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Finite-element analysis and design optioneering of an emergency tent structure

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Abstract

The paper focuses on the structural analysis of the “Multipurpose Shelter - Type 2” (T2 MP), designed and prototyped by the authors during the research activities of the European collaborative project S(P)EEDKITS. Research institutes, universities, non-profit organizations and manufacturers designed novel shelters concepts, medical care resources and other facilities provided in case of emergency. Specifically, this contribution proposes an optimized solution of the tent structure, in order to meet the UNICEF criteria for collective tents.

Keywords: lightweight structure, temporary structure, emergency sheltering, finite element analysis, structural optimization, snow load, wind load

1. Introduction

Since 2014 UNICEF has been publishing diverse Target Product Profiles (TPPs) to communicate requirements for products - shelters and others NFIs (*Non-food items*) included in procurement specifications of NGOs, which are currently not available on the market but which fulfil a priority need to be used in the unique context in which UNICEF and its partners operate. TPPs include information on how the new product will be used, by or for whom, and the minimum and ideal performance criteria. The purpose of TPPs is to guide industry to develop products that meet UNICEF’s needs, however they do not act as the final procurement

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specifications but rather as a list of desired requirements that combined describes the ideal product considering the context. UNICEF recognizes that innovation is an iterative process, and that suppliers must balance sometimes competing requirements against product development progress. To allow for creativity, and the innovation process to take its course, TPPs are less prescriptive than procurement specifications, and can therefore be challenged by the industry.

TPP shelter list included requirements for multipurpose tents with various ground area (24m², 48m² and 72m²). In emergency settings, multipurpose tents and relative add-ons (winterization kit, shade net, electrical lighting kit, inner partitioning layers etc.) are commonly used whenever timely delivery of services to affected populations can be life-saving. The capacity of UNICEF and its implementing partners to provide such services is dependent on the timely availability of fit-for-purpose spaces. Impacting negatively on the timely availability of multipurpose tents are mostly the mobilisation and transport process and, once tents have reached their final destination, the set-up complexity. Some multipurpose tents are used beyond the emergency phase and are transformed into transitional structures allowing UNICEF to move into the recovery phase. Therefore, the frame of the tent is fitted with more durable wall materials and a hard floor, sourced locally or internationally, and often also a full electrical system.

In agreement with Ferrino SpA, the commercial partner that leaded the fabrication of T2 MP during the exploitation and dissemination plan of S(P)EEKITS, the Textile Architecture Network (TAN) of Politecnico di Milano studied an optimization plan, in order to satisfy the UNICEF requirements (Table 1), and verify which is the sufficient dimension of the aluminium structure in order to optimize the balance safety and cost-effectiveness.

	<i>Minimum performance</i>	<i>Ideal performance</i>
Max weight	400 kg (packaging included)	250 kg (packaging included)
Wind load	80 km/h	120 km/h
Snow load	300 N/m ²	300 N/m ²

Table 1: UNICEF Target Product Profile referred to structural requirements of 48 m² Multipurpose tent

Although the T2 MP tent has a net internal area of 48 m², the proposed structural optimization is compliant with snow and wind load specifications of UNI EN 13782:2015 (Temporary structures. Tents. Safety) that describes safety requirements which need to be observed at design, calculation, manufacture, installation, maintenance, of mobile, temporary installed tents with more than 50 m² ground area. According to the European Standard, the limit states due to the combinations of actions is calculated, thus verifying that the design value of internal forces or moments does not exceed the corresponding design resistance of the respective part and the ultimate or serviceability limit state is not exceeded. All verifications are performed for the most unfavourable loading. For this purpose, the permanent, variable and accidental actions are always assumed to have the position and magnitude, which result in the most unfavourable limit, states for the structural components to be calculated (Bernuzzi, Mazzolani, 2007).

2. Methodology and procedure

The simulation procedure is divided in two main activities. The first phase consists in a deep analysis of the current T2 MP tent for all of the required criteria. T2 MP tent (Figure 1) has a covered area of 48 m², and a primary structure made of aluminium tubes with diameter of 35 mm and thickness of 3mm. The second phase is the changing of certain parameters in order to get an updated tent made of a different combinations of variables, in order to meet the UNICEF requirements. The performed assessment is dealing with the weight of the tent and its general structural stability as well as with the properties of its parts.



Figure 1: Multipurpose tent - Type 2 (T2 MP) developed in S(P)EEDKITS project

In both phases, the main tools for the analyses are Grasshopper and Karamba - a plug-in for parametric design and structural calculations used within 3D modelling software Rhinoceros. By using Grasshopper tools, the geometrical model of current T2 MP tent is realized including poles, fabrics and connections with its diameters and thicknesses. The model is completely parametrized, so it is possible to directly control and change the diameters and thicknesses of poles as well as their lengths, mutual angles and positions. In that way the total weight of the tent, obtained by multiplying the volume of poles and fabrics with corresponding specific weights, can be checked for infinite design combinations (Figure 2). Subsequently, Karamba allows to link material properties, support points and loads to the analytical models extracted from the geometrical one. As any FEA application, Karamba has its limitations, and the model has to be made according to the software specifications (Preisinger, Moritz, 2014). In the case of the T2 MP tent, more than one analytical model need to be used, so it's necessary to manually transfer the load data list obtained in the first analytical model to the second one (structure).

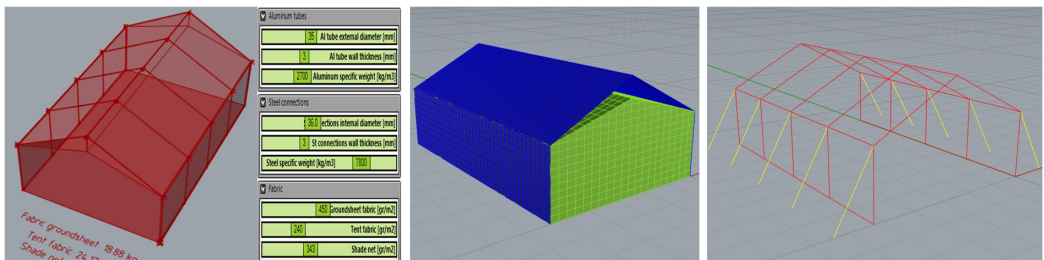


Figure 2 (from the left to the right): geometrical model and parameter sliders (data input); analytical model of a fabrics; analytical model of poles and diagonal ropes

3. Material characterization

3.1 Fabric

The fabric analytical model represents the envelope of the tent, and is done by creating a mesh surface and giving it “shell” element properties in Karamba. It is made of three different parts: groundsheet fabric, tent fabric and shade net. Groundsheet and tent fabric are fixed, while the shade net can change its position. Polyester coated PVC is used as a material of groundsheet, poly-cotton for tent fabric and shade net is made of polyester net (Table 2).

In order to perform realistic simulation, the other elements attached to the fabric sheets are replaced by support elements (Knippers et al., 2011). Those include aluminium poles and strings that connect tent with the ground. Loads are distributed over the whole surface in vertical direction. Karamba performs an approximation of the surface load with a grid of point loads, corresponding to each node of the mesh replicating the surface load.

3.2 Structure

The second analytical model replicates the system of aluminium poles and ropes by means of “beam” elements of Karamba. Poles are made of 6060 aluminium, furnished in the T6 temper (Table 2). This model includes also strings that connect poles to the ground. Supports are set on the bottom horizontal poles (that are attached to the ground) as well as on the points where the strings are anchored to the ground. For the diagonal ropes that stabilize the aluminium frame, belt fasteners made of polyester are proposed. They can withstand loads up until 8351 N; at that tension force, belts can break. In order to add this impact on the model, ropes are replaced with forces applied to the corresponding nodes of the structure.

<i>Component</i>	<i>Material</i>	<i>Traction resistance</i> [N/5cm]	<i>Young's Modulus</i> [kN/cm ²]	<i>Shear Modulus</i> [kN/cm ²]	<i>Specific Weight</i> [kN/m ³]	<i>Coeff. therm. expansion</i> [1/°C]
Groundsheet	PES/PVC 450 g/m ²	2400	252.63	94.74	11.04	0.01
Tent fabric	PES/COT 343 g/m ²	2100	246.32	92.37	7.48	0.01
Shade net	PES/PVC 240 g/m ²	1800	240.00	90.00	3.92	0.01
Poles	ALU 6060 T6 temper	-	6800	2600	26.49	23x10 ⁻⁶

Table 2: Mechanical properties of analytical models

3.3 Preliminary check on the total weight

A preliminary check of the weight requirement is performed on the geometrical model before starting the structural behaviour simulation, in order to verify the compliance of T2 MP tent with UNICEF Standards. Current tent uses aluminium poles with external diameter of 35 mm and thickness of 3 mm. Weights of single parts can be seen in Table 3.

<i>Fabrics</i>	<i>Weight [kg]</i>	<i>Structure</i>	<i>Weight [kg]</i>
Groundsheet fabric	18.88	Aluminium poles	73.06
Tent fabric	21.71	Steel joints	45.31
Shade net	27.51	Pegs and ropes	70.00
Total	68.10		188.37

Table 3: Weight of the T2 MP tent components

4. Simulation of snow and wind loads

4.1 Transfer of load from fabric to poles

Since both of load types (wind and snow) are interacting with the fabric, which transfers them to the poles. First, the whole loaded surface needs to be divided to tributary areas according to position of the poles underneath. Tributary areas are formed by the rule of equal distribution of an area load to the edges of surface. The border of tributary area is formed as a symmetry line of the angle between edges (Figure 3).

In the next step, each of these areas is approximated to a series of rectangles (similarly to integral approximation in mathematics). The precision depends on the number of the rectangles. Since every of these rectangles have its own length and width, their area can be calculated. This area is further used for determining the load that is transferred from each of these rectangles to the pole, that is simply done by multiplying the surface with the area load.

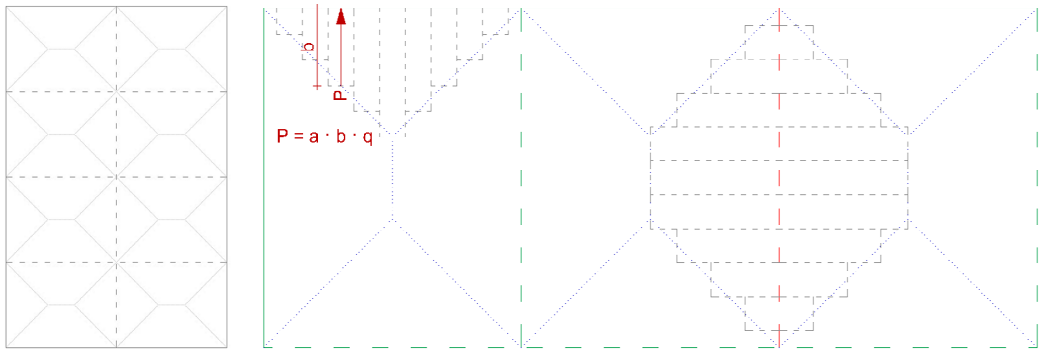


Figure 3: tributary areas subdividing the upper surface of the tent and equation for transferring an area load to a local point load (green lines represents the poles underneath)

4.2 Analysis procedure

Computation of current tent is organized in the following steps (Christensen et al., 2015):

1. Defining properties of material used for both analytical models. Properties inserted are: specific weight, Young's modulus of elasticity, shear modulus, thermal of the structure like hinges.

2. Defining direction and intensity of loads for both analytical models. At this point, for every load case is created different simulation: side wind load (of 120 km/h) and vertical snow/sand load (300 N/m²). Gravity load is added in each case.
3. Assembling all of the above defined values and elements into analytical models.
4. Performing simulation based on appropriate theory of deformations. For the sheet fabric, algorithm based on theory of large deformations is used. As it is known, in this simulation there are multiple iterations, where after every one of them the position of the structure is updated. In this way, more precise simulation is achieved. For examined case, there are used 400 iterations for the fabric computation. For the system of poles, the first order theory for small deflections was more appropriate.
5. Displaying deformed structure and values for various design options and evaluating results in a decision matrix.

5. Results of load simulation and bending moment verification

Moment of inertia determines the torque needed for a desired angular acceleration about a rotational axis. For the round hollow section the used formula is:

$$I = \frac{\pi(D^4 - d^4)}{64} \quad (1)$$

Where D is external diameter of the pole and d is the internal one. For the aluminium poles involved in calculation (diameter 35 mm, thickness 3 mm), the moment of inertia is 38943.18 mm⁴. The minimum needed moment of inertia for the poles depends on the maximum deflection based on the load and allowed deflection based on the length of the beam. If U_f is maximum deflection based on the load and U_{max} maximum allowed deflection, then the minimum moment of inertia equals to:

$$I_{min} = \frac{U_f}{U_{max}} \quad (2)$$

Since the analysed case includes a system of point loads, calculating U_f is quite complex and needs the help of the algorithm. Karamba output includes internal forces, displacement and utilization for both analytical models, the fabric one and structural one (Figures 4, 5, 6). In case of multiple loads applied, the total nodal displacement - calculated through the software at all points where the fabric is connected to the frame - can be obtained through superposition (adding displacements each other). For example, for the point A, it is calculated separately the deflection that is caused by every point load $P_1 \dots P_n$ and then all of these will be added (Bernuzzi, Mazzolani, 2007). To perform this, the following three formulas are used; at the end, for the point A, all the deflections caused by the “left” loads, “right” loads and the load exactly at the point A are added each other (Figure 7).

$$U_x = \frac{Pa(l-x)}{6EI} (2lx - x^2 - a^2), a < x \quad (3)$$

$$U_x = \frac{Pa^2b^2}{3EI}, a = x \tag{4}$$

$$U_x = \frac{Pbx}{6EI} (l^2 - b^2 - x^2), a > x \tag{5}$$

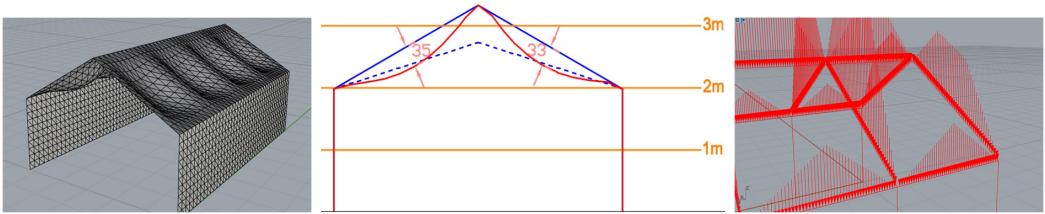


Figure 4: deformation of shade net under snow load, performed on the fabric analytical model, and load transfer to the structural analytical model

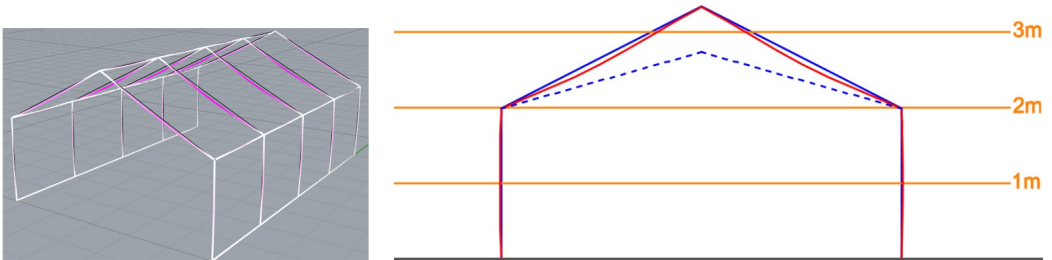


Figure 5: displacement of aluminium poles, performed on the structural analytical model under snow load

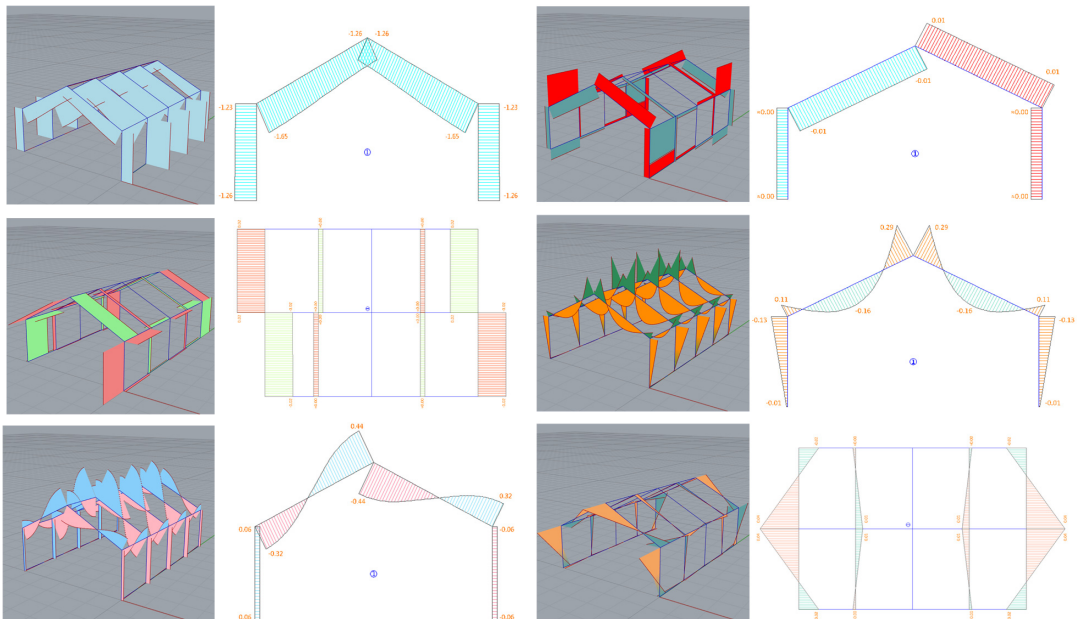


Figure 6: normal force (on the left) and bending moment (on the right) along X-axis (top row), Y-axis (centre row) and Z-axis (bottom row), performed on the structural analytical model under snow load

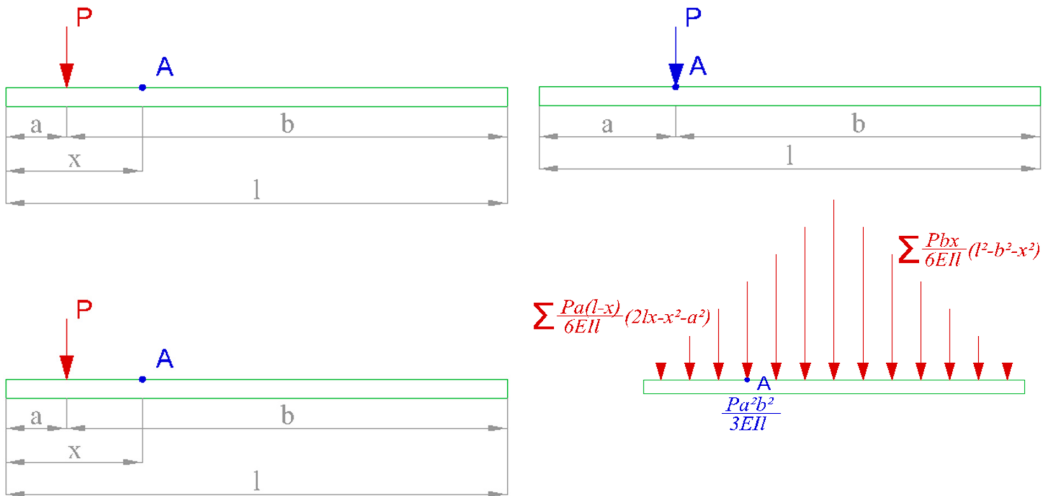


Figure 7: three cases for calculating deflection of the point A in relationship to the position of the load P, and sum of all loads that cause total deflection of the point A

Obtained values of deflection produce a minimum required moment of inertia of 629.54 mm^4 for the snow load, while for the wind load the minimum moment of inertia is 1297.56 mm^4 . As it is shown above, required moments of inertia are highly below the moments of inertia of cross section used, so the poles are possible to resist the torque created by both snow and wind. Considering the resistance to the bending moment, plastic section modulus needs to be calculated first and then using, the maximum bending moment that poles can resist. Formula are the following ones:

$$W = \frac{D^3 - d^3}{6} \quad (6)$$

$$M_{c,Rd} = \frac{W \times f_d}{Y_{MO}} \quad (7)$$

Where D is external diameter of the pole and d is the internal one. For used sections of poles W is 3081.0 mm^3 , while $Y_{MO}=1.1$ and represents partial factor for resistance of cross sections. Referring to the material characterization, the computation considers an Aluminium 6060-T6, with $f_d = 160 \text{ N/mm}^2$ and tensile strength $\sigma_d = 160 \text{ N/mm}^2$.

Allowed bending moments for observed poles and material are 0.48 kNm . The performed analysis shows that the maximum bending moment is 0.55 kNm for the snow load and 0.37 kNm for the wind load, so the conclusion comes that the aluminium poles with yield strength of 160 N/mm^2 cannot resist the bending moments generated in the structure.

6. Design optioneering stage

6.1 Optimization of fabrics - adding diagonal reinforcement

Deformation cause by side wind as this can disable normal use of interior space. This is the reason why some types of the reinforcement need to be added. The most effective is adding linear diagonal reinforcements on the lateral fields. In Karamba it is possible to model and determine the needed strength of the reinforcements. First, on the already deformed model, diagonal section of the deformation is extracted. This part will be observed as a string and theoretical model of the tension in strings will be applied. And by this model, if the string is strained with the force R , every part of the string is applying force R in its own direction.

Each of these forces can be “split” into its components R_x that has direction as the load and R_y in the perpendicular direction to the load. For the calculations, only R_x is taken into the consideration. After several iterations of tests, it is obtained a result that reinforcing the fabric with the string able to resist tension of 165 N, because that is the force needed for resisting the wind of 120 km/h. Additionally, all the analyses are again performed on the reinforced tent. As it can be seen in Figure 8, the deformation is significantly decreases up to 8 ± 10 cm. In this way, the tent can remain useful even under the lateral wind of 120 km/h.

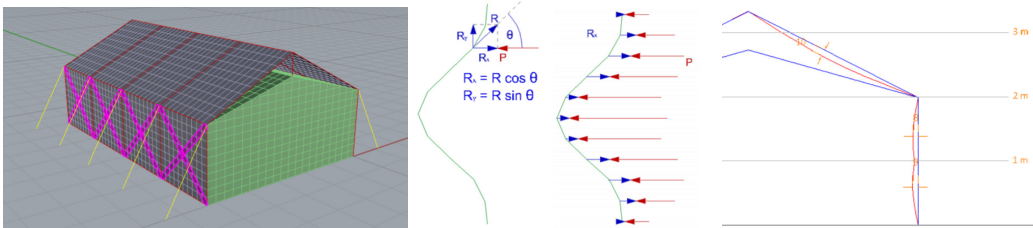


Figure 8: position of reinforcements on the lateral sides; diagram of tensile force at each point of the string and its components R_x and R_y ; diagram of resistance of R_x to the load P ; final shell deformation

6.2 Optimization of the cross section of Aluminium 6060-T6 poles

As it can be seen in par. 5, current steel poles are unable to resist the maximum bending moment that is occurring in the structure. This moment is present in the case of the snow load and equals 0.55 kNm. By combining formula (6) and (7), it is easily noticeable that the maximum allowed moment can be increased either by increasing the external diameter D (in comparison to d) or by increasing the minimum yield strength of the material.

In Table 4 it is possible to see value of maximum allowed moment depending on the external and internal diameter of poles in Aluminium 6060-T6. Change of the material (or more precisely its minimum yield strength) has a proportional impact on the values in the table. In this work, this change is not examined.

In the further step, the tested diameters can be set as parameters for the geometrical model that computes the total weight of the tent. Thus it is possible to verify if the needed profiles fulfil the UNICEF weight requirements. As the final conclusion, it is possible to see that the aluminium 6060-T6 poles that can resist maximum bending moment of the snow (still remaining below the weight of 400 kg) are:

- diameter of 31 mm and thickness of 6 mm; total tent weight of 289.20 kg;
- diameter of 32 mm and thickness of 5.5 mm; total tent weight of 286.50 kg;
- diameter of 33 mm and thickness of 5 mm; total tent weight of 282.70 kg;
- diameter of 34 mm and thickness of 4.5 mm; total tent weight of 277.70 kg;
- diameter of 35 mm and thickness of 4 mm; total tent weight of 271.60 kg.

$M_{c,Rd}$		Internal diameter (d) [mm]																
External diameter (D) [mm]	[kNm]	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
	27	0.36	0.34	0.31	0.28	0.25	0.22	0.18	0.14	0.10	0.05							
	28	0.41	0.39	0.37	0.34	0.31	0.27	0.24	0.20	0.15	0.11	0.06						
	29	0.47	0.45	0.42	0.40	0.37	0.33	0.30	0.26	0.21	0.17	0.11	0.06					
	30	0.53	0.51	0.49	0.46	0.43	0.40	0.36	0.32	0.28	0.23	0.18	0.12	0.06				
	31	0.60	0.58	0.56	0.53	0.50	0.46	0.43	0.39	0.34	0.30	0.25	0.19	0.13	0.07			
	32	0.68	0.65	0.63	0.60	0.57	0.54	0.50	0.46	0.42	0.37	0.32	0.26	0.20	0.14	0.07		
	33	0.75	0.73	0.70	0.68	0.65	0.61	0.58	0.54	0.49	0.45	0.39	0.34	0.28	0.22	0.15	0.08	
	34	0.83	0.81	0.79	0.76	0.73	0.69	0.66	0.62	0.57	0.53	0.48	0.42	0.36	0.30	0.23	0.16	
	35	0.92	0.90	0.87	0.85	0.81	0.78	0.74	0.70	0.66	0.61	0.56	0.51	0.45	0.38	0.32	0.25	

Table 4: maximum allowed moment of the pole in relation to its external and internal diameter

Weight		Internal diameter (d) [mm]																
External diameter (D) [mm]	[kg]	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
	27	256.6	249.9	242.9	235.5	227.7	219.5	210.9	202.0	192.6	182.9							
	28	267.6	261	253.9	246.5	238.7	230.5	222.0	213.0	203.7	194.0	183.9						
	29	279.0	272.3	265.3	257.9	250.1	241.9	233.3	224.4	215.1	205.4	195.3	184.8					
	30	290.8	284.1	277.1	269.6	261.8	253.7	245.1	236.2	226.8	217.1	207.0	196.6	185.7				
	31	302.9	296.3	289.2	281.8	274.0	265.8	257.2	248.3	239.0	229.3	219.2	208.7	197.9	186.6			
	32	315.4	308.8	301.7	294.3	286.5	278.3	269.8	260.8	251.5	241.8	231.7	221.2	210.4	199.2	187.6		
	33	328.3	321.7	314.6	307.2	299.4	291.2	282.7	273.7	264.4	254.7	244.6	234.1	223.3	212.1	200.5	188.5	
	34	341.6	334.9	327.9	320.5	312.7	304.5	295.9	287.0	277.7	268.0	257.9	247.4	236.6	225.3	213.7	201.7	
	35	355.3	348.7	341.6	334.2	326.4	318.2	309.6	300.7	291.4	281.7	271.6	261.1	250.3	239.1	227.5	215.5	

Table 5: total weight of the tent in relation to the external and internal diameter of the pole

7. Conclusion

In conclusion, a set of last considerations to take into account while a workflow for structurally designing of temporary tents is established. The difficulty to work inside the emergency field is to arrange a standard solution adaptable to different situations and conditions. Needs are related to the context, to the cultural and economic background of affected population, to the climate zone and to the entity of the disaster. Therefore, the solutions should be extremely flexible, but at the same time ready to be used and highly customizable. Finally, novel shelter designs have to face strong project limits: structural reliability, cost and weight for the transportation.

The methodology elaborated allows the creation of a decision matrix on which is based the selection of the structural optimization strategy for the S(P)EEDKITS “Multipurpose Shelter - Type 2” (Ulrich, Eppinger, 2012). The State of Art analysis allows to create an overview on the current T2 MP tent - already commercialized as multipurpose or collective solution in emergency – and shows its limitations in terms of compliance with both UNICEF targets and European regulation on temporary structures. The decision matrix is not the only factor influencing the design optioneering. At the same time, the still ongoing collaboration with the shelter team of S(P)EEDKITS and Ferrino SpA can produce different score evaluations for each required criterion (e.g., reducing cost may be the most influencing requirement for humanitarian applications). Further studies shall evaluate the use of different kind of structural materials, e.g. composite materials for the framework or for connectors, or simply a more resistant aluminium in substitution of 6060, would allow the decrease of weight without losing the required safety.

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References

- Bernuzzi C., Mazzolani F.M. (2007), *Edifici in acciaio, materiale calcolo e progetto secondo l'Eurocodice EN 1993-1-1*, Hoepli, Milan.
- Christensen J.T., Parigi D., Kirkegaard P.H. (2015), *Interactive tool that empowers structural understanding and enables FEM analysis in a parametric design environment*. Proceedings of IASS IASS 2014 Brasilia Symposium: Shells, Membranes and Spatial Structures: Footprints - Computational Methods, pp. 1-8(8).
- European Commission (2011), *Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC Text with EEA relevance*. European Product Reg. Off. J. Eur. Union.
- European Committee for Standardization (2015), UNI EN 13782 - *Temporary structures. Tents. Safety*. ICS 91.040.99. Start Validity Date: 8 October 2015.
- Ferrino Spa (2016), *T2 Multipurpose Collective Shelter*. Available at: <https://www.ferrino.it>. Accessed: 13 March 2019.
- Knippers J., Cremers J., Gabler M., Lienhard J. (2011), *Construction manual for Polymers + Membranes. Materials, semi-finished products, form-finding, design*. Edition Detail, Munich.
- Leitão, António, Renata Castelo Branco, and Carmo Cardoso (2017), *Algorithmic-Based Analysis. Protocols, Flows, and Glitches*. Proceedings of the 22nd Annual Conference of the Association for Computer-Aided Architectural Design Research in Asia, Suzhou, pp. 137–147.
- Preisinger C., Moritz H. (2014), *Karamba - A Toolkit for Parametric Structural Design*. Structural Engineering International, n. 24 (2), pp. 217–221.
- Ulrich K.T., Eppinger S.D. (2012), *Product Design Development*, McGraw-Hill, New York.
- UNICEF Supply Division Innovation Unit (2014), *Supplies and Logistics: Target Product Profiles*. Available at: https://www.unicef.org/supply/index_91816.html. Accessed: 21 February 2019.
- UNICEF Supply Division Innovation Unit (2016), *Target Product Profile: Multipurpose tent*. Version: 3.0. Available at: https://www.unicef.org/supply/files/Multipurpose_Tents_TPP_-_V3.pdf. Accessed: 13 March 2019.
- Zanelli A, Buyle G., Giabardo G., Viscuso S. (2014), *S(P)EEDKITS & Smart Packaging. Nuove applicazioni tessili per ridefnire la risposta alle emergenze*. TECHNE n. 8, Firenze University Press, pp. 250-260.