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**Citation for published version (APA):**

Meijers, M. H. M., Cox, M. G. D. M., & Gijsbers, R. (2007). Design process of a temporary light weight emergency shelter with integrated climate control. In *Proceedings of CIB World Building Congress 2007, Construction for development, 14-17 May 2007, Cape Town, South Africa*

**Document status and date:**

Published: 01/01/2007

**Document Version:**

Accepted manuscript including changes made at the peer-review stage

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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CIB2007-315

# Design process of a temporary light weight *emergency shelter* with integrated climate control

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## KEYWORDS

Emergency shelter, design process, temporary, light weight, climate control

## ABSTRACT

Within the SlimBouwen<sup>®</sup> philosophy of prof. dr. ir. J. Lichtenberg, an *emergency shelter design* was developed that can supply humanitarian, governmental and military organizations with an alternative form of shelter that can offer great relief to a large group of victims within a short time frame and be adapted to the actual (local) needs.

Especially the integral approach of this design methodology leads to a solution that meets the complex requirements of an emergency shelter in the field of management, transport, construction and social implications under different circumstances. Smart means of transport, installation, construction and covering lead to a fast- and easy-to-install shelter type that is flexible and offers integrated climate control.

## 1. INTRODUCTION

In case of calamities and emergencies, such as wars or natural disasters, i.e. earth quakes, tsunamis, volcanic eruptions and floods, easy-to-install shelters bring great relief to the victims. However the momentarily available products have several disadvantages.

*Simple tent structures, often grouped together to form a 'tent city', are commonly made of canvas military issue tents which are criticized for being heavy, bulky, uninsulated, expensive, and for rotting in under a year.*

Besides these aspects tents can only reach a maximum span, do not have integrated climate control and the logistic chain in which tents are

prepared, transported to the place of emergency, assembled, erected and installed within the shortest possible timeframe is far from ideal.

In spite of the extensive available information and requirements for tents, mainly produced by first-in-line humanitarian organizations, no real alternatives are momentarily available. Perhaps the traditional design approach of architecture may not lead to the desired solutions.

Within the SlimBouwen<sup>®</sup> philosophy of prof. dr. ir. J. Lichtenberg (2005), that relates more to the multidisciplinary design approach of industrial design, an *arched stable* was developed that brings new insights in some of the specific problems of tents as mentioned above. As a stable it suits its purpose very well. But for an emergency shelter it still remains too heavy and inflexible and does not offer climate control or easy transport and installation solutions.

Therefore research has to be done to develop a modular, light weight emergency shelter with integrated climate control to provide a new, comfortable and flexible way of instant housing that offers victims relief in case of calamities.

## 2. DESIGN PROCESS

Unlike most academic articles, this paper is not written on the basis of the paradigm of explanatory science like physics or mathematics but on the basis of the paradigm of design sciences like engineering and medicine.

According to Van Aken (2004), the core mission of an explanatory science is to develop valid knowledge to describe, explain and predict. Research in an explanatory science can be seen as a quest for truth, for shared understanding of the objects of interest. The core mission of a design science, on the other hand, is to develop valid knowledge which can be used by the professionals in the field in question to *design* solutions to their field problems (hence the term "design science"). Research in a design science can be regarded as a quest for improving the human condition. The test of the knowledge of a design science is not truth but whether the solutions designed from it work, i.e. produce the intended results.

Also in the case of the design of a new emergency shelter that meets the international requirements, the *design science* approach is preferred over the explanatory science.

More specific, the SlimBouwen<sup>®</sup> philosophy that has been used, promotes building solutions which are flexible, industrially produced and can be installed and dismantled at any time. Within this SlimBouwen<sup>®</sup> approach, an integral, multidisciplinary design process is used where every party within the development chain is identified, analyzed and involved in relation to its contribution to the collective goal.

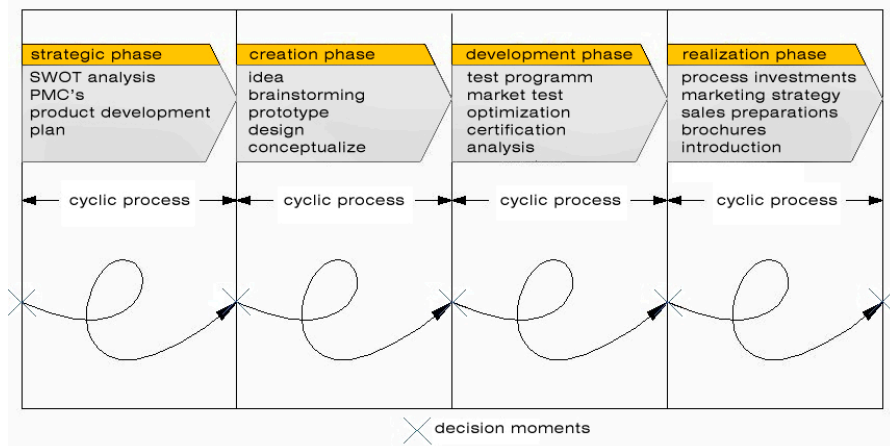


Figure 1.1 - SlimBouwen<sup>®</sup> Product development process

As a response to an emergency situation where instant shelter is required, the next stages can be determined:

1. inventory of the needs and desires of victims after an emergency
2. matching results with available shelter, logistic and site options
3. transport and assembly
4. use and maintenance
5. disassembly and transport

Since the first two stages are of a reactive kind and depend on the availability of adequate solutions and the last stage will exist of the same actions of stage 3 in reverse, the research and development of a new shelter type focus especially on the stages 3 and 4.

### 3.1. Transport

In order to response fast, adequately and efficiently in case of an emergency, it is necessary that a shelter that may bring relief and security will be available within a short time frame. A delivery time of 12 hours after a major disaster has occurred, is an important requirement. Most common package of a shelter will be a container that can be shipped either by truck, boat, train, plane or helicopter.

Thus an important requirement for the disassembled design of the shelter is that it has to fit within conventional sea containers where the 20 feet (type 1C) and 40 feet container (type 1A) are the most common. These containers have a maximum gross weight of 24.000 and 30.490 KG. Furthermore transport has to be safe, economically justifiable and reusable. Protection of the payload in combination with a light weight construction, an easy-to-handle fixation and release of the containers content are important aspects of the shelter concept.

In case smaller parts or boxes will be placed in the container, they preferably will have to be stored on top of pallets that meet the international standards. Europallets (1200 x 800 mm) or industrial pallets (1200 x 1000 mm) are the prescribed sizes within Europe.

### 3.2. Assembly and installation

Not only the time the shelter takes to be transported but also the time it takes to be assembled and installed will be of great importance within a situation where instant help is needed.

Once the containers have reached their destination, the installation area will already have been determined the parts of the shelter will have to be taken out in the right order to prevent installers of making mistakes and have parts lying around in unwanted conditions. Especially in the case of calamities, a **simple, logical and intuitive** process of assembly and installation without any hassle can prove to be life saving. In this field, designers of shelters should be aware that cultural differences may lead to miscommunication and errors.

### **3.2.1. Site selection**

According to Ashmore (2004), the site where the shelter will be installed will have to meet several requirements. The site should be flat with a stable soil, away from dead trees and areas that may be of risk because of flooding, landmines, landslides, polluted water, fire, wind and other potential threats. Fresh water within the neighborhood is a strong preference.

### **3.2.2. Installation time**

The target for a good emergency shelter design should be an assembly time of less than 24 hours from arriving at the perimeter. Of course any extra time that can be saved should be taken into account. If it will be possible, each segment of the shelter could be taken into use without having to wait for the whole construction to be erected. One can imagine that most victims will find great relieve once they have a roof above their head. Therefore the assembly and installation of the shelter should be the primary focus before implementing climate control and other features.

The design of the shelter has to be suitable to be packed, fixated, transported, unpacked and installed in an easy, intuitive way that meets the extreme circumstances in which it may be used.

### **3.2.3. Managing the assembly and installation**

To be able to place a shelter within such a short period a team of building workers will be needed. The question how many depends for a great deal on the size of the shelter and the complexity and number of parts that will be required. Furthermore several disciplines should be available within the building team.

A general shelter manager who will be familiar with the technical, logistic and social aspects of installing this type of emergency shelter will have to control and manage the general process of transport, crew composition, site determination and more. Attention should be given to the people who are in need and can not yet make use of the shelter facilities until it is installed. A construction manager will have to coordinate all building activities. This person will have to decide whether local people will be capable to support and realize the positioning and building of the shelter. If not, external helpers should be flown in. The construction manager might also coordinate all installation activities i.e. installing climate control, fresh water supply, stove etc.

The total number of persons in the building team and the composition of it may largely depend on the situation. However different scenario's

should be available and the managers will have to be trained in order to handle and decide under great stress and within very short time frames.

### **3.3. Use and Maintenance**

Both social and constructional aspects will determine the comfort of use of the emergency shelter. A minimum amount of space will be needed per person, depending on the (expected) term of stay. Also cultural and religious aspects have to be taken into consideration. An arched construction such as described hereafter in the section 'A case study – the arched stable' may prove to be a very suitable basis for an emergency shelter design. Such a form can be constructed light weight, offers a great span capacity and can very well be provided with a double layered skin and integrated climate control.

#### **3.3.1. Required space for sheltering**

The people who are a victim of an emergency or calamity require a minimal amount of shelter space per person. Based on the term of stay, two different scenarios are used in order to determine the recommended shelter area per individual.

**Short Term Occupancy** is based on 20 net assignable square feet per person, which is the American Red Cross requirement for shelter space during a storm. (20 square feet = 1.8 m<sup>2</sup>)

**Extended Term Occupancy** is estimated based upon the unassigned space and allocations of 50 net assignable square feet per individual. This space allocation is suggested by the University of Florida to shelter individuals for an extended period. An extended period is defined as any length of time greater than 24 hours (50 square feet = 4.5 m<sup>2</sup>)

If the spanned area of the emergency shelter is 4.000 m<sup>2</sup> (average) then this form of accommodation can offer shelter to a maximum of 2.000 persons in case of short term stay (<24 hours) and 650 persons in case of an extended term occupancy.

#### **3.3.2. Social context**

Since many people will be sheltered within one accommodation this will lead to certain implications. At first instance all attention will be focused on offering relief to victims and/or refugees. Especially in the situation where environmental conditions are harsh, for instance if the nights are extreme cold or the days are unacceptably hot, a suitable shelter will bring comfort and will be considered a safe zone.

However within a few days a new social context will originate where tension between people and groups with different cultural, social and religious backgrounds and habits may lead to unwanted situations i.e.

discussions, conflicts and even fights. Strong emotional feelings such as fear, despair, uncertainty about the future and anger have to be taken into account if designing the interior plan of the shelter.

Room division within the shelter, spaces where one can find some privacy, parts of the shelter that are assigned specific functions such as religious rituals and clear and acceptable rules for conduct and social control and tolerance should be available from the first day the shelter is taken into use. As far as this is possible, victims and refugees need to be offered information on their actual situation, their legal status and if possible an estimate of the time they will need to stay within the shelter settlement. This may bring some ease-of-mind within their troublesome situation.

If the term of stay may take more than several days, additional accommodation and/or services may have to be offered.

### **3.3.3. Construction**

Some specific technical aspects have to be tackled in order to make an arched construction work as an emergency shelter.

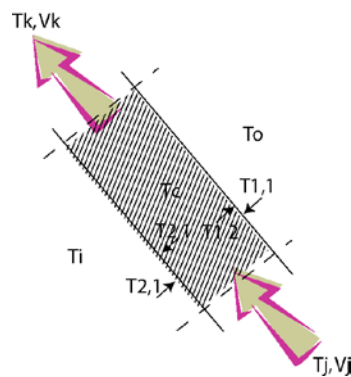
1. The bases of the metal arcs will have to be connected with a horizontal draw bar or steel wires to prevent them of sliding sideways. Once the arc is erected, the bases have to be moored in the ground. In the best possible situation, the quality of the anchoring will not depend on the composition and quality of the underlying soil. A sturdy, reliable and reusable fixation method will have to be developed. This might be possible with steel anchors which are led through the base elements at different angles into the ground, thus creating stability and strength in different directions.
2. To make them fit into the containers, the arcs will have to be composed of several curved elements. They will be assembled lying flat on the floor. Then each arc has to be lifted in an easy way, being sure that it will stay in place and controlling the movement at every moment of its lifting. An integrated hinge in the base element that keeps the arc in place, guides its rotation into the final position and offers the possibility to fixate the arc in the desired position would be a logical solution.
3. Once the arcs are lifted, the double layered skin has to be attached in between them. It might be suitable to have the foil being rolled off cylinders with a flexile tendon at both sides that is led into a profile that follows the curve of the arc. A steel wire that is attached to the beginning of the tendon can be turned up with a winch at the other side of the arc, pulling the skin over the desired distance.

### **3.3.4. Climate control**

The basic idea behind the emergency shelter is to apply a skin that consists of a double layered membrane. The cleft between the two membranes will

be used as an insulation zone and a manner to control the temperature of the internal climate and supply the space with active ventilation. The availability of different membrane materials and coatings offers many options to combine and vary the capacity of the shell to reflect, absorb and transmit light, air or energy. This way an active ventilation circuit can be created so the thermal features and behavior of the emergency shelter can be adapted to the actual climate and circumstances where the shelter is being used and the internal space can reach a comfortable and healthy atmosphere. If necessary more than two different foils could be applied.

A physical modeling will be set up from a wide angle perspective. Next the model will be specified by using simplified cells (see Figure 1.2).



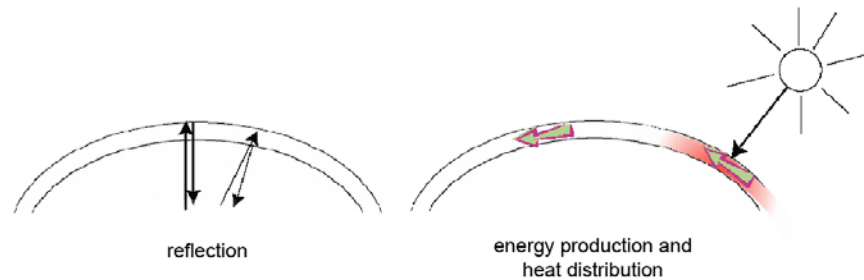
**Figure 1.2** Impression of a single cell (simplified)

Once the ventilation issue is tackled the possibility of integrating air conditioning and cooling of the interior of the shelter will be looked in to. Flexible plastic tubes that are integrated in between the two membranes and can easily be connected to a water pump will supply the shelter with a unique cooling facility. If the temperature of the environment might drop below zero degrees Celsius, a frost-proof substance has to be added to the water.

### 3.3.5. Potential energy production and saving

The large roof surface of the emergency shelter in combination with the available potential heat sources make the emergency shelter an attractive option for energy saving and production. If an economic way of heat production, distribution and ventilation can be supplied, the emergency shelter may bring new and attractive features to the housing of people.





**Figure 1.3** internal reflection and energy production/heat distribution

At this moment research takes place of several different types of energy storage and transformation systems that may be applicable within the emergency shelter design. Some of the options are the deposit by evaporation of solar cells, Peltier elements and thermo-couple array. Also thermo-magnetic generators seem to be an alternative on the long term.

#### 4. A CASE STUDY – THE ARCHED STABLE

Within the Department of Architecture of the Eindhoven University of Technology, an arched construction has been developed in order to function as a stable for dairy cattle. This so called *arched stable* was created by ir. Roel Gijsbers within the SlimBouwen® approach and enthusiastically introduced as a pilot in October of 2006 in Dieteren in The Netherlands. It proved that a rather slim construction, covered with a double layered membrane can be installed within a relative short period and offer the inhabitants a large amount of comfort.



**Figure 1.4** Impression arched stable

The basis of the construction exists of steel arcs with a triangular cross section that can span a width of 30 to 40 meters. The length can vary from 20 meters to any desired size by adding more arched segments to the construction. The arcs are fixated in concrete base elements which are subsequently moored within the ground. In between two successive arcs, a double layered membrane is placed in order to form a natural insulation and

create a ventilation system that can be regulated. In between the arcs beams are shored for cross directional stability.



**Figure 1.5** Impression of the construction of the arched stable

The arched stable produced new and valuable information on an large span arched construction, availability and usage of different membranes, ventilation within a double layered skin and a general impression of the atmosphere within a membrane covered shelter.

However the arcs were made of steel, thus being too heavy for efficient, fast transport. The whole construction was not wind- and water resistant, it didn't need to be, and the cleft could be ventilated but no climate control was integrated. Finally floor covering was realized by using pouring concrete. Therefore reusing the material is not possible.

Nevertheless the arched stable may function as a kind of blueprint for an emergency shelter design that can cover an average spanned area of 4.000 square meters and that can be applied at almost every flat soil all over the world. The concept offers the possibility of modularity where segments can be taken into use before finishing the whole construction, segments can be added or removed, depending on the need of that moment and each segment could be assigned a different function.

## **5. CONCLUSIONS AND DISCUSSION**

The design of an adequate and effective emergency shelter that suits all possible circumstances all over the world and can be available and installed at any spot within 24 hours after a disaster may seem to be an illusion. There are just too many variables that can influence the effectiveness and suitability of the offered shelter option. Besides, social and religious differences between cultures and nations may require different solutions.

However the described emergency shelter design may add several new and improved features to the existing tent options and can therefore contribute to a better match between the actual needs of victims and the chosen shelter type, a shorter installation time and an improved way of usage and maintenance. One of the best additions however will be the double layered membrane that can be used both as an insulation cleft and as a climate control option.

With the introduction of these options, new questions come up and need to be answered in order to create a solution that will work, even in extreme and painful circumstances. Is transport of a shelter within containers feasible, can suitable sites be found in the neighborhood of a disaster, should a team of managers and building workers be transported to the place of settlement or should workers be selected out of local personnel, what light weight construction will be the best choice in relation to size, costs and durability, should different membrane options be integrated within the concept in order to offer solutions for different circumstances, how can climate control best be implemented and what are the requirements for tubes, connectors and materials? These are just a few questions where many more need to be discussed and answered before refugees, victims of wars and disasters may find the best relief in troublesome circumstances.

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