Thermal Comfort Calculations*[37]

Scott tent

heat input (kW)	0.28
Internal temp (°C)	-11.7
Clothing (Clo)	3.5
PPD (%)	50
temp of clothed body	4.21
neutral temp	-4.5

Yurt

heat input (W)	4.8
Internal temp (°C)	17.7
Clothing (Clo)	1.6
PPD (%)	5
temp of clothed body	23
neutral temp	17.7

UNHCR tent

heat input (W)	7.3
Internal temp (°C)	17.7
Clothing (Clo)	1.8
PPD (%)	5
temp of clothed body	23
neutral temp	17.7

The Scott tent is not heated in reality, so the only heat input is casual gain from 2 occupants. The internal air temperature achieved with an outside temperature of –20 °C , is –11.7 °C but even with 3.5 clo of clothing, the Percentage of (normal) People Dissatisfied is 50%. This may be because the model does not account for bedding, which will certainly increase the temperature of the clothed body closer to comfort levels.

The UNHCR tent needs 7.3 kW of heat to achieve comfortable conditions for occupants with the maximum realistic clothing value possible with normal fabrics. This means the largest heater will have to be run constantly at full power in severe conditions and does not account for convective heat losses every time the door is opened. In contrast, the Yurt achieves thermal comfort with a 4.8 kW heat input and has nearly double the floor plan area of the UNHCR tent.

[37] Using Fanger's Predictive Model.

4 Conclusions

4.1 Limitations of comparison

One may ask how valid is a comparison between such different shelters. Certainly, it is difficult to draw comparisons between thermal strategies when the user groups considered have such varied motivations and cultural backgrounds. Participants on polar expeditions are often not part of ethnic groups that live in severely cold environments but make a personal choice to endure difficult conditions. The entire culture of yurt dwellers is based on nomadic herding and so this user group is particularly well adapted to the use of temporary dwelling, whilst in nearly all cases, the occupants of UNHCR shelters are not. This may well mean that the thermal comfort varies for each user group and so will affect the direct comparisons made in this essay. However, several conclusions are drawn from this study which are detailed below.

4.2 Logistics

The UNHCR tent needs to maintain its floor plan and internal volume whilst reduction in weight would be an advantage. Lightweight, insulation and structural materials used in the Scott tent such as ‘Ventile’ cotton, ‘Polartec’ and aluminium, are all beyond the budgets of aid programmes, but alternative modern materials with similarly useful properties, such as hydroscopic breather membranes used for roofing and fibrous polyester insulation, and cheap plastic tubing may be considered instead. The UNHCR tent can also learn form the Scott tent, which makes effective use of its packing casing and can be put up in a third of the time needed for the UN tent. The yurt can be seen as an alternative strategy as it can be easily separated into component parts for travel and uses basic construction methods to joint the shelter structure together.

4.3 Thermal strategy

The yurt has a building fabric that is able to respond to a wide range of climatic conditions. This flexibility is not possible with the current aid tent and would seem to be a useful feature for a standard shelter that is deployed for emergencies in a similarly wide range of climates. The yurt continues to evolve in contemporary society in terms of changing use and the integration of new materials within tradition designs[38]. The fact that it has remained part of nomadic life in Asia whilst so many other shelter typologies have all but disappeared, adds greater weight to the logistical and thermal strategies it employs.

Expedition clothing is able to achieve double the clo value that is possible with natural fibre clothing garments by using artificial materials with high thermal resistance and relatively low volume. It should be noted that if clothing and bedding levels are required to compensate for a lack of suitable, or affordable, emergency shelter, then high thermal performance garments made from artificial materials are likely to have lower transport costs per unit as compared to natural fibre garments.

The UNHCR tent aims to provide not merely survival conditions, but a living environment for displaced people, and so one would expect the U-value of the shelter fabric construction to be similar, or even higher than that of a Yurt. However, figure 7 indicates that the UNHCR tent ‘U’ value is below that of the yurt and close to that of the Scott tent. Figure 9 indicates that the maximum sized heater would have to run constantly to provide thermal comfort to occupants. This would appear inappropriate when one considers that even professional nomads, such as yurt dwellers, choose to forgo the savings in cost and weight in favour of adequate insulation for their living environment during the winter months. Furthermore, even if the air temperature is maintained at the UNHCR target of 15 to 19 degrees Celsius, thermal comfort will be adversely affected by the low surface temperature of thin canvas, which will be similar to that of the outside air temperature[39]. The current policy is justified by providing survival conditions until more suitable accommodation can be found, such as renovated buildings or more sophisticated (military) heated tents. It may be the case that future development into emergency shelter might investigate how thermal performance can be improved by incorporating modern, lightweight insulation materials into the existing UNHCR design, without adversely affecting weight, volume, cost and delivery lead time.

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[38] Humphrey, C. (Oct. 1974). p.273-5. These include the addition of tailored canvas covers which adds greater water resistance to the felt insulation as well as steel stoves with flues which replace an open hearth.
[39] p*ers comm* Robinson, D.

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